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TITLE: - EHEALTH SYSTEMS INTEROPERABILITY ASSESSMENT FRAMEWORK IN CASE OF FMoH

BY

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A Thesis Submitted to School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Information Systems

BY:

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Declaration

This thesis has not previously been accepted for any degree and is not being concurrently submitted in candidature for any degree in any university.

I declare that the thesis is a result of my own investigation except where otherwise stated. I have undertaken the study independently with the guidance and support of my research advisor. Other sources are acknowledged by citations giving explicit references. A list of references is appended.

Signature: _____

Yitayal Chanie Alehegn

This thesis submitted for examination with my approval as university advisor.

Advisor's Signature:

_____

Getachew Hailemariyam (PhD)

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Abstract

In today's digital world almost all data, information and other functionalities which are vital to the society day to day life are stored, processed and probably exchanged by plenty of information systems. Those systems might also be independent and scattered which are installed to meet the required specific purpose; for healthcare service is among many.

In the case of AARHB is not an exception making interoperate ehealth systems in general, and particularly ehealth systems in Addis Ababa Regional Health Bureau level, is an urgent problem.

However, the first stage towards attaining interoperability is to conduct interoperability assessment , here the aim of this research is to keep AARHB healthcare institutions effort in developing and implementing full-fledged interoperable ehealth systems. By developing multidimensional interoperability assessment framework for ehealth systems implemented in AARHB healthcare institutions.

The researcher examined many related studies through document analysis method to extract basic interoperability assessment framework perspectives followed by gap analysis. Then, this study constructed by four basic interoperability perspectives namely: Organizational interoperability, Informational interoperability, Technical interoperability and other interoperability perspectives having 19(nineteen) sub components.

Structured questioner was developed for each sub component to be validated or rejected by 14 purposefully selected domain experts. Simple descriptive validation conducted involving binomial test analysis technique; usually show that the proposed framework's basic interoperability perspectives through their corresponding key components are deliberately validated by domain experts, by quantifying the proportion of domain experts acceptance for each key component.

Hence, the interoperability assessment framework and all the key components proposed by the researcher are important appropriate and valid to be fully considered and used not only by AARHB but also by FMoH, on their future practical efforts to create seamlessly interoperable ehealth systems at the line of healthcare service delivery.

The findings of this research have great contribution to theory by providing insight to the complex healthcare systems interoperability perspectives and further enhance the knowledge source in this area. Also decision makers in AARHB healthcare institutions will practically benefited from this study being aware of multiple interoperability perspectives and one possible approach, when they need to tackle ehealth systems interoperability barriers.

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Acronyms

AARHB…….....Addis Ababa Regional Health Bureau

C2G……..Citizens to Government

C2P……...Citizens to Private

CBHIIS ……Community Based Health Insurance Information Systems

CCIS……..Cold Chain Inventory System

CHIS…….....Community Health Information System

CI……..Confidence Interval

DHIS……District Health Information Systems

DLIFW ……..Data Level Interoperability Framework

DOD……...Department of Defense

EHR……..Electronic Health Record

EFY……Ethiopian Fiscal Year

EI……..Enterprise Interoperability

EIFW……..Enterprise Interoperability Framework

EIMM…….....Enterprise Interoperability Maturity Model

FMIS……Family Medicine Information Systems

FMoH……...federal Ministry of Health

G2G……Government to Government

G2P……Government to Private

GCM……...Generic Component Modeling

GHS……..Ghana Health Systems

HCMIS……..Health commodity Management Information Systems

HIMS……Health Information Management System

HIS……..Health Information Systems

HIS-DF……Health Information Systems Development Framework

HL7……..Health Level 7 Standard

HRIS……Human Resource Information Systems

HSTP……..Health Sector Transformation Plan

ICTDA……Information Communication Technology directorate Agency

IIF…….Informational Interoperability Framework

IMM……..Interoperability Maturity Measure

IPLS……Integrated Pharmaceutical Logistics Systems

ISO……International Standards Organization

LAN ……Local Area Network

LCIM……Levels of Conceptual Interoperability Model

LIS……..Laboratory Information Systems

LISI ……Levels of Information System Interoperability

MDA…… Model-Driven Architecture

MMEI……..Maturity model for enterprise interoperability

NGO……Non-governmental Organizations

NHDR ……...National Health Data Repository

OIF……...Organizational Interoperability Framework

P2P……... Private to private

PCA……..Principal component Analysis

PFSA……...Pharmaceutical Fund and Supply Agency

RUP ……...Rational Unified Process

SCOR …….Supply Chain Operations References

SOA …….Service-Oriented Architecture

SPSS…….….Statistical Procedure for Social Science

TIF……Technical Interoperability Framework

USAID ……...United States Agency for International Development

VPN……...Virtual Private Network

WAN ……Wide Area Network

CHAPTER ONE

1. Introduction

Many developing countries health information are stored in heterogeneous autonomous Health Information Systems developed by various companies, hence it has caused serious information access and interoperability problems (Olaronke Iroju, 2013).

In Ethiopia Federal Ministry of Health (FMoH) manages and coordinates the health sector thorough the country. FMoH has a vision to improve the access and quality of care as indicated by a five year Health Sector Development Plan (FMoH, 2014/15). To realize this vision, the Ministry has recognized and positioned eHealth as a key transformation enabler. However, preliminary survey assessment indicates that eHealth initiatives in Ethiopia are characterized as small scale, duplication of efforts, isolated and unable to effectively communicate (interoperable) with each other (HSTP IV, 2015).

Scholars propose for the must existence of informational interoperability in the healthcare institutions. Clinical notes, observations, laboratory tests, diagnostic imaging reports, treatments, therapies, drugs administered, allergies and letters, x-rays, and bills with in and across the healthcare service domain/boundary are expected to be exchanged (Olaronke Iroju, 2013), (Shane, 2019).

Most of the time ehealth information may be heterogeneous in terminologies, schema, syntax, semantics, data types, and data formats and constraints, as a result, the healthcare system is consequently characterized by increased costs, high error rate, and knowledge mismanagement which ultimately results in high rate of mortality (Olaronke et.al, 2013).

Currently the FMoH owns various national e-health applications developed by different venders and implement to all levels of governmental Healthcare institutions. Over the years, FMoH owned eHealth applications like, DHIS2, EMR/EHR, CHMIS, HRIS and others. LIS, hub Store IS, HCMIS (drug dispending), CBHIS and many other applications are also developed and deployed by other initiatives (FMoH, 2014/15).

According to the findings from the eHealth applications inventory analysis; conducted to help guide the evaluation of new proposed applications and support the design of the integration and interoperability layer of the eHealth Architecture, most of these applications have not been registered officially with the FMOH, it is difficult to have a precise idea on the number of apps, the number and type of users, and on the effectiveness, resource utilization, their purpose, implementation approach, data flow, the technology they use, and in their platform and associated costs (FMoH, 2018).

Based on the data collected from FMOH directorates, all 11 regions, 9 federal agencies/institutes, 6 woreda health offices, 31 public hospitals, 5 health centers, 9

private hospitals, and 1 clinic, the eHealth apps inventory analysis identified a total of 228 apps among which 77 are unique and those apps are characterized based on thematic areas, data, programming languages and platforms used, ownership type, and supporting partners among other things (FMoH, 2018). This finding revealed that, FMoH failed to harmonize eHealth systems the mere coverage of implementation.

Maintaining interoperability in the line of healthcare service delivery increases productivity and reduces costs, provides better public health data, reduced errors, improves patient privacy and improves the patient experience (experian health, 2019).

On the other hand, Interoperability level assessment allows companies to know their strengths and weaknesses in terms of ability to interoperate with each other's, and defining priorities (Guédria, David , & Yannick, 2013).

After all, this study provides broader view of eHealth Systems interoperability aspects or issues to resolve any business, informational, technological and other ehealth systems interoperability problems that has not been studied by any other previous researcher at the local level. Thus, the researcher has developed an interoperability Assessment framework for eHealth systems owned by FMoH from the Technical interoperability, Informational interoperability, Business /Organizational interoperability, Cultural Interoperability, knowledge interoperability and Human resource interoperability viewpoints to indicate the root causes of eHealth systems interoperability challenges and provide one way of addressing them.

2. Statement of the Problem

Ethiopia has launched National Growth and Transformation plan (GTP I & II). Based on this development plan, FMoH Ethiopia has derived the Health Sector Transformation Plan (HSTP) with four successive phases having five years duration to achieve quality and equity, universal health coverage and transformation objectives in health service. To achieve its mission and vision, the Ministry of Health sets out four pillars of excellence hoping to excel the health sector. This document defines that, among these pillars, Excellence in health system capacity comes at the forefront and a fundamental element to attain their overall objective (FMoH HSTP, 2015).

FMoH also planned towards Multi-sectorial approach with various information systems managed by other sectors like Civil Registration and Vital Statistics, Central Statistics Authority database, Agriculture and weather information systems, Geographic Information system, financial information system, education information systems and many others hence, it significantly contributes for information revolution in the health sector (HSTP, 2015). The Ministry recognized that, Harmonization and appropriate interoperability and integration with these information sources are crucial and mandatory (HSTP, 2015).

Systems interoperability is a growing interest area, because of the continuously rising need of integration of legacy, new and evolving systems, in particular in the context

of networked organizational businesses like FMoH Healthcare institutions using Health Net infrastructure to work collaboratively with multiple sectors.

However, there is an investment of huge amount money to develop, implement and run eHealth systems financed by Ethiopian FMoH and many NGO partners in order to improve the quality of healthcare service in the country; FMoH reported they are being challenging with lack of interoperability between eHealth systems (FMoH, 2016/17). Meanwhile, the FMoH working on the ehealth apps inventory analysis to help guide the evaluation of new proposed applications and support the design of the integration and interoperability layer of the eHealth Architecture (eHA) (FMoH, 2018).

The absence of eHealth system interoperability and fragmented eHealth systems implementation negatively affects patients' safety and privacy, caused the commission of frequent medical errors during healthcare service delivery (FMoH, 2016/17).

In healthcare service delivery, if data exchange, services, process and other functionalities from multiple systems along the entire continuity of patient care doesn't happen, the healthcare organization face poor quality healthcare service poor coordination, inefficiencies in administration, and repetitions of avoidable medical errors resulted from redundant data, inappropriate data, due to adverse drug events caused by lose if HIS interoperability (William, 2006).

Lack of interoperability characterized by many things in healthcare, few of them explained as healthcare system is characterized by increased costs, high error rate, and knowledge mismanagement in return this could result in high rate of mortality (Olaronke et.al, 2013).

Annual review meeting report presented by AARHB state, the result of physical connectivity level (LAN) assessment shows the existence of high level of differences at implementation of Physical connectivity (from partial connectivity up to full Connectivity LAN) with absence of Experts as a problem from healthcare institutions side, however Health Net installation coverage reported as 100% achievement (AARHB, 2017/18).

Furthermore, studies also presented that interoperability barriers could be tackled by developing an interoperability framework applied for the application development phase. The study by (Diego, Lopez , & G.M.E, 2008) presented an interoperability framework covering all the developmental stages including architecture lifecycle process. The study presented separated views during requirement gathering including medical, legal, administrative, financial, technical, organizational and social restricted to platform-independent aspects of the architecture such as information system's enterprise, information, and computational views (Diego, Lopez , & G.M.E, 2008).

The Aim of this study is to provide one way of addressing healthcare service problems considering lack of eHealth systems interoperability as the main source of these healthcare service problems in FMoH healthcare institutions such as: lack of service coordination and patient experiences, lack of patients' safety and privacy and repeatedly committed medical errors up to patients death so far, by providing an eHealth systems interoperability assessment framework as a primary step to visualize the source of these problems. The need of interoperability is clearly visible but achieving interoperability in health data exchange has many constraints that have to be addressed (Shalini & Deepti , 2014).

Additionally, Interoperability problems raised from the diversity or non-uniformity in various technical and administrative services like the mode of accessing the data, powers and authorities available to IT team (developers), data storage schemas, security rules and policies generate lots of complexities in the path of data sharing between independent systems organizations from Architectural parameter differences, vocabulary, Message formats, Languages and models (Shalini & Deepti , 2014).

On the other hand, A research conducted (in Ethiopia) to show the existing Data level interoperability problems between two selected eHealth systems (LIS and HER) taking two hospitals as sample case study and propose Data interoperability Architectural Framework (Wondwosen, 2013) as a solution. However, FMoH and AARHB reported ehealth systems interoperability problems not yet resolved (FMoH, 2016/17) therefore; this study conducted to provide one way of addressing this problem adopting data level interoperability from this local research work as one of the key interoperability concern and extend it by including additional interoperability perspectives.

Even though assessing the data level interoperability is critical component for eHealth systems interoperability, the overall view of eHealth Systems Interoperability weakness and strengths should be studied from business level interoperability, process level of interoperability, service level interoperability, cultural interoperability level, Knowledge level of interoperability, human resource perspective and the maturity level of the existing eHealth systems with in healthcare institution or with other systems in the healthcare service domain.

To combat/tackle the above mentioned and other related problems it's obvious that establishing ehealth systems interoperability is not only mandatory but also an urgent task for FMoH healthcare institutions (FMoH, 2016/17) (FMoH, 2018).

The first step to create systems interoperability is the development of interoperability assessment framework. Because interoperability assessment framework is a prerequisite to establish a proper and effective interoperable systems, hence it helps to set priorities and continue focused, to build high level interoperability between systems, to easily visualize and get insight on the strength and weakness of ehealth

systems among other advantages (Committee, 2001), (Guédria, David , & Yannick, 2013).

Having the existence of the above mentioned facts FMoH healthcare institutions not only failed to create and established full-fledged ehealth interoperability systems, never attempt to prepare the first step work in building interoperable ehealth systems; interoperability assessment framework.

Therefore, this researched is an attempt to develop an interoperability assessment framework for ehealth systems in FMoH hence, to help and ease the sector future inevitable effort in establishing effective and responsive ehealth systems.

3. Research questions

- What are the critical treats they could impact on ehealth systems interoperability and further for the overall quality of healthcare service delivery in FMoH?
- How can we address healthcare service challenges originated from lack of eHealth systems interoperability?

4. General Objective

The general objective of this research is to examine the critical elements of systems interoperability with the view to explore solutions for FMoH owned ehealth systems interoperability problems through the development of relevant interoperability assessment framework towards improving overall quality of healthcare service delivery.

4.1. Specific Objectives

The above general objective can be addressed via performing the following specific objectives:

- To examine relevant related literature (papers, books and healthcare industry reports such as FMoH annual reports) used for relevant knowledge extraction concerning key elements of ehealth systems interoperability.
- To examine different countries experiences concerning ehealth systems interoperability challenges and how they addressed it?
- To propose an interoperability assessment framework with key interoperability elements relevant for FMoH owned ehealth systems
- To evaluate the validity of proposed interoperability assessment framework

5. Scope and Limitations of the study

This study will focus on the development comprehensive Interoperability Assessment Framework for eHealth Systems in general and for FMoH healthcare Institutions in particular. The study will emphasize on investigating the current situations of eHealth

systems interoperability and try to contribute ideas that will assist the future development of eHealth systems interoperability nationally. Therefore, the scope of this research is limited only on FMoH owned eHealth Systems specifically implemented in Governmental Healthcare Institutions and using the National Health Net network infrastructure as a back bone for collaboration.

Furthermore, this study covers governmental healthcare sector ehealth systems and potentially others systems found in healthcare service domain which are using The National Health Net (VPN) infrastructure.

The limitations of this study are the following: There is lack of previous studies in Ethiopia regarding identifying the key for eHealth systems interoperability by developing assessment framework beyond data level. To overcome this problem, the researcher tried to look for other countries experiences and other related studies conducted by other countries.

On the other hand, due to time constraint and corona virus pandemic this study has focused only development of interoperability Assessment framework excluding the development of Assessment tool drawn from four perspectives.

6. Significance of the study

The findings and result of this research may of potential value for the Ministry of Health (FMoH) to understand the complex nature of eHealth systems interoperability and how to approach the existing interoperability barriers via interoperability assessment multi-dimensionally.

Also, the finding will help FMoH as a guide to formulate an interoperability assessment tool derived from four basic interoperability perspectives then conduct an assessment to know the degree of eHealth Systems interoperability considering multiple aspects and plan to tackle the eHealth Systems interoperability challenges and successfully transform into the required healthcare service quality through harmonization of eHealth systems.

Further, this study will be a breakthrough for other researchers in other governmental sectors or national wise in health sector for the future work on the area and also provides additional knowledge to the area that could help as a reference knowledge base for this growing area and cop up with the corresponding technological advancement.

7. Organization of the Thesis

This thesis is organized in to six chapters towards achieving the goal of this study as follows:- In the first Chapter, background of the study discussed through highlighting the following points, eHealth Systems and their purpose, Implementation of eHealth Systems in Ethiopia and current situations, descriptions about eHealth Systems

interoperability concepts, Problem statements, research Question, Objective, Related works, Relevance and Scope of the study as well as operational definitions clearly discussed in this chapter.

Second Chapter presents reviews of literatures and organized in to three major sections that introduce the reader about over all Systems interoperability basic concepts and issues such as: The importance of interoperability, the meaning of interoperability, Problem of interoperability in the healthcare, The Ethiopian healthcare and AA health care system profile and Data Exchange and Interoperability Frameworks.

In the Data Exchange and Interoperability Frameworks section, different interoperability frameworks related to Healthcare Systems investigated and reviewed, in the second section, different e-Business Based interoperability frameworks were reviewed.

Then this chapter deals with eHealth systems interoperability experiences of countries investigated, including the international journals and articles investigated to have detailed understanding of interoperability issues multi-dimensionally. Then, based on the description of reviewed interoperability frameworks summarizing, synthesizing, Checking for relevant descriptions, ideas, concepts and interpretations conducted about the systems interoperability. Then after, essential features, components are summarized to Compare and contrast the completeness of each interoperability Frameworks and countries experience using the summarized basic components.

At the end of this chapter the strength and weakness points of each interoperability framework and Countries Experiences summarized in order to propose an appropriate interoperability Assessment framework that fulfills the gap or the key interoperability concerns specifically in order to fit with the context or scope of this study.

Third Chapter, Discusses the Theoretical framework development part, in order to show how and what components involved to propose compressive eHealth Systems Interoperability Assessment Framework in the context of FMoH Healthcare institutions.

Chapter four presents detailed description how the research design, population and sampling procedures of the study conducted. It also explains the data collection methods, interoperability perspectives along with their attributes for interoperability assessment as well as the techniques used to analyze the data in order to test the validation of the framework developed in previous chapter.

Chapter five presents detailed description of the data analysis result for the data collected through structured questioner. Brief analyses, interpretation and discussion of data were presented in this chapter.

Under chapter six general summary of the paper, final conclusion, possible recommendations and further research area were included.

8. Operational definitions

EHealth systems: Encompasses all the systems that are implemented in healthcare institutions and used as health data sources that required by FMoH to plan and implement its national health strategy.

Healthcare Domain systems: it includes all systems which are implemented in FMoH healthcare institutions also combines vital and health statistical data from multiple sources to derive information and make decisions about the health needs, health resources, costs, uses, and outcomes of healthcare. Examples of data sources are electronic health records for patient care, health facility data, surveillance data, census data, population surveys, vital event records, human resource records, financial data, infrastructure data, and logistics and supply data.

CHAPTER TWO

2. Literature Review

2.1. The meaning of interoperability

Many literatures confirmed that healthcare service sector involves collaboration of multiple other sectors to work together along the entire continuity of patient care, and supposed to share data and other functionalities accurately and fully among multiple care providers (Shane, 2019).

The term "interoperability" describes the ability of two or more information systems or components to exchange information and other functionalities based on standards, to interpret that shared data and to use the information that is exchanged. Interoperability enables different HIS to work together in and across organizational boundaries to advance the health status of individuals and communities and the effective delivery of healthcare to them (HIMSS, 2013).

Another study defined Interoperability is the extent to which the cooperation of a group of stakeholders to ensure the application of consistent rules across technical domains. It must also be done with sensitivity to legal, ethical, and societal requirements, including security, privacy, and confidentiality (Hammond, Bailey, Bouche, & Spoh, 2010).

2.2. Problems of interoperability in the healthcare

In healthcare service delivery, if data exchange, services, process and other functionalities from multiple systems along the entire continuity of patient care doesn't happen, the healthcare organization face poor quality healthcare service poor coordination, inefficiencies in administration, and repetitions of avoidable medical errors resulted from redundant data, inappropriate data, due to adverse drug events caused by lose if HIS interoperability (William, 2006).

Lack of interoperability characterized by many things in healthcare, few of them explained as healthcare system is characterized by increased costs, high error rate, and knowledge mismanagement in return this could result in high rate of mortality (Olaronke et.al, 2013).

2.3. The Ethiopian healthcare ehealth systems profile

As mentioned by GTP I and II (HSTP, 2015) Health sector has been one of the key priorities the for Government of Ethiopia in the past two decades focused on robust health policy and innovative strategies, towards increasing universal access to health services and improvements in health outcomes. In addition, the governments of Ethiopia and FMoH have been working on the process of building resilient and responsive health system that can address health issues in a sustainable, equitable and effective manner (FMoH, 2016/17).

The government has been struggling to improve the quality of healthcare service at different levels and through implementation of HIS as a key enabler of healthcare service quality. Furthermore, FMoH owned various national e-health application developed by different venders and implemented to all levels of governmental Healthcare institutions over the years, FMOH owned ehealth applications includes: DHIS2, EMR/EHR, CHMIS, HRIS etc. Other initiatives includes LIS, hub Store IS, HCMIS (drug dispending), CBHIS, etc. developed and deployed (FMoH, 2016/17).

FMoH also planned towards Multi-sectorial approach with various information systems managed by other sectors those who significantly contribute for information revolution in the health sector such as Civil Registration and Vital Statistics, Central Statistics Authority database, Agriculture and weather information systems, Geographic Information system, financial information system and education information systems (HSTP, 2015).

FMoH HIS Strategic document indicated that governmental health institutions built healthcare data repository (Data warehouse) in health centers, hospitals and regional level to exchange data between the above mentioned HIS furthermore, FMoH built high capacity central data repository Data warehouse at the federal ministry of health level administered by Health Information system directorate ((FMoH, 2016/17).

2.4. Data Exchange and Interoperability Frameworks

In this section different ehealth Systems Interoperability Frameworks such as: Data exchange interoperability framework between LIS and EHR, A development framework for semantically interoperable health information systems, NEHTA Interoperability Framework(Australia), Building a Strong and Interoperable Health Information System for Ghana (2018), A mashup based framework for multi-level healthcare interoperability, An Interoperability Test Framework for HL7-Based Systems, An eBusiness-based Framework for eHealth Interoperability examined.

Data level interoperability is the most important and essential interoperability level in healthcare service domain which improves the quality of healthcare by fascinating the exchange of information, such as clinical notes, observations, laboratory tests, diagnostic imaging reports, treatments, therapies, drugs administered, allergies and letters, x-rays, and bills with in and across the healthcare service domain/boundary (Olaronke Iroju, 2013).

Another studies clarified the prerequisite for an enterprises achieve interoperability of Information Systems Data level, it needs the ability of an enterprise to identify all the required data types, data formats, data constraints, the relationships between data, Data access roles, Data Ethics, Data security, Data privacy and legal issues related to enterprise data within and across the Enterprise service domain (Reza, Thiam, & Sai, 2014), (Koussouris et. al, 2011).

Other researchers in the study area suggested different mechanism to maintain HIS interoperability, (Tuncay , Gunes, & Asuman, MAY 2009) by developing automated interoperability test framework for the HL7- based systems, for checking the following interoperability stacks: Testing Business Process, Application, Transport, and Network Layers using web based and dynamically configurable system towards testing eHealth systems interoperability at different levels following key principles of HL7 standards (Tuncay , Gunes, & Asuman, MAY 2009).

Furthermore, studies also presented that interoperability barriers could be tackled by developing an interoperability framework applied for the application development phase. The study by (Diego, Lopez , & G.M.E, 2008) presented an interoperability framework covering all the developmental stages including architecture lifecycle process. The study presented separated views during requirement gathering including medical, legal, administrative, financial, technical, organizational and social restricted to platform-independent aspects of the architecture such as information system's enterprise, information, and computational views (Diego, Lopez , & G.M.E, 2008).

On the other hand, (Payam, Morad, & Craig E, 2011), came up with process based development methodology through awareness model to the actors of healthcare delivery collaboration domain, hopping as a means to develop interoperable health systems at different levels like: Data interoperability, Team member and task interoperability, Policy and procedure interoperability, Collaboration interoperability, Social interoperability, Knowledge exchange interoperability, Privacy and security (Payam, Morad, & Craig E, 2011).

on the contrary to unique features and complex nature of health service domain that involve the collaboration of multiple sector, the study by (Craig E, 2009) Suggested that eHealth agenda can benefit from research in e-business (Supply Chain Management) to resolve common challenges like heterogeneous pre- existing systems, existence of complex stakeholders' harmonization of different legislations, non-existence of standards and conformance evaluation checking methods for interoperability of systems.

The study by (CHEN, 2006) provides interoperability framework relied on preexisting interoperability frameworks and models, which have three basic dimensions of enterprise interoperability namely: Barriers to interoperability, Levels or aspects of interoperability and Approaches of interoperability (Reza, Thiam, & Sai, 2014).

The components and concepts of interoperability frameworks elaborated based on the situation focusing on the concepts that are more relevant in defining the enterprise interoperability (CHEN, 2006).

The following diagram represents the three dimensional interoperability framework developed by (CHEN, 2006).

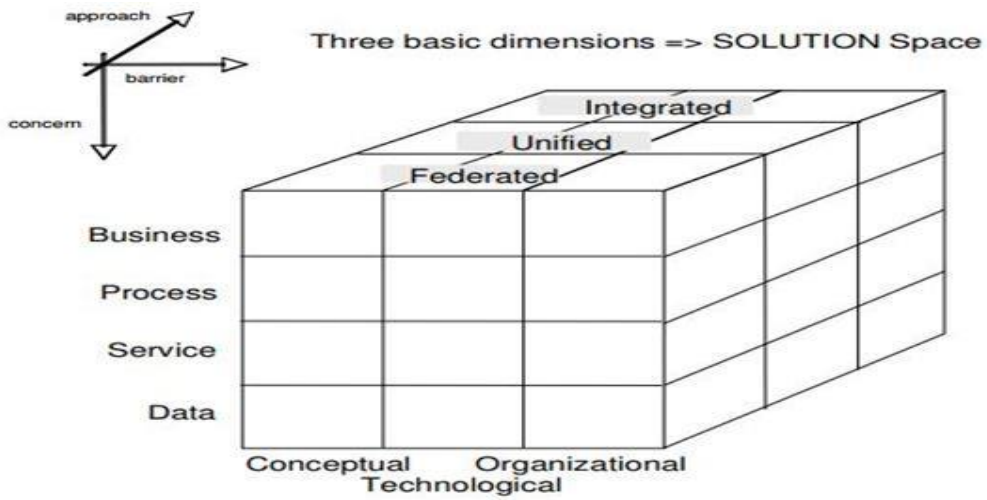

Figure 1: CHEN DAVID (2006) three basic dimensions of the Enterprise Interoperability Framework

Many countries or enterprise took different actions or approaches to maintain interoperability between their information systems. Ghana applied an interoperability assessment approach using an assessment tool developed by United States Agency for International Development (USAID).

Ghana assessed their existing eHealth Systems interoperability level by using HIS interoperability maturity model matrix, HIS interoperability maturity model matrix has domains, defined three possible domains as key perspectives namely: Leadership and governance; human resources; and technology further each domain is divided into subdomains, for a total of 18 subdomains (MEASUREEvaluationteam, 2018).

Here the researcher learned interoperability assessment is applied as a preferable solution for developing countries like Ghana and most likely for Ethiopia case too, thus this study provides an interoperability assessment framework.

Australian eHealth interoperability experience also examined during literature review, NEHTA interoperability framework aimed to provide a common reference point that provides guidance to business and IT experts in delivering interoperable ehealth systems in Australia (National E-Health Transition Authority , 2007).

The study relied on three basic interoperability concepts or perspectives namely: informational interoperability perspective, Organizational interoperability perspective and Technical interoperability perspective (National E-Health Transition Authority , 2007). The following diagram shows NEHTA interoperability framework perspectives.

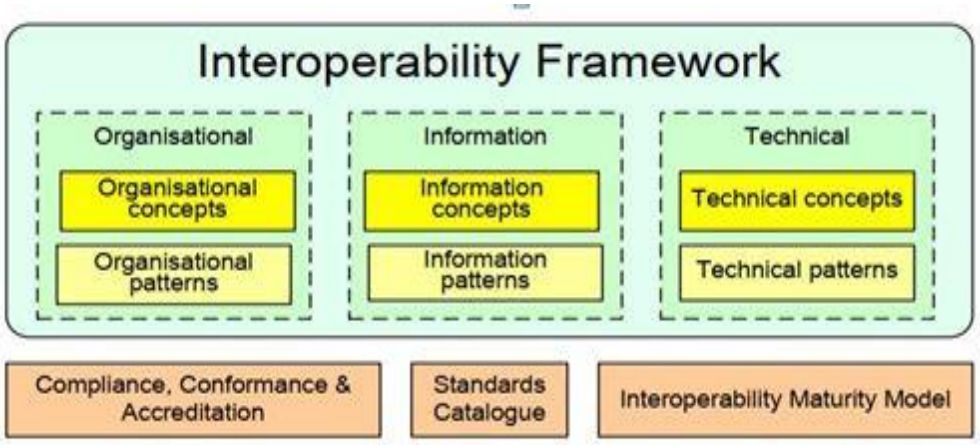

Figure 2: National E-Health Transition Authority (2007) three perspectives of NEHTA framework

2.5. Summary of Reviewed Interoperability Frameworks

In this section outlines of different interoperability frameworks and countries experiences are summarized. Further compare and contrast each interoperability frameworks and countries experiences comprehensiveness through gap analysis with extracted interoperability issues or enterprise interoperability scientific areas to show their corresponding coverage in each of the following particular Interoperability issues: Interoperability Levels or Concerns, Define Systems interoperability Barriers, Define Systems interoperability Approaches and their overall Strengths and weaknesses.

2.5.1. Systems interoperability Levels or Concerns

As presented in the previous section reviews, interoperability levels or concerns refers to the degree of systems interoperability each other without any obstacle in the service domain, they stated interoperability level or concern as the ability of system to exchange and work in collaboration with their Data or information, Service, process, people, Business, technical and semantic. The following Table presented coverage or levels of Interoperability in each Framework:

Interoperability Frameworks	**Interoperability Levels**					
	Data or Information	***Service***	***Process***	***Business***	***Technical***	***Semantic***
DLIFW for LIS and HER	√					
Interoperability Test Framework for HL7-Based Systems	√	√	√		√	
Development Framework for semantically	√	√	√	√	√	√

interoperable HIS						
Mashup based framework for multi-level healthcare interoperability	√	√	√			
An eBusiness-based FW for eHealth	√		√		√	
EIFW						
Ghana Experience	√		√		√	
NEHTA	√	√		√	√	√

Table 1: *Summary of Interoperability levels in Frameworks ((National E-Health Transition Authority, 2007), (Payam, Morad, & Craig E, 2011), (Koussouris et.el, 2011), (CHEN, 2006), (Wondwosen, 2013))*

NB: table 1 indicates that ehealth interoperability concerns are approached or visualized from different perspectives based on the existing organizational context also shows the gaps (coverage of key interoperability concerns) between the reviewed related works, later the researcher included in the proposed interoperability framework.

2.5.2. Systems interoperability Barriers

The following table shows the extent to which the reviewed interoperability frameworks addressed interoperability barriers from Conceptual, Technological, and Organizational barriers additionally People dimensions.

Interoperability Frameworks	**Interoperability Barriers**			
	Conceptual	***Technological***	***Organizational***	***People/culture***
DLIFW for LIS and HER	√	√		
Interoperability Test Framework for HL7-Based Systems	√	√	√	
Development Framework for semantically interoperable HIS	√	*Conceptual level*	√	
Mashup based framework for multi-level healthcare	√		√	√

interoperability				
An eBusiness-based FW for eHealth	√	√	√	
EIFW				
Ghana Experience	√	√	√	
NEHTA	√	√	√	

Table 2: *Summary of Interoperability Barriers in Frameworks ((National E-Health Transition Authority, 2007), (Payam, Morad, & Craig E, 2011), (Koussouris et.el, 2011), (CHEN, 2006), (Wondwosen, 2013))*

2.5.3. Systems Interoperability Approaches

The following table shows how the reviewed interoperability Frameworks and Countries experiences clearly presented the way or method applied for alleviating the hindering factors or interoperability barriers.

Interoperability Frameworks	**Interoperability Approaches**					
	Integrated	***Unified***	***Federated***	***Maturity Model***	***RUP & GCM Methodology***	***Barrier Driven***
DLIFW for LIS and HER	√	√	√			
Interoperability Test Framework for HL7-Based Systems	√ (HL7)					
Development Framework for semantically interoperable HIS					√	
Mashup based framework for multi-level healthcare interoperability	Types of awareness creation given to different Healthcare providers to support various aspects of collaboration in the Domain during requirement gathering					
An eBusiness-based FW for eHealth	Based on the Benefits of Supply Chain Operations References (SCOR) model to adopt for eHealth processes in the service domain collaboration					
EIFW						√

Ghana Experience				√		
NEHTA				√		

Table 3: *Summary of Interoperability Approaches in Frameworks ((National E-Health Transition Authority, 2007), (Payam, Morad, & Craig E, 2011), (Koussouris et.el, 2011), (CHEN, 2006), (Wondwosen, 2013))*

2.5.4. Weakness and strength points in different frameworks

In this section the limitations (Weaknesses') of the existing frameworks and countries experiences are explained. The following table summarizes weaknesses and strengths' of investigated studies in the study area.

Interoperability Frameworks	**Weakness & Strength of Interoperability Frameworks**	
	Strength	**Weakness**
DLIFW for LIS and HER	Focused on the most valuable interoperability aspect that is data level interoperability. Identified data Fields mismatch on the Data entry Forms of the two systems by using a prominent messaging standard in the health domain HL7 Standard for both eHealth Systems, Identified common barriers of interoperability such as: lack of common understanding caused by the use of different representations, different purposes, different contexts, and different syntax-dependent approaches, incompatible data format schema fields (including documents, multimedia content and digital resources),	Focused only on the Data level specifically messaging layer of interoperability issue, Ignored the Business process and Service level interoperability issue among the two eHealth systems, Ignored Human resource level of interoperability.
Interoperability Test Framework for HL7-Based Systems	The effort to automate the conformance test of Health systems developing web base and dynamically configurable system,	The framework ignores to check the cultural issues, knowledge interoperability issues,

	Used the best fitting Standard HL7 for Healthcare domain at multiple Layers of interoperability, Business Process, Application, Transport, and Network Layers,	This framework didn't consider the infrastructure availability to work the conformance test in the developing countries like Ethiopia, This framework doesn't work for architectural standard like SOA other than HL7standards,
Development Framework for semantically interoperable HIS	The application of flexible system development approach to take advantages of integrating multiple architectural approaches such as Service-Oriented Architecture (SOA), Model-Driven Architecture (MDA), ISO 10746, and HL7 development Framework involved in the healthcare domain, Detailed view Applied during requirement analysis by decomposing Healthcare interest and other Healthcare sub Domains interest to overcome the complexity of healthcare Domain and Structural complexity during development,	The framework works for developmental phase only, Nothing stated about the Maturity Model or ignored the dynamically changing feature of Service delivery modals so far doesn't mentioned about measuring maturity level of interoperability continuously, This Framework didn't mention Human resource domain as one component of HIS interoperability.
Mashup based framework for multi-level healthcare interoperability	Introduced collaborative based interoperability framework approach that allows the actors in the Healthcare domain to better understand the processes being happened, Helps to better determine requirements involving Non-Technical staffs in the requirement determination through awareness model.	It covers the conceptual level of interoperability issues and completely relied on the Awareness creation about the collaboration process in the Healthcare domain, Leave the technical aspect of interoperability,
An eBusiness-based	Identified three granularity levels of healthcare service delivery and	This framework didn't consider knowledge

FW for eHealth	more emphasized on patient centric approach, Allows the service model more flexible to support the uniqueness of Healthcare service delivery to each individual Patient, The effort to take advantages of eBusiness based Frameworks and integrate with the eHealth service model to support eHealth interoperability concerns effectively,	interoperability and the cultural difference issues exist in the health domain, Ignores the maturity model to handle the dynamic changes in the healthcare service domain,
EIFW	Provides set of principles for organizational collaborating of e-government services. Present e-government interoperability issues in a broader dimensions,	This framework considers interoperability solutions only specific for business, technical and semantic, Ignored other interoperability perspectives like Maturity measure, Cultural interoperability and Human resource domain of interoperability,
Ghana Experience	Considered Interoperability maturity assessment as an approach to resolve interoperability barriers, The Maturity model used for assessment considered the basic interoperability component "Human resource interoperability",	It gives more emphasis to Human resource domain on the contrary ignores the cultural and knowledge interoperability issues, The process descriptions or situation statements to describe practices to achieve the desired goal were linear/rigid for the corresponding major component and sub components,
NEHTA	This framework focused on majority of interoperability concerns in the health sector and	This framework only focuses on guidelines and standards to be followed in

	applied maturity model to evaluate interoperability,	their local context, Didn't mention about the Human resource Domain as a component of interoperability,

Table 4: Weakness & Strength of Interoperability Frameworks ((National E-Health Transition Authority, 2007), (Payam, Morad, & Craig E, 2011), (Koussouris et.el, 2011), (CHEN, 2006), (Wondwosen, 2013))

NB: The above summary presented in table let the researcher to extract the best fitting interoperability assessment framework framed with local context and learnt the examined related studies and other countries experience had some limitations, thus the researcher decided to provide the possible comprehensive interoperability assessment framework rather than directly adopt them.

2.6. Related works

Compared to literatures on interoperability area, in local context very few researchers tried to investigate about interoperability, a study by (Wondwosen, 2013) was one of them, this study conducted based on the information gathered concerning data level interoperability between two HISs implemented in two selected reginal Hospitals.

The study relied on Laboratory information system (LIS) and Electronic Health Record (EHR) based on the FMoH, 2010 Annual performance report about small-scale HIS implementation with greater duplication of efforts and interoperability problems. It provides Data level interoperability framework between LIS and EHR following qualitative research approach with the data gathered through open ended questioner conducting interview for System users and experts in Yekatit 12 and Minilik Hospital followed by validation of the study. This research used NVivo-10 software for coding the interview and analyzes the data (Wondwosen, 2013).

Finally the DEIF is designed based on two pillars I) Operational layers and Applications layers and II) infrastructure layers (Wondwosen, 2013), then the researcher conducted detailed discussion with developers, system users and decision makers to test the validity of the proposed framework through their opinions'.

The proposed Data exchange interoperability framework by (Wondwosen, 2013) presented by diagram as follows:

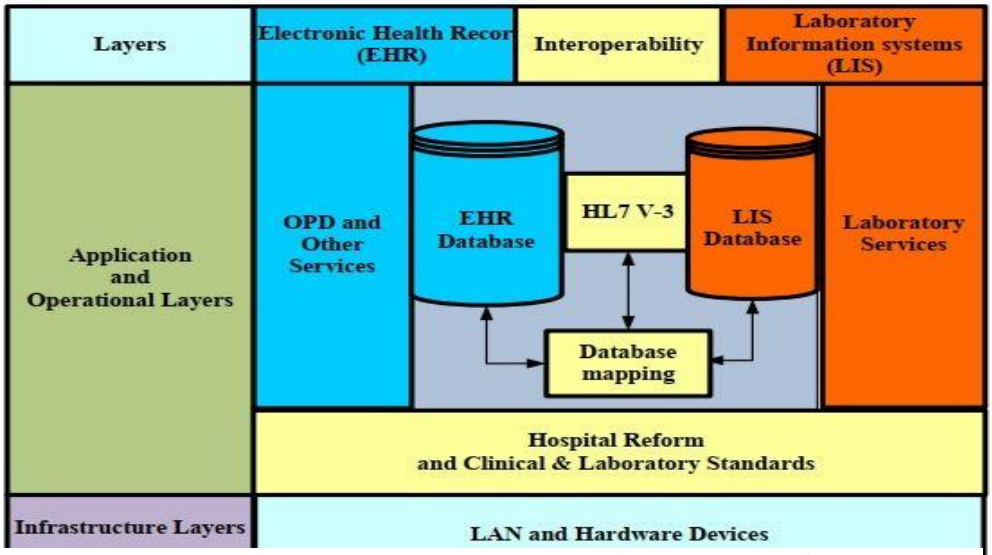

Figure 3: Data level interoperability framework for LIS and EHR (Wondwosen, 2013)

NB: Here the researcher identified how much data level interoperability is critical in healthcare service delivery and how to extend it including additional ehealth interoperability key components like organizational interoperability issues and others, as per specified in the future work part of the above local study (Wondwosen, 2013).

Another Study by (Kolsoom, Masoumeh, & Nasrin, 2011) Examined different interoperability frameworks and interoperability experiences of some countries through qualitative approach involving content analysis method and extracted components.

Further, those extracted components validated involving method of model evaluation based on survey-description research method through a designed questioner in the form of five point Likert Scale to gather experts' opinion to determine the importance of key components (Kolsoom, Masoumeh, & Nasrin, 2011).

Finally, this study proposed an interoperability assessment framework with basic dimensions: business, information, semantic and technical after the model validated applying Binomial test technique on the data replied by experts for each component. Further, the study provided an e-government interoperability assessment framework for Tehran municipality organization after validation (Kolsoom, Masoumeh, & Nasrin, 2011).

NB: Here the researcher adopted some key attributes of interoperability such as Technical interoperability components, informational interoperability components to support the validity of the proposed interoperability assessment framework.

CHAPTER THREE

3. Interoperability Assessment Theoretical Framework Development

3.1. Introduction

This thesis focuses on the development of an Interoperability Assessment Framework (broader interoperability aspects beyond data level) for eHealth Systems implemented at all governmental Healthcare Institutions under FMoH. In order to meet this objective the researcher implemented qualitative research methodology using Content analysis to extract the key components of the proposed interoperability assessment framework from related studies and other countries experiences.

Thus, the research used qualitative methodologies to construct the intended interoperability assessment framework by examining a wide range of primary and secondary information sources. The research process divided into two main stages: extensive literature review for framework component extraction and validation of the proposed interoperability assessment framework appropriateness and relevance to FMoH.

The study established theoretical framework to guide the review of literature and the empirical study conducted after the extraction of framework components at different stages of the research.

The research theoretical framework includes systems interoperability concepts or issues and perspectives, systems interoperability assessment frameworks and systems interoperability assessments models and approaches for eHealth systems interoperability assessment framework development.

Those frameworks were used to better understand the critical systems interoperability perspectives, methodologies and interoperability assessment models that helped to develop the intended multi-dimensional eHealth systems interoperability assessment framework by integrating the unique features with additional perspectives to fit with the context of this research scope.

3.2. Theoretical Framework Development of the study

There are three key theoretical framework components that have been used as an integral part of the proposed interoperability assessment framework these are: Systems interoperability perspectives and Concepts, systems interoperability assessment frameworks specifically from other countries experience and systems interoperability assessment models and approaches.

The examined concepts on the area of this study later help to formulate a fitting interoperability assessment framework with additional key components in order to address exceptional issues from these former theoretical frameworks that studied in

other countries context then extended for eHealth systems and healthcare institutions under FMoH after tested the validity of each component.

Generally eHealth systems interoperability used HIS to enable the health service delivery quality from many different perspectives or to let the healthcare organization achieve its goals from different interoperability perspectives. Accordingly Interoperability goals are characterized by the ability of eHealth system to support the way of service delivery by reducing time and money or improving coordinated service and process or any functionality, increase the availability and accessibility of data with high privacy and security, also the ability to reduce data redundancy further ehealth systems can collaborate with other systems in the same domain based on an agreed semantics at different level of interoperability stack.

Since Healthcare domain is so much complex that involves many institutions like medical, financial, accreditation and certification institutions, Legal institutions, statistics agencies and other so much related institutions at different hierarchy and different concerns or level of interoperability therefore, eHealth systems and Healthcare institutions has to come up a better interoperability requirements and implementation considering the collaborating parties in the healthcare domain with a defined scope.

In the case of this study, Healthcare institutions under FMoH implemented many fragmented eHealth systems to enable the service delivery but as reported by the regional bureau annual report, as they are being challenging with lack of interoperability between these eHealth systems and across the healthcare domain.

If so, there are many ways to address eHealth systems interoperability problems such as, the development of proper eHealth strategy at different situations such as applying Standard system development process assessment (Reference Model) during the development phase using development process models others might prefer conducting interoperability Assessment conformance and certification through different interoperability metrics using different types of interoperability Assessment frameworks or Assessment models as a method to address the eHealth systems interoperability barriers.

This study intended to formulate a comprehensive interoperability assessment framework for eHealth systems under FMoH healthcare institutions, the interoperability assessment framework outlined the foundational perspectives and elements needed for eHealth systems Interoperability and provide the methodology how to approach and implement interoperability Assessment.

This research conducted by examining different countries experiences and interoperability frameworks and assessment models such as: DLIFW for LIS and EHR, Interoperability Test Framework for HL7-Based Systems, Development Framework for semantically interoperable HIS, Mashup based framework for multi-

level healthcare interoperability, An eBusiness-based FW for eHealth, EIFW, Ghana Experience and NEHTA.

Nonetheless, the above interoperability Frameworks were developed based on their own countries context, Enterprise System Architectural settings, level of ICT Infrastructural availability, Type of Governance Structure, even their Number of skilled man power (Skilled Human resource), type of demographic information about their population (diversity of community) and focusing on different interoperability perspectives with variety of details (this study intended to provide an interoperability assessment framework taking advantages of the strength of the existing studies and removes their weakness) as mentioned in chapter two (Table 8: Weakness & Strength of Interoperability Frameworks).

Finally, this study adapted the most widely used interoperability framework components as a foundation and later adds other key interoperability assessment framework components to address the contextual features (interoperability issues) for FMoH eHealth systems interoperability Assessment framework.

Because, there has not been previous study conducted locally concerning eHealth systems interoperability assessment framework (except data level). Among all the examined interoperability frameworks NEHTA covers interoperability framework development by defining goals based on three mostly used interoperability perspectives (Informational, organizational, and technical) up to interoperability Assessment framework development considering the Healthcare institutions at different healthcare domains/ scope from National e-health community context, however this study ignored the most unique features like Human resource interoperability, Cultural interoperability and knowledge interoperability.

NEHTA also formulated in enterprise or local domains, including regional states and healthcare enterprises that is almost similar context with Federal Government, Regional States, woreda level Healthcare institutions in Ethiopia healthcare sector architectural setting and Federal governmental structure too.

Having the above similarities between NEHTAs' context with the case under study and comprehensiveness of NEHTAs' interoperability assessment framework that contains the most valuable interoperability perspectives found in most of Interoperability framework developers and other related studies as foundational key elements namely Informational, Technological and Organizational this study followed NEHTAs' interoperability assessment model (IMM).

Further this study includes additional interoperability concerns/perspectives reflecting FMoH eHealth systems interoperability issues as key interoperability components of eHealth systems or Healthcare institutions interoperability assessment framework such as: Cultural interoperability issues, Knowledge interoperability, interoperability Approach and Human resource issues after validated by an empirical result.

3.3. Four Interoperability Perspectives

This study developed an interoperability assessment framework having four interoperability perspectives namely Informational, Technological, Organizational and others interoperability perspective along with key components using other enterprise interoperability scientific areas from different journals and articles, interoperability issues, basically using results of the FP7 ENSEMBLE project (Koussouris, Lampathakil, Mouzakitis, Charalabidis, & Psarras, 2011) as a lens to view interoperability perspectives/issues as categorizes into four different granularity levels.

The study structured in to four interoperability perspectives as follows: Organizational or Business interoperability, Informational interoperability, Technological interoperability and other Interoperability perspective contains issues like Human Resource, Cultural, Knowledge, and Maturity Measures etc.

On the other hand Ethiopia as a country where FMoH healthcare institutions are located at a diversified community plus variety of languages, culture and social trend/ norms also shortage of capable and skilled Human resource (Experts) in the health sectors as reported by FMoH ICTDA repeatedly, thus to handle the impact of these situations on the interoperability of ehealth systems, this study integrated Human Resource, Cultural, Knowledge interoperability issues under the fourth perspective.

3.3.1. Organizational Interoperability Perspective

The organizational perspective of the IF (OIF) addresses the business context as well as legal and policy issues of relevance for understanding, specifying and deploying e-health systems. The OIF allows for the description of business processes, business policies and organizational structures, covering the scope of intra-organizational, inter-organizational and cross-jurisdictional interactions. This also supports the description of both the strategic and operational governance aspects of various corporate and technology structures (National E-Health Transition Authority , 2007).

Organizational/Business interoperability refers to working harmoniously at the organizational levels despite different modes of decision making, work practices, culture, legislations, commercial approaches, and so on achieving a harmonious environment could aid in developing businesses between the companies (Chen et al., 2008a).

(Reza, Thiam, & Sai, 2014) (CHEN, 2006) They clearly mentioned Organizational interoperability perspective from their barriers point of view considering barriers as the responsibility, definition, and authority, in addition to the incompatibility, of organizational structures and functionalities.

As mentioned by (Kolsoom, Masoumeh, & Nasrin, 2011) Organizational/Business interoperability consists of policy, organization, legal and business issues. Its aim is

facilitating collaboration between organizations. They identified common integration areas and cooperation opportunities how business processes integrated in order to deliver services to other organizations or customers.

These Interoperability Frameworks and Countries experiences' reveal that Organizational perspective as a significant interoperability framework component along with variety of sub-Areas accordingly, some of these sub components of Organizational perspective are Rules and Regulatory policies, Organizational objective, Process reengineering/standardization, Service, knowledge, Culture, enterprise architecture. Thus, this study incorporated organizational perspective along with sub components as an important and valid metrics towards assessing the level of ehealth systems interoperability under AARHB healthcare institutions.

- **Rules and Regulatory policies Interoperability**

As noted by NEHTA legislative and regulatory constraints need to be well understood and addressed for the design of e-health systems to enable organizational interoperability across health organization boundaries and between jurisdictions (National E-Health Transition Authority , 2007).

This sub area explained by (Koussouris, Lampathakil, Mouzakitis, Charalabidis, & Psarras, 2011) as the harmonization of the enterprise rules and policies in accordance with the countries, regions, or any organizational rules and regulatory policies which are in the line of the interoperation or under the Service domain.

According to (Craig E, 2009), policy is one of different needs that the healthcare system must support or deliver including healthcare services by eHealth framework.

Healthcare institutions should clarify Policies and procedures for all the interoperability requirements that involve electronic exchange of healthcare data (Payam, Morad, & Craig E, 2011).

In this regard NEHTA explained the purpose of policies is to address uncertainty in the world of imperfect information and thus increase trust among the actors involved. For example, well-developed privacy policies in e-health will help to increase trust of individuals in the confidential use and disclosure of health information for the collaborating parties (National E-Health Transition Authority , 2007). Furthermore NEHTA explicitly presented the importance of policy interoperability for healthcare institutions towards seamlessly interoperate without any constraint by specifying their policies in to three core types as follows: Obligations specify a required behavior, Permissions specify behavior that is allowed to occur, Prohibitions specify behavior that must not occur and these basic policy types form the basis for expressing more complex organizational policy types such as delegation, accountability, privacy and consent.

Rules and regulatory policies should be clearly identified and enabled in the domain of interoperation to conduct a legitimate interoperation among the organizations and

governmental regulatory bodies in the domain of AARHB healthcare boundary. Specifically rules and regulatory interoperability implies the ability of Healthcare institutions to conduct the exchange of data, service, process or other entities of interoperation with other organizations in the healthcare domain in accordance with the legitimate law or rules and the privacy of clients. Thus, this study added this sub component as a valid appropriate component of the proposed framework.

- **Business Objective Interoperability**

Business objective also related with the ability of healthcare organization to define their objectives explicitly. On the other hand the ability of healthcare organization to make visible and open tactical or strategic objectives for the other organizations under the service domain.

The second principle of NEHTA emphasizes the importance of well-articulated business objectives of an organization or community and how the IT systems implemented to support this objective. The implication of this principle is that there needs to be a way of defining value that IT brings to the organization or community (National E-Health Transition Authority , 2007).

Thus, business objective interoperability included under organizational interoperability perspective as a valid and important measurement item to check how much healthcare organization created transparent and clearly defined business objectives towards achieving harmonized interoperation internally or with other organizations under the healthcare service domain. AARHB healthcare institutions could benefit more with shared Business objective between other organizations' business objectives under healthcare service domain by creating enabling environment to align their Process, Enterprise Service, Enterprise Culture, Enterprise knowledge and Enterprise Architecture between the Enterprises under healthcare Service domain boundary towards attaining their organizational objective mutually.

- **Process reengineering/standardization/modeling**

Process reengineering refers to the ability of healthcare organization to transform the entire common ways of steps; procedures or processes in to more generic or universally acceptable processes by the involved organizations for interoperation further, explicitly define in the objective of healthcare organizational document (Koussouris, Lampathakil, Mouzakitis, Charalabidis, & Psarras, 2011).

Process interoperability intends to make various processes work together and requires knowing how to connect the internal processes of two companies necessary to create common process in a networked enterprise (CHEN, 2006) (Reza, Thiam, & Sai, 2014).

Process Standardization also another sub area of objective interoperability which refers to the ability of healthcare organization to adopt the entire tactical or

operational process with the standardized process accepted in the healthcare service domain (Koussouris, Lampathakil, Mouzakitis, Charalabidis, & Psarras, 2011).

(Payam, Morad, & Craig E, 2011), also developed process based development methodology through awareness model to the actors of healthcare delivery collaboration domain to develop interoperable health systems at different levels considering process interoperability as a pillar for other interoperability requirements in healthcare sectors.

The other sub area of Objective interoperability is Process Modeling which refers to the ability of healthcare organization to represent the entire procedures or sets of procedures through a type of abstraction or symbolization and share to the involved organizations under the healthcare service domain (Koussouris, Lampathakil, Mouzakitis, Charalabidis, & Psarras, 2011).

A business process is a structured style of behavior usually described in terms of a number of related concepts, including: each business step can have one or more input artifacts and one or more output artifacts, atomic steps that cannot be decomposed into other business steps, business functions, composed of other business steps or separate business processes; such constituent processes are sometimes referred to as sub-process and they may be assigned to roles which are responsible for the enacting of the step (National E-Health Transition Authority , 2007).

Business process standardization further explained as a process of capturing a number of standard business processes considered important in facilitating interoperability between people, organizations and systems (National E-Health Transition Authority , 2007).

Therefore, business process reengineering/ standardization/modeling included as a sub area of the proposed ehealth systems interoperability assessment framework considering as valid and valuable measurement item for organizational interoperability perspective.

- **Service Interoperability**

As noted by (Koussouris, Lampathakil, Mouzakitis, Charalabidis, & Psarras, 2011) Service interoperability refers to the ability of organization to align or disclose their service or organizational function by taking best practice/standard service in their service domain organizations. They also defined as identifying or composing the best service procedures and best way of service delivery which can handle the interoperation between involved organizations in a harmonized manner (Koussouris, Lampathakil, Mouzakitis, Charalabidis, & Psarras, 2011).

Service interoperability refers to identifying, composing, and making various applications that are implemented and designed independently function together. The term “service” is not limited to computer-based applications; it also covers networked enterprises and company functions (CHEN, 2006) (Reza, Thiam, & Sai, 2014).

According to NEHTA business service in the OIF is a particular abstraction of behavior expressing the guarantees of service providers. Typically such guarantees are expressed in terms of service offers which, if accepted by service users (as a requestor for service delivery) form the basis of a service level agreement (National E-Health Transition Authority , 2007).

(Arne-Jørgen, et al., 2007) Accommodates service interoperability as critical issue, the study also suggested that Interoperability within the service level involves identifying, composing, and executing various applications that are implemented and designed independently. Services are an abstraction and an encapsulation of the functionality provided by an autonomous entity.

Therefore, the above arguments revealed that service interoperability is vital issue, further more formulating generic service standard procedures aligned with the other organizational service concepts, vocabularies and following governmental legislatives in the healthcare service domain. Thus, this study added service interoperability sub component under organizational interoperability perspective as an important measurement item in the proposed framework.

- **Enterprise Architecture Transformation**

As noted by NEHTA Enterprise Architectural transformation presents an architectural foundation based upon service principles including provision of reusable business services and separation of interface from implementation. Depending on the system being described, architecture specifications will consist of varying degrees of organizational, information and technical contents (National E-Health Transition Authority , 2007).

(Kasunic, 2001), argued the importance of enterprise architecture transformation towards interoperability success as follows: 'When well-defined architectures exist, engineers can design individual components and builders can implement them with a high degree of confidence that the end results will work as expected and meet user needs'.

According to NEHTA Enterprise Architecture Transformation also denotes the ability of an enterprise to look forward for the batter business model or service delivery methodology and align with others organizations business model for a mutual benefit via upgrading the quality of service and product and implement it on the systems under the service domain. This interoperability issue needs clear identification of the collaborating parties and identification of all the entire actors and allocation of roles and responsibilities accordingly (National E-Health Transition Authority , 2007).

Thus, Enterprise Architecture refers to the ability of healthcare organization to transform the existing business model or the entire organizational Structure in to a compatible form or business model which allows the healthcare organization to deliver service or product seamlessly on the way that all the collaborating

organizations in the Healthcare Domain benefited. These implies that an interoperability assessment framework has to include the metrics to measure the capability of healthcare institution to transform organizational operations towards the latest and most effective architectural setting to cop up with the dynamically changing mode of healthcare service delivery across the service domain. As a result, this study included Enterprise Architecture transformation concept as a valid measurement item in the proposed framework under organizational perspective.

- **Governance approaches and Structures**

This sub category also captures various issues associated with needs to establish control of organizational or technical processes in an organization. The problem domain is divided in terms of corporate and technology governance. Typically, each health organization will have corporate governance and depending on its size and technology maturity, it will also have one or more other, technically focused, governance structures (National E-Health Transition Authority , 2007).

According to (Measureevaluation, 2018), governance approach and leadership structure is the exercise of technical, political, and administrative authority to manage national HIS affairs at all levels of a country's health system. The governance structure consists of the mechanisms, processes, and institutions through which actors and stakeholders articulate their interests, exercise their rights, meet their obligations, mediate their differences, and oversee the functioning of the HIS.

Thus, this study included governance approach and structure under organizational interoperability perspective as a basic and important issue (measurement item).

3.3.2. Informational Interoperability Perspective

NEHTA presents informational perspective containing key sub units that allows to addresses the semantics of information relevance for understanding, specifying and deploying e-health systems. The IIF allows for the description of key information components and their relationships. Typically the information components will represent certain artifacts in the organizational perspective. On the other hand NEHTA noted that the IIF is not meant to replace the existing information models or introduce a new information model but rather facilitate the co-existence of different information modeling approaches through a common reference point (National E-Health Transition Authority , 2007).

According to (HIMSS Board of Directors, 2013) in healthcare, interoperability is the ability of different information technology systems and software applications to communicate, exchange data, and use the information that has been exchanged. Further they defined sub areas of informational interoperability such as: Data exchange schema and standards should permit data to be shared across clinicians, lab, hospital, pharmacy, and patient regardless of the application or application vendor towards effective delivery of healthcare for, individuals and communities.

The importance of Informational perspective also supported by (Carlile P., 2004) who stated that interoperability refers to the ability of a system to use and share information or functionality, of another system by adhering to common standards, furthermore the study elaborated as healthcare organizations generate information or data which is huge and complex in type and magnitude, and this information or data need to interact and be accessed by healthcare practitioners in a uniform and transparent way, anywhere and anytime, as required by the treatment path of the patients or between organizational systems with in healthcare domain.

Also (Olaronke Iroju et.al, 2013) mentioned healthcare providers need to exchange information, such as clinical notes, observations, laboratory tests, diagnostic imaging reports, treatments, therapies, drugs administered, allergies and letters, x-rays, and bills with in and across the healthcare service domain/boundary. In addition this study clarified that, this information may be heterogeneous in terminologies, schema, syntax, semantics, data types, and data formats and constraints this shows interoperability of eHealth systems has to be assessed with their informational aspects.

Common data and information can be achieved by leveraging controlled terminologies and using conceptual models such as ontologies to promote common understanding of the healthcare domain (Craig E, 2009).

The above studies agreed that Informational perspective is one key component of interoperability frameworks. Further, NEHTA includes the following sub components aligned with Informational perspective for healthcare organizations/ ehealth systems as a base: Information policies to identify the rights and obligations of different stakeholders involved throughout the lifecycle of information, including: Copyright, Moral Rights, Exclusivity, Access and Distribution rights, Modification rights and/or Transferability of rights (National E-Health Transition Authority , 2007).

Another Informational perspective sub component is Meta-Data to describe information of concern like information about the creator of the component, date, or version further meta-data describes about the structure of the information for the interacting systems or healthcare organizations (National E-Health Transition Authority , 2007).

The other critical component of informational perspective presented by NEHTA is that Information Quality issue, first by defining Characteristics of Quality Information in the healthcare domain using many attributes like Accuracy, Access control, Accessibility, Relevance, fitness for purpose and consistency of representation during creation, storage and exchange. Then after, measuring the quality of healthcare information using the quality metrics mentioned as core Informational perspective sub components (National E-Health Transition Authority , 2007). Therefore, this study added informational interoperability perspective as valuable component in the proposed framework.

- **Data interoperability**

According to (Reza, Thiam, & Sai, 2014), data interoperability considered as a sub area of Informational interoperability issue that refers to the ability an enterprise to identify all the required data types, data formats, data constraints, the relationships between data, Data access roles, Data Ethics, Data security, Data privacy and legal issues related to enterprise data within and across the healthcare service domain/boundary.

Furthermore (Koussouris, Lampathakil, Mouzakitis, Charalabidis, & Psarras, 2011) also considered the following sub areas under data interoperability: Data representation, Data Access Principles, Data Standardization and Data lifecycle including the following definitions. Thus, this study included data interoperability sub component under informational perspective as an appropriate measurement item.

- **Data Access principles and Data Ethics**

Data Access principles refers to the ability of healthcare organization to determine the level of data visibility, accountability, data accessibility and role of the collaborating enterprises on the healthcare data in accordance with the rules and regulations of the enterprises. Defining data access roles and responsibilities for each and every actor in the organizational structure accordingly (Koussouris, Lampathakil, Mouzakitis, Charalabidis, & Psarras, 2011). Thus, this study avail data access principles and data ethics as one of the important and valid measurement item.

- **Data standardization**

Data standardization refers to the use of the same set of data types, formats, documents, multimedia content and digital resources or codes to create generic, yet expandable, data standards to be used by all enterprise systems under the Healthcare service domain data privacy also considered here (Koussouris, Lampathakil, Mouzakitis, Charalabidis, & Psarras, 2011). Therefore, data standardization included in the proposed framework as a basic and valuable measurement item for informational perspective.

- **Data representation**

Data representation refers to the potential of healthcare organization to model or represent the entire data requirements and required data content, type, use and structure based on the service transactions, business rules and objective of the organization. Further data representation includes identification of data fields, relationships and Data constraints in accordance with the collaboration of enterprises in the service boundary or domain. Data representation should address the confusion or lack of common understanding caused by difference in purpose, context and representation among the collaborating parties (Koussouris, Lampathakil, Mouzakitis, Charalabidis, & Psarras, 2011). Thus, this study added this sub component as an important measurement item for the proposed framework.

- **Data Life cycle**

Data life cycle refers to determining the healthcare data access levels, hierarchical data visibility, data collection, data generation, data aggregation, data management, data transition and data storage privileges and roles between the enterprises under Healthcare service domain (Koussouris, Lampathakil, Mouzakitis, Charalabidis, & Psarras, 2011).

Therefore, this study added data life cycle measurement item as a valid component for informational perspective.

3.3.3. Technical Interoperability Perspective

Technological interoperability related to the compatibility of information technologies such as infrastructure, architecture, and platforms. These are concerned with the standards for the processing, exchange, storage, presentation, security, systems development technology and communication protocols and physical connectivity of computers and data formats (CHEN, 2006).

According to (National E-Health Transition Authority , 2007), The Technical perspective provides a framework for specifying functionality to be delivered by the technologies employed within e-health applications - but oriented to a business purpose, as documented by the organizational concepts organizational functionalities towards meeting its objective. Therefore technical perspective allows facilitating the coexistence of different technical modeling approaches through common reference points and Provides a set of concepts and technical interoperability patterns which serve as a common denominator for a number of specific technical solutions that can be employed in e-health systems today or into the future (National E-Health Transition Authority , 2007).

According to (Measureevaluation, 2018) Technology perspective of HIS interoperability explained issues like National HIS Enterprise Architecture, Technical Standards, Data Management, HIS Subsystems, Operations and Maintenance (for Computer Technology) , Communication Network: Local Area Network (LAN) and Wide Area Network (WAN), Hardware, HIS enterprise architecture, data management processes, and data exchange standards are likewise critical.

Generally technical perspective of interoperability reflect the capabilities of underlying technologies (Basic ICT infrastructures), supports service provisioning, access and use, as part of delivering business value to the end users (National E-Health Transition Authority , 2007).

On the other hand this perspective should define the best fitting technological requirements towards facilitating the abstraction to business services, a composition capability to support business processes and orchestration, and ultimate access through service delivery channels thus services reflects functionalities required by the

business context, including the contained business logic also, Software components, Service, Service interface, Service composition, Action, Event, Message and interaction as core concepts in Technical perspective of interoperability (National E-Health Transition Authority , 2007).

Further, (National E-Health Transition Authority , 2007) presents technical interoperability perspective attributes to assess the capability of ehealth systems in capturing some commonly occurring, existing or emerging, structures, approaches and technical characteristics identified to be of important for many enterprise systems through their service delivery channels, styles of component interactions, technical quality aspects and architectural styles.

Thus, this study comprises technical perspective sub components like Technological requirements in a hardware or software level, which includes the type of hardware devices like computers, network devices(communication devices), physical cabling types, used considering all the advantages for specific enterprise and collaborating organizations as well. Those components allow the healthcare institute to assess the level of ehealth systems interoperability.

Software view point also refers to the selection of best fitting software systems and the entire components like best communication protocols, messaging standards, logical connectivity standards, system architecture, security mechanisms, platform, software development tools and other many technological issues as a metrics to measure the level of interoperability across the healthcare service domain integrating with maturity model. Thus, technical interoperability perspective and the corresponding components included as a valid and important construct in the proposed framework.

- **Technical Standards and specifications**

An established norm based on a set of requirements, specifications, guidelines, or characteristics that can be used consistently to ensure that digital health systems, health information services, and processes are appropriate for their purpose. Standards provide a common language and set of expectations that enable interoperability among systems and/or devices. The technical standards include standards for data exchange, transmission, messaging, security, privacy, and hardware (Measureevaluation, 2018).

Standards and specifications are important elements in delivering an interoperable future. They support the separation of implementation from specification allowing for component replacement and system evolution in the future (National E-Health Transition Authority , 2007). Thus, this study included technical standards and protocols concept as an integral and valid measurement item under technical perspective of the proposed framework.

- **Software systems interoperability**

Software systems interoperability refers to the ability of eHealth systems to work with other eHealth Systems seamlessly without special effort from the stakeholders this can be achieved by advancing systems architecture, selection of proper messaging protocols, communication protocols, security protocols, development tools, platform selection and other best technical selections to be included in the health information systems (Koussouris, Lampathakil, Mouzakitis, Charalabidis, & Psarras, 2011).

Under this interoperability perspective, eHealth systems interoperability level measured by the following key features as metrics: type of business model and system architecture applied, how much organizational objective enabled, the quality of information, service or other functionalities exchanged between systems to system or System to human in accordance with the agreed set of semantics or syntax with high level of security and privacy across the service domain (Koussouris, Lampathakil, Mouzakitis, Charalabidis, & Psarras, 2011).

Based on the above arguments this study included software systems interoperability as an appropriate measurement item for technical interoperability perspective.

3.3.4. Other interoperability perspectives

- **Cultural interoperability**

Cultural interoperability refers to the a ability of healthcare organization to harmonize the internal trends, natural differences like religion, language differences, Ethics difference, social Norms and Value differences and other unique trends of organizational practices under the healthcare service domain. Further Cultural interoperability is the ability of healthcare organization to accommodate the above social and public Cultural differences in the eHealth systems to increase the acceptance of the eHealth Systems used for interoperation under the complex healthcare service domain. The ability of healthcare organization to explicitly define cultural differences and overcome this barrier through the implementation of healthcare information systems based on mutual benefits of the interacting organizations and their actors in the entire healthcare service domain (Koussouris, Lampathakil, Mouzakitis, Charalabidis, & Psarras, 2011).

According to the review on eBussiness based interoperability frameworks by (Reza, Thiam, & Sai, 2014), cultural interoperability issue along with language interoperability subarea included by ATHENA Interoperability Framework and Grid Wise Interoperability Context-Setting Frameworks as critical issue.

Business interoperability involves working harmoniously at the company and organizational levels despite different modes of decision making, work practices, culture, legislations, commercial approaches, and so on. Achieving a harmonious environment could aid in developing businesses between the companies, therefore

Cultural interoperability issue is one of the factors for the success or failure of interoperability (Chen et al., 2008a) (Reza, Thiam, & Sai, 2014).

The study by (Arne-Jørgen, et al., 2007), described Interoperability at the enterprise/business level should be seen as the organizational and operational ability of an enterprise to factually cooperate with other, external organizations in spite of e.g. different working practices, legislations, cultures and commercial approaches in order to addressing their business needs and technical requirements for interoperability.

According to (Payam, Morad, & Craig E, 2011) Cultural interoperability is necessary in the healthcare service domain and tied to handle this issue through awareness model to develop an interoperable healthcare systems considering social interoperability requirements for the interacting parties in the healthcare domain.

Therefore, this study included Cultural interoperability issue under 'others' interoperability perspective as an important measurement item in order to handle the cultural diversity barriers on the ehealth systems interoperability across AARHB healthcare institutions or between systems in the Healthcare service domain.

- **Knowledge interoperability**

Knowledge interoperability is an essential component of service interoperability especially it's key for Service or process oriented organizations like Healthcare organizations. This refers to the capability of healthcare information system to easily share the experiences, skills, detailed understanding of healthcare services and best practices among the collaborating parties under the healthcare service Domain (Koussouris, Lampathakil, Mouzakitis, Charalabidis, & Psarras, 2011).

Interoperability Infrastructure clarified as the necessary prerequisite for interoperability in eHealth and eBusiness alike is the sharing of data, information and knowledge as Interoperability concerns (Craig E, 2009).

According to the study on eBussiness based interoperability frameworks by (Reza, Thiam, & Sai, 2014), knowledge interoperability is another critical issue for interoperability frameworks and further included Knowledge sharing & knowledge repositories, Business units knowledge alignment, Ontology matching, Business knowledge reasoning analysis & representation sub components.

On the other hand, ATHENA Interoperability Framework focus on knowledge sharing and knowledge repositories, business units' knowledge alignment, and ontology matching sub-areas in knowledge interoperability issue (Reza, Thiam, & Sai, 2014).

Knowledge interoperability allows the interacting or collaborating healthcare system users or actors get mutual benefit from the shared knowledge. Knowledge sharing enables the healthcare organizations to provide best services or products by merging

the skills and knowledge assets between the collaborating organizations under healthcare service domain (Koussouris, Lampathakil, Mouzakitis, Charalabidis, & Psarras, 2011).

Thus, this study pointed out Knowledge sharing capability of ehealth systems as a basic and important measurement item in the proposed framework under the 'other' interoperability perspective.

- **Human Resource issues**

As mentioned by (Koussouris, Lampathakil, Mouzakitis, Charalabidis, & Psarras, 2011), human resource is a vital component for interoperability framework and explained,' human resources are the creators and the carriers of knowledge within the boundaries of an enterprise, and which is either individuals or teams that carry expertise and knowledge in specific domains and contributes a lot to the success of interoperability'.

Healthcare sector is process oriented and complex by its nature, thus human resource interoperability is critical to attain different skills and share knowledge through health information systems because it involves care delivery by multiple providers across multiple settings (Payam, Morad, & Craig E, 2011).

According to (Measureevaluation, 2018) there are three basic human resource issues as a metrics in order to assess the interoperability of ehealth systems those are Human resource Policy related to Health information systems, Human resource capacity in number or availability and Human resource Capacity Development.

Human resource Policy related to Health information systems indicates that an organization should developed the guideline, policy, rules and regulations to manage or govern the employees, assign roles and responsibilities related to Health information systems (Measureevaluation, 2018). Human resource capacity considered as the ability of healthcare organization to fulfill all the required number of skilled employee to support the implementation of health information system in the healthcare institutions and across the healthcare service domain to achieve clearly defined objective (Measureevaluation, 2018).

The last sub area human resource capacity development refers to the ability of healthcare organization to upgrade or educate existing employees continuously to build an up to date skills, knowledge of employees and develop specific competencies about health information system features (Measureevaluation, 2018).

The above studies revealed that, Healthcare industry needs the collaboration of multiple disciplines like Medicine, pharmacy, Laboratory, finance, Information Technology and others this sector has to plan for human resource interoperability development to interact each other seamlessly. Specifically in a developing country like Ethiopia technology acceptance is not yet matured so the basic skills and trainings towards Health information systems required at all level. Thus, this study

adds Human resource interoperability issue as a basic and valuable component for the proposed AARHB eHealth systems interoperability assessment framework under 'others' perspective.

- **Interoperability Approach/Principle**

Another study by (Chen, 2006) defined interoperability approach as the way how to handle the barriers of interoperability into three basic sub areas as follows: Federated, Unified and Integrated approach as a solution space based on the resulted interoperability barriers.

According to (Committee, Realizing the Potential of C4I, 1999) interoperability barriers should be addressed accordingly after interoperability assessment result organized in to four problem space as follows Technical compliance measures, Systems interoperability measures, Operational interoperability measures, Organizational and cultural measures.

Interoperability approach refers to the way how to address the existing barriers of health information systems and upgrade to the next better level of interoperation between systems. There are many ways or principles to achieve interoperability after aware of systems current interoperability level.

Thus, this interoperability assessment framework includes interoperability approach as a valid and important measurement item in the proposed framework under the 'other' perspective.

- **Interoperability Maturity Measurement**

Interoperability maturity measures guide the strategically linked process and service improvements help an organization to know the current status and indicate the roadmap to where that organization aims to be in the future. Low interoperability maturity means there is a large gap in attaining the organizational objective and described with low quality of process, services and other functionalities (Measureevaluation, 2018).

As mentioned by (Measureevaluation, 2018) maturity model describes the process components that are believed to lead to better outputs and better outcomes. They can be a reference point for identifying the foundational elements needed to create an enabling environment for digital HIS within a national HIS to become interoperable.

Accordingly, the above studies generally agreed that, after the eHealth systems or healthcare organizations assessed their interoperability barriers and opportunities focusing on the basic interoperability perspectives and their goals towards seamlessly interoperate with other systems in the healthcare service domain, maturity planning required.

The maturity planning also requires a reference point for identifying the foundational elements needed to create an enabling environment for ehealth systems in order to improve the resulted interoperability barriers towards the better step up (MEASUREEvaluationteam, 2018).

Thus, this study seeks for comprehensive interoperability maturity model for defining a managed path to be followed as benchmark to compare organizational practices internally or externally also gives an insight to interoperability improvements from the current stage up to maximum capability.

Therefore this study integrated maturity model as a core feature considering Maturity level measurement enables healthcare institutions to understand the existing health information systems' weakness compared with the maximum attainable implementation of fitting adjustments on the four basic interoperability perspectives to cop up with the dynamic changes over the service boundary. Then, this study investigated many interoperability maturity models developed for many different objectives or focuses, to select the best fitting maturity model for the case under study; some of them are presented below:

According to the review on Interoperability Maturity models (Wided, Chen, & Naudet, 2013), LISI (Levels of Information System Interoperability) maturity model focuses on technology (IT) issues, and mainly concerns communication, data exchange and service (application) interoperability, LCIM (Levels of Conceptual Interoperability Model) deals with data interoperability and focuses on data representation issues, EIMM (Enterprise Interoperability Maturity Model) aims at evaluating enterprise modeling/model maturity and covers data, service and process interoperability issues only.

Even though, Maturity Model for Enterprise Interoperability (MMEI) is generalized Enterprise interoperability model aimed to map main maturity models in a barrier driven approach which is focused on Barriers from three perspectives, Conceptual, Technical and Organizational which needs extra effort and resource to classify existing barriers which is already covered by the developed four interoperability assessment goals/key components to measure the existing interoperability practices and interoperability outputs at different interoperability stacks. Also MMEI studied under the consideration any type of Enterprises interoperability that makes broader and not focused on the unique features of healthcare service domain.

As a result, this study preferred NEHTAs' IMM maturity model and integrated with eHealth systems interoperability Assessment framework for FMoH healthcare institutions because this model provides all the required interoperability maturity levels by enabling ehealth systems or overall health care organizations interoperability maturity planning easy and clear from four interoperability perspectives.

Note: The application of IMM is based on a process of continual improvement that links goals, practices, and work products and each of these three are interrelated each

other since Goals, practices and Work products are attributes to conduct interoperability assessment.

On the other hand, work product interoperability assessment ensures the service/ product do actually reflect the predefined Goals/key components at different interoperability perspectives and interoperability maturity assessment checks that organizational practices are delivering interoperable outcomes (based on the Maturity levels). Reaching each level requires the attainment of the previous levels; a set of predefined interoperability goals/ key components, identified within the e-health domain, NEHTA interoperability maturity model by itself was developed based on the main concepts of CMMI (Capability Maturity Model Integration) which is considered as an instance of ISO/IEC 15504.

Therefore the proposed eHealth systems interoperability Assessment framework includes the following maturity levels adopted from NEHTAs' IMM; those levels captured all the maturity capabilities along with clearly defined characteristics under the predefined four interoperability perspectives of ehealth systems or healthcare organizations.

- **Initial**: There is an early awareness of e-health interoperability requirements and characteristics and perhaps some early e-health interoperability solutions adopted, typically localized within certain clinical or administrative domains (as these provide environments with limited complexity) (National E-Health Transition Authority , 2007).
- **Managed** (or under development): An organization will begin accomplishing some interoperability goals, such as the adoption of specific e-health standards, while gaining an early shared understanding of data, services or internal processes, as well as initial governance established to ensure repetition of earlier successes (National E-Health Transition Authority , 2007).
- **Defined:** An organization has defined a set of guidelines for the adoption of e-health standards for data, services and processes, according to the lessons learned from previous maturity levels. These are further augmented with explicit focus on policy and legal compliance. Governance is well defined and defined levels of organizational readiness for interoperability outcomes are established. Communication standards for interaction with internal and external partners are established as are the supporting organizational structures facilitating a shared understanding across technical and semantic issues (National E-Health Transition Authority , 2007).
- **Measured:** An organization has established processes for appraising and measuring e-health interoperability. This can be done before the system is deployed such as through conformance and compliance activities or during the operation of the system, i.e. run-time monitoring (National E-Health Transition Authority , 2007).

- **Optimized:** The organization has implemented processes to support continuous interoperability improvements, driven by feedback from monitored processes, with the aim of improving overall e-health interoperability capability. The consistent use of this approach supports a shared understanding of maturity between organizations. Each of the levels in Figure below defines an increasing level of maturity that can be used to define specific interoperability maturity goals that provides continuous improvement in interoperability (National E-Health Transition Authority , 2007).

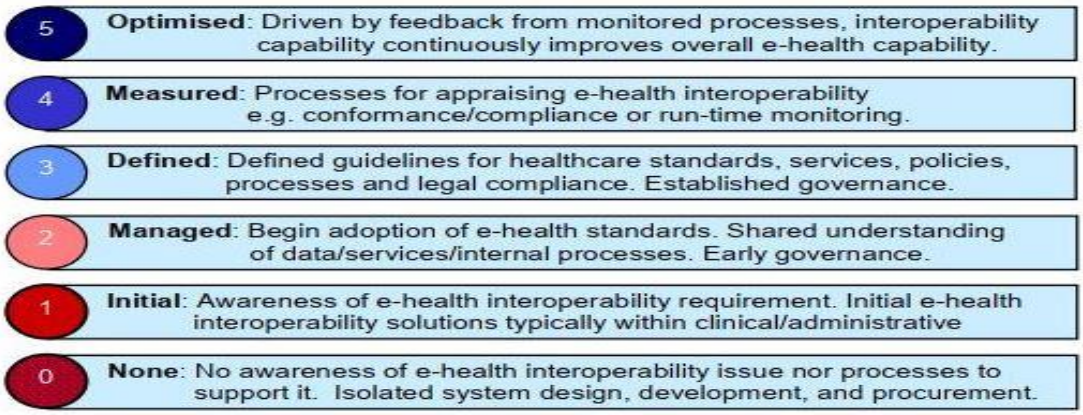

Figure 4: Levels of Interoperability Maturity Model adopted from NEHTA (National E-Health Transition Authority, (2007)

The aim of this study is to provide the best fitting interoperability assessment framework for FMoH owned ehealth systems, by examining different countries interoperability frameworks, interoperability assessment models and other related issues about systems interoperability requirements as a solution to tackle healthcare service challenges caused by failure of ehealth systems to interoperate each other. Then after, the researcher incorporated and integrated additional interoperability perspective and basic elements to handle the overall interoperability features of ehealth systems. Checking that, implementation of fragmented ehealth systems causing many challenges in the healthcare service delivery, thus this study provides the roadmap to view the critical interoperability aspects of ehealth systems, know weaknesses and plan to improve the level of interoperability towards overall improvement of service delivery.

The study presented key components of the proposed interoperability assessment framework in the following diagram.

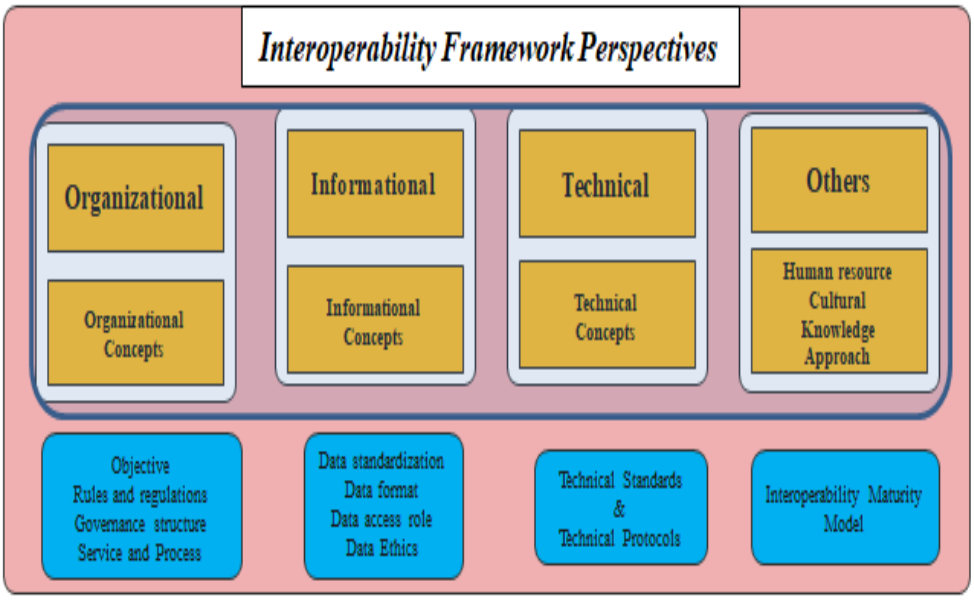

Figure 5: The proposed Interoperability Assessment Framework Perspectives

- **Interoperability Assessment**

An Interoperability assessment provides a sequence of steps to be followed for assessing eHealth systems or healthcare organizations interoperability as a guide and the result of assessment lets the organization understand their strengths and weakness of interoperability issues (National E-Health Transition Authority , 2007).

Thus, this study clarified those steps and the methodology how to approach the assessment of the predefined four interoperability perspectives along with linked components by characterizing the entire interoperability goals, practices and work outputs/ services as follows:

This section provides the steps required to be followed for assessment of eHealth systems or healthcare organizations interoperability under AARHB by integrating the predefined interoperability maturity model (NEHTAs' IMM) and the eHealth systems or healthcare organizations interoperability practice attributes (characteristics) from four perspectives.

Clearly, the first step will be selection of the scope or target of interest whether eHealth system on which an interoperability assessment conducted or healthcare organization. This is to be followed by identification of the interoperability domains which includes the eHealth systems in the healthcare organization or other potential systems that are found in the healthcare domain. These two steps followed by identification of proper goals /key interoperability components in accordance with predefined interoperability perspectives related to particular domain of interoperation using the key components characterized with expected features of each goal.

NOTE: Here interoperability goals are derived from four interoperability perspectives as these four perspectives were explained with their own expected attributes and

characteristics which were elaborated as sub components of four basic perspectives, additionally those interoperability goals will be different according to the selected interoperability Domain for assessment.

In the case of a maturity assessment for an e-health organization, the IMM also requires that the interoperability practices used to accomplish the interoperability goals be defined and then assessed. That is, each interoperability practice should be explicitly linked to a set of interoperability goals with a corresponding interoperability dimensions, and the interoperability assessment should identify the success or failure of these practices in attaining the interoperability goals, typically by assessing outputs (eHealth service quality parameters or Indicators) of those practices. Maturity assessments of either organizations or e-health systems will typically locates the level of the existing interoperability using those five levels of interoperability elaborated as levels of IMM and identify the need for an interoperability maturity planning program.

Even though this is beyond the scope of this thesis following this steps any healthcare organization can assess their eHealth systems interoperability level or measure the maturity level of institutional interoperability using the following two methods, first by assigning weights to each goals with their corresponding key components, secondly they may assess by assigning expected cost for to address interoperability barriers.

Note that not all goals have the same importance and individual importance weightings should be assigned (e.g. high, medium, low) to each goal. These weightings (Rating values) can be used to focus the assessment on important goals first, or to select priority organizational practices for interoperability maturity program planning.

In the second case, the selection process could also be driven by the results of a lightweight cost benefit analysis, undertaken for the purpose of assessing costs and benefits of interoperability, for broader e-health benefits realization purposes.

3.4. The proposed eHealth Systems Interoperability Assessment Framework

The proposed interoperability Assessment Framework basically relied on the strengths of reviewed related studies and filled their gaps and provide relevant interoperability assessment framework for healthcare institutions under FMoH. The study relied on the existence of the following situations in the study area: - Cultural diversity, High rate of Human resource displacement (absence skilled employee) and Shortage of Knowledge sharing mechanism. With these modifications to preceding interoperability assessment frameworks examined from other countries, the following Interoperability assessment framework developed from four basic interoperability

perspectives after tested to validate the proposed interoperability assessment framework components importance.

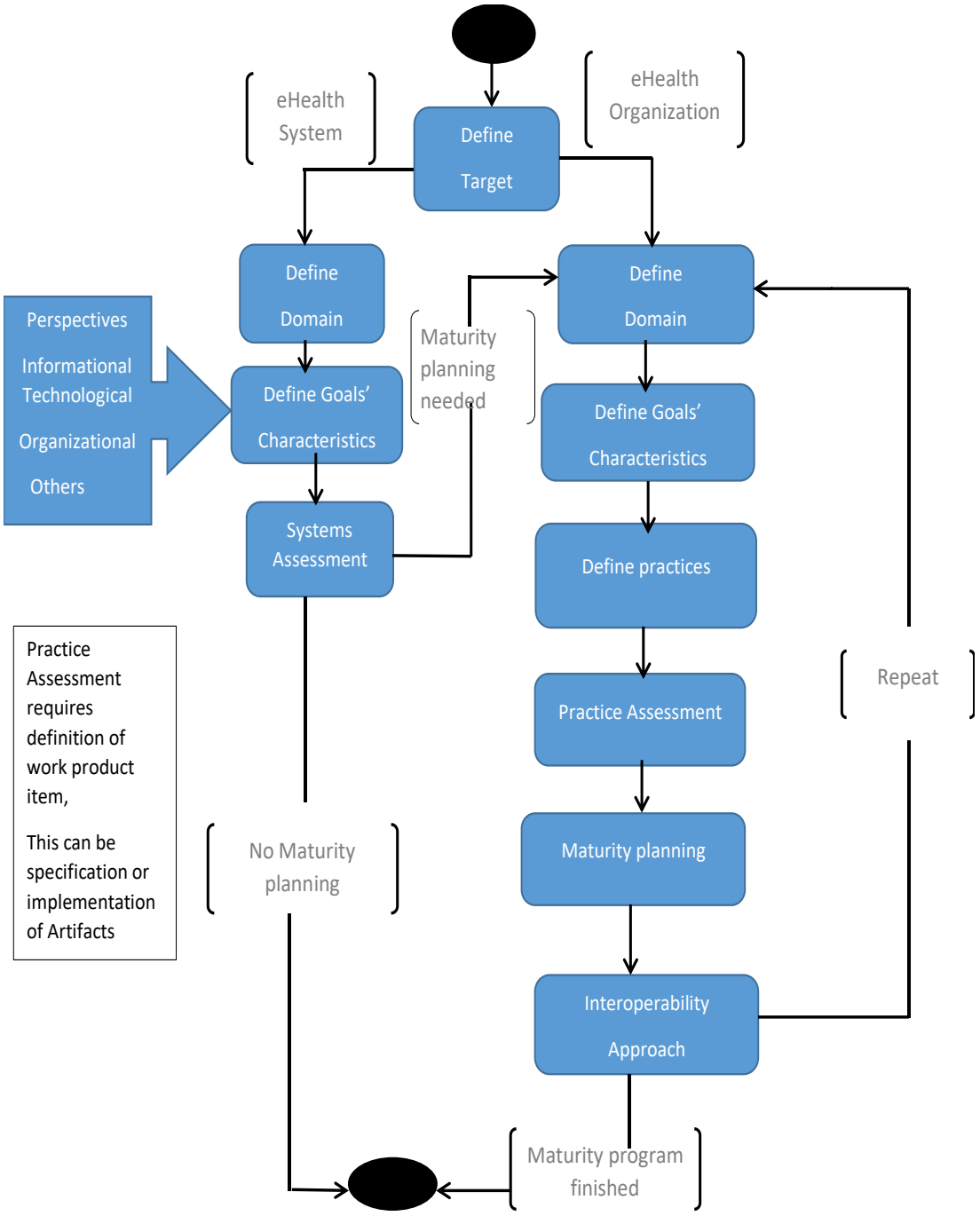

Figure 6: The proposed Interoperability assessment framework, extracted from (National E-Health Transition Authority, 2007), (Payam, Morad, & Craig E, 2011), (Koussouris et.el, 2011), (CHEN, 2006)

CHAPTER FOUR

4. Research Methodology

4.1. Chapter Overview

This chapter discusses how the research design, population and sampling procedures of the study conducted. It also explains the data collection methods, interoperability perspectives along with their attributes for interoperability assessment as well as the techniques used to analyze the data in order to test the validation of the framework developed in previous chapter.

The research designed using both the theoretical knowledge seeking in-depth understanding of the issue under study involving document analysis; extracted the number of components as an integral part of the developed interoperability assessment framework, then after the development of the framework components qualitatively through content analysis method validation conducted involving qualitative methods.

4.2. Research Design

The aim of this research is to propose interoperability assessment framework by identifying key interoperability perspectives in the healthcare domain considering the lack of interoperability between ehealth systems as one major cause healthcare service problems and to provide the possible way of maintaining interoperability between ehealth systems in FMoH.

The researcher described the current interoperability problems impacted on quality of healthcare service in FMoH involving qualitative methods to extract basic elements of interoperability challenges and proposing solution as primary aim of this study; hence the lack of interoperability driven problems in FMoH with examples and evidence was presented in an in-depth ways under the statement of problem of this study. Therefore qualitative approach was appropriate and applied by the researcher.

This study is explanatory and deductive in nature. It is supported mainly by a qualitative research design involving document analysis method to construct the proposed interoperability assessment framework followed by evaluation (validation) with semi-structured questionnaire to collect data from purposeful selected 15 ehealth experts (summative focus groups) by giving scores points out of the pre-specified weighted key elements, later used for validation of the proposed interoperability framework in combination with the feedbacks.

4.3. Research Approach

This study is intentional to point out the basic perspectives and key elements of ehealth systems interoperability that could impact on the overall quality of healthcare service in FMoH and develop one way of addressing lack of interoperability through

the development of interoperability assessment framework, In that context, this study is deductive in nature and applied Qualitative approaches to achieve its objectives because the study conducted involving these two phases:

The first phase applied qualitative research approach through content analysis method to construct the proposed Interoperability Assessment Framework Key components from selected countries experience. The second phase employed Qualitative content analysis method involving summative focus groups to validate the importance and appropriateness of the proposed interoperability assessment framework based on the opinions' of ehealth experts in a measurable way by giving point values for each key elements presented in the proposed interoperability assessment framework out of the pre-specified weighted values presented at the first column parallel to each key element through (Semi-structured questioner form).

4.4. Study Area

This study conducted by taking the entire employees of FMoH as study area and the sample candidates selected applying purposive Sampling Technique. Because the study needs respondents with in-depth understanding of the area and the respondents should be information reach in order to get credible result; instead of using random sampling technique purposive sampling is better in collecting information in such area of studies since there are some experts among the employees who know about ehealth system interoperability elements in detail.

4.5. Population of the Study and Sampling

This study selects the sample population focusing on the target individual ehealth experts from FMoH employees those who have an in-depth involvement in ehealth systems development, implementation, administration and support; in addition sample selection focused on ehealth experts those who involved in the "ehealth app inventory document analysis" project conducted by FMoH. Because they do have detailed understanding of the existing ehealth systems interoperability level from different interoperability elements view point such as data, programming languages and platforms used, ownership type, and supporting partners among other things from the ehealth app inventory analysis outcome.

Thus, this study purposefully selected participants particularly individual domain experts from FMoH ICTDA and from NGO partners because eHealth applications had initiated by the Federal Ministry of Health in collaboration with NGO partners such as TUTAPE, USAID and CDC.

The sample population selection categorized in to four groups: The first group consists of ehealth experts employed by government working under FMoH ICTDA; in Infrastructure and Service department who are fully involved in ehealth project. The second group consists of eHealth experts employed by government working under FMoH ICTDA; in Software Development department who are fully involved in

ehealth project, and the third group consists of ehealth experts employed by government working under FMoH ICTDA; in System Administration department who are fully involved in ehealth project, the last group consists of ehealth experts from NGO partners (from TUTAPE, CDC, USAID), furthermore, the respondents mostly selected from members participants in "eHealth app inventory analysis project". This is because they do have an in-depth understanding of the existing level of ehealth systems interoperability from different interoperability elements.

Purposive sample sizes are often determined on the basis of theoretical saturation (the point in data collection when new data no longer bring additional insights to the research questions). Thus, criteria based purposeful sampling technique applied in order to get senior experts (most experienced >3 years) with full involvement of ehealth development, implementation, administration, support and detailed understanding of ehealth systems interoperability issues to provide credible response required to validate the proposed interoperability assessment framework.

Accordingly, this study selected a total of 15 ehealth expert individuals, enough or sufficient as per saturation of the analysis result from data collected to conduct validation of the proposed interoperability assessment qualitatively.

Then selected sample ehealth experts allocated based on the above four categories three departments of FMoH ICTDA and NGO partners as follows: -

Respondents Category	**Number of respondents**	**Respondents Position**						
		System Administrator	**System Analyst**	**Database Administration**	**SW developer**	**HIS Coordinator**	**HIS Infrastructure Advisor**	**IT Specialist**
System Administration	**5**	**3**	**1**	**-**	**-**	**-**	**-**	**1**
Software Development	**5**	**-**	**--**	**1**	**2**	**1**	**-**	**1**
Infrastructure and Service	**2**	**-**	**-**	**-**	**-**	**-**	**2**	**-**
NGO Partners	**3**	**-**	**-**	**-**	**1**	**1**	**-**	**1**
Total	**15**							

Table 5: Respondents working department and positions

4.6. Method of Data Collection

After the development of the intended interoperability assessment framework based on the existing interoperability problems mentioned in problem statement section obtained through document analysis method; prior to the evaluation of the proposed interoperability assessment framework, the document containing the proposed interoperability assessment framework key elements and their detailed description, the proposed interoperability assessment framework in the form of artifact along with the semi-structured questioner form and the discussion questions were sent to the ehealth experts via email just three days before the discussion.

This allows the respondents to know the overall objective of the study. Then, experts were contacted face to face to conduct detailed discussion in accordance with their departments in order to obtain additional feedbacks on the proposed interoperability assessment framework. Those documents were sent three days before the detailed discussion conducted, then the data for this study were collected through semi structured questioner form formulated in 4 basic perspectives weighted 25% that accounts 100%; along with 19 sub components or key elements weighted under each perspective by dividing 25% accordingly to each sub key component listed under the main 4 interoperability perspectives (see Appendix I and II). The evaluators were expected to give their points for each key element out of their provided weights in order to indicate their level of acceptance (agreement) on the validity and appropriateness of the proposed interoperability assessment framework.

The data was collected from eHealth experts who are involved in development, implementation, administration and support for FMoH owned ehealth systems employed by FMoH as well as NGO partners such as TUTAPE, US AID and CDC.

In order to evaluate the proposed interoperability assessment framework the researcher used semi structured questioner with predefined set of weighted measurement items key interoperability elements under each perspective; were adapted from validated studies in the literature across different countries' ehealth systems interoperability assessment frameworks and framed based on the proposed Assessment Frameworks' four perspectives along with their attributes/measurement items. Since the proposed interoperability assessment framework pass through deductive approach, its importance and appropriateness has to be evaluated.

Additionally in designing the semi-structured questioner, the perspectives and the corresponding item measurements are adapted from pretested standard questioners developed by investigators based on the potential interoperability assessment metrics and the corresponding attributes such as, "Interoperability Maturity Assessment of a Public Service: IMAPS v1.1.1 Questionnaire" (EU,European Commission, 2018) and "WP3_STOPandGO_D3.2_Guidelines-on-interoperability-assessment-for-deployments_v2.0" (EU,STOPandGO project, 2020).

Furthermore, we used "Health Information Systems Interoperability Maturity Assessment Tool Version 1.0" (Measureevaluation, 2018) questionnaire to frame the contents of the questioner to fit with four basic perspectives/constructs and interoperability metrics attributes (measurement items) accordingly.

The final Questioner consists of two sections. The first section gathers general information about respondents' demographic data. Under the second section, the proposed frameworks' four perspectives and the corresponding measurement items presented with a given weighted value provided at the right column parallel to each key element seeking to validate the proposed interoperability assessment framework. The data collected from semi-structure questioner form and the feedbacks gained from discussion points was recorded (noted) in the written format. Secondary data were collected through reviewing of relevant documents and literature.

4.7. Proposed interoperability assessment framework evaluation implementation

Three days after the necessary documents (mentioned above) were given to the selected ehealth experts, the proposed interoperability assessment framework evaluation conducted after detailed discussion; moreover, the experts were given more chance to ask questions on any section from the evaluation questioner provided to them for further explanation. Similarly, during discussion as per experts recommendation's some of the pre-specified weighted values key interoperability elements were modified (assigned another weight) with common consensus, then experts were instructed to use the validation questioner provided to indicate the extent to which they agree or accept the proposed interoperability assessment framework by giving values out of the pre- specified weighted values for each key element listed under four interoperability perspectives. Then the researcher collected the evaluation (results) from the ehealth experts in accordance with their possible additional feedbacks.

4.8. Data analysis method

Since this study was conducted using descriptive research approach, descriptive statistics (frequencies and percentages) were utilized to evaluate the collected data including their feedback data gained from the discussion questions. All the collected data from the ehealth experts were recorded and organized, reduced through summarization and categorization, and patterns and themes in the data are identified.

Scores given by each ehealth expert for each key elements of the proposed interoperability assessment framework aggregated in the form of summation then the average value score point for each key element calculated by dividing the aggregate sum value to the number of ehealth experts (15) like summative focus groups; then after, the Sum of Average response values gained and presented as analysis result. The researcher used content analysis method to find thematic meaningful result that

allows generating report and enables to conclude the overall validity of the proposed interoperability assessment framework and the corresponding key elements.

CHAPTER FIVE

5. Analysis result and Presentation

5.1. Introduction

This chapter presents study analysis, findings and interpretation of the entire research. This study investigates the key elements of ehealth systems interoperability they could impact on the overall quality of healthcare service delivery, reviewed the possible solutions taken by other countries and examined the existence of interoperability barriers between FMoH owned ehealth systems involving document analysis from annual reports of FMoH; then the researcher provides one possible solution to improve the healthcare service delivery practices in healthcare organizations under FMoH through the development of relevant interoperability assessment framework.

As it is already presented in chapter four methodology parts, this study was employed the qualitative research methodologies by selecting participants purposively to validate the proposed interoperability assessment frameworks. So to present the results of the participants' information the researcher utilized the simple descriptive analysis methods (average value points given for each key measuring elements) and also depended up on thematic meaning extraction from among the data collected from detailed discussion point feedbacks of informants invited from three departments under FMoH ICTDA and NGO partners.

5.2. Demographic information of the respondents

In total, 15 semi-structured interview questioners were distributed through email three days before the discussion conducted and all those 15 ehealth experts had common in-depth understanding on the study; those respondents replied credible information to this study.

The result was organized from 15 key respondents that mainly contribute to figure out the validity or appropriateness and their feedbacks on the proposed interoperability assessment framework along with four perspectives. The issues raised in the discussion are summarized into four thematic areas (the validity of four interoperability perspectives and the corresponding key elements); depended up on thematic meaning extraction from among ideas of respondents invited from three departments under FMoH ICTDA and NGO partners.

From all respondents, 9 (33.3%) of them had work experience 5 to 10 years and respondents with more than 10 years of experience accounts 5 (33.3%) the rest 1(6.6%) had 3 to 5 years of experience.

Respondents Category	No of Respondents	Respondents Position							
		System Administrator	System Analyst	Database Administration	SW developer	HIS Coordinator	HIS Infrastructure Advisor	IT Specialist	Experience (year)
System Administration	5	3	1	-	-	-	-	1	1 3 1
Software Development	5	-	-	1	2	1	-	1	1 4 -
Infrastructure and Service	2	-	-	-	-	-	2	-	2 -- -
NGO Partners	3	-	-	-	1	1	-	1	1 2 --
Total	15								

Years of Experience	More than 10
Key	years 5 to 10 years
	3 to 5 years

Table 6: Summary of demographic details of the respondents for main study

5.3. Evaluation result of the study

5.3.1. Summary of the analysis results

The data from semi-structured questioner evaluation form and the feedbacks were received from 15 ehealth experts after detailed discussion face to face. After the researcher provided the entire proposed interoperability assessment framework key

elements, the final study artifact and the evaluation metrics (semi-structured questioner) and the major discussion points for the selected ehealth experts; then, three days later discussion conducted in addition the experts were given more chance to ask questions on any section from the evaluation documents provided to them for further explanation.

However, there is an ad hoc ehealth strategic document prepared by FMoH ICTDA; all the respondents mentioned that lack of interoperability between ehealth systems is still the major treat to healthcare service. The data collected and analyzed from these ehealth experts showed that FMoH owned ehealth systems absolutely needs to maintain interoperability.

Thus, the proposed interoperability assessment framework was shined over the FMoH as it was scored an overall acceptance value of 92.9% result aggregated from all ehealth experts' evaluation (Appendix III). It opened the gate to bring change on the existing view, practice and patterns of ehealth systems interoperability in FMoH believing it will provide support to top level management to resolve such a problem via interoperability assessment. The codes provided to participants were "Experts and number" and in the analysis part the word respondent is abbreviated as "E" to refer ideas of respondents.

5.4. Major Findings' interpretation and Discussion

Here this study intends to show evidence that gained from the analysis of data in order to validate the proposed interoperability assessment framework and the corresponding key interoperability assessment elements under each interoperability perspectives.

The following section discusses the detail analysis result summarized to show the validity of the proposed interoperability assessment framework along with four interoperability perspectives.

12 key ehealth experts out of 15 participants were actively suggesting (gave feedbacks) on the proposed interoperability framework: 10 from FMoH eHealth experts in particular experts those who involved in "ehealth app inventory analysis project by FMoH" and two of them from NGO partner ehealth experts involved in development and implementation of ehealth systems in FMoH the rest 3 respondents involved in evaluating the proposed interoperability assessment framework through the semi-structured questioner form by giving score with no additional feedback on the study.

Those 12 Respondents involved in the "ehealth app inventory analysis project" clearly stressed that lack of interoperability between eHealth applications still not handled by FMoH. The respondents also focused that most of eHealth applications are developed and implemented without the support of national eHealth policy and because of this; many ehealth applications are unique and working in a fragmented way. They suggested that overall managements of eHealth applications should consider harmonization and integration such as creating strong monitoring and evaluations on the interoperability elements.

They also stated that, this study will be workable and valuable in order to make effective and efficient interoperability between ehealth systems across the healthcare domain.

According to the research participants' feedback, the study has great contribution for FMoH to resolve all the main interoperability challenges beyond data level, using this study as a benchmark to point out all the possible interoperability barriers like service level interoperability, Knowledge interoperability, human resource interoperability issues and other interoperability elements.

Finally most respondents agreed that this study provides valuable insight for decision makers how to approach healthcare service problems caused by lack of key interoperability elements and enables to know the ehealth systems interoperability level involving assessment as one option to approach the problem.

5.4.1. Analysis result of Organizational Interoperability perspective

During the discussion time respondents explained their feelings that FMoH should work more on harmonization of ehealth systems (considering all key elements of ehealth systems interoperability) specifically organizational interoperability key elements to attain the required quality healthcare service and also mentioned valuable and helpful attain all the necessary organizational objectives of FMoH via ehealth systems. Those all alarming feedbacks were considered in this thesis and evidences given by respondents were presented here below:

The respondents mentioned some of the healthcare service challenges caused by lack of interoperability such as service delay, process misalignment, and objective misalignment then; they argued that the proposed interoperability assessment framework key elements listed under organizational interoperability perspective are very useful to resolve those mentioned healthcare service problems.

According to the research participants' feedback during discussion, they explained that this study helps the FMoH to clearly articulate interoperability issues and improves the ability of addressing those interoperability barriers.

As compared with other related studies, the empirical evidence of the study indicates that components included in Organizational interoperability perspective of this proposed framework had high acceptance or validation approval gained an average score point of 23.5% out of pre-specified weighted point (25%) for organizational perspective which accounted 94.13% acceptance validity by ehealth experts' opinion.

This result slightly differs with previous findings of (Kolsoom, Masoumeh, & Nasrin, 2011), they gained 99% observed proportion mentioned as valid by domain experts' to the components listed in organizational interoperability perspective. Nonetheless, those key components listed in the organizational perspective presented by both studies finally validated by majority of ehealth experts.

A study by (Wondwosen, 2013) conducted locally focused to resolve data level interoperability problems existed between LIS and EHR, the study completely ignored the organizational interoperability perspective, this is one of the gaps identified and differed from our study which incoprises many interoperability elements to visualize (approach) the existing ehealth systems interoperability problems.

5.4.2. Informational Interoperability perspective analysis result

Respondents from NGO partners (software developer and IT specialist), recognized that the study shows the major interoperability elements which were not identified before in the form of interoperability assessment framework and the researcher proposed a valuable assessment guideline to point out and address all the possible interoperability elements through assessment as solution; that addresses local interoperability challenges in the FMoH and improve health service delivery.

Respondents from FMoH ICTDA and NGO partners also provided comments on the existing ehealth systems interoperability level inferring the findings of "ehealth app inventory analysis document" conducted by them and other FMoH ICTDA staffs and appreciated the proposed interoperability assessment framework, further acknowledged the detailed view of Informational interoperability perspectives.

Accordingly, the respondents recognized that all the key elements listed under informational interoperability perspective were presented properly and validated by giving an average cumulative score of 23.5% out of the pre-specified weighted value of (25%), this implies that the respondents provide high acceptance rate for key interoperability elements listed under Informational interoperability perspective.

As compared with other related studies, the evidence indicates that components included in Informational interoperability perspective of the proposed interoperability assessment framework gained higher acceptance value or validation approval value.

On the other hand, all key components of informational perspective in the proposed framework validated similar to the previous related study, however there is a slight difference in the average aggregate acceptance score value in percentage.

As compared previous study by (Kolsoom, Masoumeh, & Nasrin, 2011), the analysis result gained from evaluation slightly differs from previous findings of the key interoperability elements listed under informational interoperability scored, thus all components listed under informational perspective in both studies validated fully.

On the other hand, the study by (Wondwosen, 2013) conducted locally to resolve data level interoperability problems existed between LIS and EHR proposing DEIF and tested the validity through discussion in qualitative method and gained excellent acceptance and fully validated the same as this study.

5.4.3. Technical Interoperability perspective analysis result and interpretation

Based on the respondents feedback during discussion along with the evaluation result given to each key interoperability elements presented under Technical interoperability perspective, it's agreed that this interoperability assessment framework is important and appropriate to achieve the intended interoperability options in the healthcare service delivery and it's also provide additional view of addressing those interoperability barriers.

They also recognized that, the findings on this research provide solutions on how to create interoperability and make the data exchange process efficient, remove service delay and many other healthcare service delivery challenges in FMoH.

Respondents acknowledge that the study shows how other countries resolved ehealth systems interoperability challenges and identified the major key interoperability elements based on the gap analysis result from previous related studies then provide potential solution to address those challenges. Furthermore, they agreed that, the proposed interoperability assessment framework clearly addressed the problems that arise from technical interoperability perspective.

According to the evaluation conducted by respondents, the analysis result shows the key interoperability elements listed under technical interoperability gained an average cumulative score of 23.3% out of the pre-specified weighted value of (25%), this implies that the respondents provide high acceptance rate for key interoperability elements listed under technical interoperability perspective.

This evaluation result differs with previous findings of (Kolsoom, Masoumeh, & Nasrin, 2011); because, unlike the complete validity or acceptance guaranteed to this study, three key interoperability components listed under technical interoperability perspective marked as invalid from the previous study.

Compared with the study conducted locally by (Wondwosen, 2013) to resolve data level interoperability problems existed between LIS and EHR proposing DEIF and tested the validity through discussion in qualitative method asking system users, decision makers and system developers opinions'. For both studies the respondents fully validated all the key elements listed concerning technical interoperability.

5.4.4. Others Interoperability perspective analysis result and interpretation

According to the respondents from FMoH ICTDA and NGO partner, in the "Others" interoperability perspective part of the interoperability assessment framework the research clearly demonstrated the Human resource interoperability issue, cultural

interoperability issues, knowledge interoperability and other key elements of interoperability which impact on the quality of healthcare industry service delivery; which were given less emphasis during system development or interoperability assessment phase.

According to the respondent from FMoH ICTDA specifically from HIS Infrastructure advisor, the proposed interoperability assessment framework address challenges of infrastructure in FMoH healthcare organizations by creating a harmonized linkage between ehealth systems and saves huge amount of money being invested for infrastructure and implementation of redundant fragmented standalone ehealth systems.

So, they strongly agreed that the proposed interoperability assessment framework mainly considers the existing ehealth systems implementation and infrastructural setting that are being the main challenges and extravagancy for FMoH.

On the other hand, according to the evaluation conducted by respondents, the analysis result shows the key interoperability elements listed under others interoperability gained an average cumulative score of 22.6% out of the pre-specified weighted value of (25%) which accounts (90.4%), this implies that, compared with key interoperability assessment framework elements listed in the other three interoperability perspectives the respondents provide lower acceptance rate for key interoperability elements listed under others interoperability perspective (fourth interoperability perspective).

Further, all the key components listed in "other" interoperability perspective of the proposed framework validated fully. The others interoperability perspective along with list of five sub components presented in this study are unique feature incorporated based on the gap analysis result from the previous related studies (Kolsoom, Masoumeh, & Nasrin, 2011), (Wondwosen, 2013), because those components were not included in both of the specified related studies.

Therefore, as a summary of the findings revealed that, the proposed interoperability assessment framework is validated by ehealth experts providing their opinion as for them, the study is very relevant, appropriate and it's one means to create a planned solution for seamless interoperation of ehealth systems at different levels of interoperability stacks in FMoH.

CHAPTER SIX

6. Conclusion and recommendations

6.1. Conclusion

This research aimed at developing an eHealth systems interoperability assessment framework for FMoH owned ehealth systems framed with four basic interoperability perspectives and the corresponding additional key components examining the existence of low quality healthcare service backed with lack of interoperability between ehealth systems at different levels of interoperability stack. Thereby, examining other countries experiences towards maintaining interoperable eHealth systems and investigation of plenty interoperability assessment models through content analysis method, then the proposed interoperability assessment framework tailed with simple descriptive validation process.

This study basically aimed to answer the following research questions, the first is: - What are the critical treats they could impact on ehealth systems interoperability and further for the overall quality of healthcare service delivery in FMoH. Secondly, how can we address healthcare service challenges originated from lack of eHealth systems interoperability?

To answer those questions the study focused on examining the basic interoperability related works and many reports of the ministry of health, examine key interoperability elements that helps to visualize interoperability challenges from different perspectives.

Thus, this study provides an interoperability assessment framework framed with four interoperability perspectives and the corresponding components (attributes) adapting three widely used interoperability perspectives and further additional 4^{th} interoperability perspective along with key interoperability components in it.; after examined other countries experiences how they addressed such interoperability barriers then gap analysis conducted and this study proposed by removing limitations of the reviewed works and including essential strengths.

After examined many related studies, contextual differences between the previous related studies and the case under study identified via gap analysis step, then the researcher proposed an interoperability assessment framework structured with four interoperability perspectives namely: Informational interoperability perspectives, Organizational interoperability perspectives, Technical interoperability perspective and including the 4^{th} perspective (other perspectives) and the corresponding 19 key interoperability assessment components validated by domain expertise.

The study conducted based on the data gathered from 15 ehealth experts through semi-structured questioner asking their opinion to validate the importance and appropriateness of proposed framework involving detailed discussion on the study. Followed by respondents participation by giving score value for each key

interoperability element listed under four perspectives along with their weighted values pre-specified to be rated by those ehealth experts. The data collection conducted involving high administrative role of the researcher in clarifying and further describing the proposed framework components when needed.

The findings revealed that the proposed interoperability assessment framework is found to be valid, important, appropriate and relevant for FMoH in the process to resolve health service delivery problems caused by lack of ehealth systems interoperability.

The findings of this research also show that, "organizational interoperability perspective" and "Informational interoperability perspectives" were found to be the most favored and critical interoperability perspectives for FMoH; both interoperability perspectives gained too much positive feedback along with the highest Average commutative score value (23.5%) out of the pre-specified weighted value (25%) by ehealth experts. This result suggests that domain experts perceived components listed in "organizational" and "Informational" interoperability perspectives are more valuable and important metrics for eHealth systems interoperability assessment framework for FMoH.

Therefore; it can be concluded that Healthcare institutions found in FMoH should give higher focus on components listed under organizational and informational perspectives in order to resolve the existing interoperability barriers being impacted on the quality of healthcare service delivery.

On the other hand, those key components presented in "Technical" and "others" interoperability perspectives gained an Average commutative score point 23.3% and 22.6% respectively out of the pre-specified weighted value (25%) by ehealth experts that is slightly less acceptance of domain experts; nonetheless, all the key elements of the proposed framework had a very good acceptance mentioned as a feedback during detailed discussion.

This result implies that, nevertheless the approval of all components of the proposed framework, domain experts perceived that key components listed in Technical and Other interoperability perspectives should be given less priority than organizational and Informational interoperability perspectives.

This study provides broader view of eHealth Systems interoperability aspects or issues that has not been studied by any of previous researcher locally through the development of an interoperability Assessment framework; as a mechanism to resolve ehealth systems interoperability for FMoH eHealth systems.

This study has contributed interoperability assessment framework for eHealth systems under FMoH Healthcare institutions from the following viewpoints:-

Technical interoperability, Informational interoperability, Business /Organizational interoperability, Cultural Interoperability, knowledge interoperability, Human resource view point, also provide appropriate interoperability assessment model.

Overall, the result of this study indeed provides a relevant interoperability assessment framework confirmed by domain experts as helpful and valid to healthcare institutions found in FMoH, and acknowledged as one way of addressing interoperability barriers and serve as a bench mark or guide to harmonize eHealth systems interoperability.

Further, this can be used as a base for the researchers to conduct future researches on this study area for governmental service sectors other than health sectors in the country.

6.2. Recommendation

Based on the findings of this research, the following suggestions are forwarded to FMoH healthcare institutions to resolve interoperability barriers of multiple key elements contributed for the seamless interoperation of their eHealth systems at any level of interoperability stack.

The FMoH should take in to consideration the existing situations found in the healthcare service environments like cultural interoperability (diversity of system users and clients), Human resource interoperability issues and take advantage of the continuous interoperability assessment work using those key interoperability elements listed in this study to cope up with the dynamically changing technology in the health service delivery; also examine the service and process level interoperability because health care industry mainly conducted focusing on process, service and other functionalities.

The other key point that the researcher highly recommended to FMoH is that, the ministry should give great emphasis to key components listed under Organizational and Informational perspectives as a metrics that most determine the current level of ehealth systems interoperability across the healthcare service domain and sketch their maturity planning to the next higher level of interoperability maturity model.

Eventually, FMoH should also promote researchers focusing on investigation of how much technical and other interoperability key elements components negatively affect the overall seamless interoperation of ehealth systems in the entire line of healthcare service delivery.

In addition, FMoH should have to understand the importance of cultural interoperability, knowledge interoperability, human resource interoperability and further focusing on defining basic requirements(unique standard) like technical standardizations before system development as a specification or before implemented by Vender Company in the health sector.

Based on the result of this study FMoH healthcare institutions should have a mechanism or health information systems strategy to control ehealth systems interoperability assessment considering all the above key components of the proposed interoperability assessment metrics.

6.3. Future Research

This research conducted to provide one way of addressing ehealth systems interoperability barriers through the development of comprehensive interoperability assessment framework for ehealth systems implemented in FMoH. Since the area under study especially concerning interoperability assessment framework in the health sector has been investigated by few researchers in the local context, this study still has rooms to be further investigated; some of them are listed below:

- This study conducted under the consideration of FMoH owned ehealth systems (only Governmental healthcare organizations) but future researchers may investigate an interoperability assessment framework considering broader scope like developing an interoperability assessment framework for systems found in other sectors or country wise including non-governmental healthcare service delivery organizations.
- Future researchers may also improve this study considering additional basic, valid and important key elements of interoperability evolved through time and technological advancements or social and mental changes of the society.
- Future researchers may further provide an interoperability assessment tool bounded by the outcomes of this study then conduct ehealth systems interoperability assessment at the selected healthcare institutions under FMoH.
- On the other hand future researcher may try to disproof the validity of this research following other research design or research approach considering the skills, perception, diversity change over time of the ehealth system users, clients and all the stakeholders in the healthcare service delivery.

4.1. Implications of the study

Generally the findings of this study contribute to FMoH healthcare institutions what are the major interoperability elements they contributed to the overall ehealth interoperability success that should be considered during assessment and how ehealth systems interoperability assessment better approached.

This study also contributed to FMoH healthcare institutions interoperability assessment guideline to marginalize the level of ehealth systems interoperability as they planned in Health Sectors Transformation Plan nationally.

On the other hand this study could be used as a motivation to FMoH health care institutions for further investigation of additional metrics to their ehealth systems interoperability assessment for the improved healthcare service delivery.

This study contributed to a theory, by providing a tested and validated interoperability assessment framework structured with four basic interoperability perspectives considering the shortage of previous studies that currently exist in the local context in general about systems interoperability assessment frameworks, specifically about ehealth systems interoperability barriers, basic perspectives and the corresponding key components of interoperability in health sector. Thus, this study helps as a starting benchmark to enrich related system interoperability assessment frameworks by exploring additional key interoperability issues using their own research process and approach.

This study contributed practically, giving an insight to the decision makers and NGO system developers in the health sector by indicating the basic components they should be focused on to create harmonized ehealth systems throughout the entire line of healthcare services delivery.

The study made a significant contribution to FMoH healthcare institutions in understanding the complex nature of the healthcare service and helps to visualize ehealth systems interoperability problems from multiple perspectives along with the key components integrating with assessment model, as one option to address existing interoperability barriers.

Further, this study support decision makers in the health sector to develop unique standards including predefined requirements for all the key elements contributed to ehealth systems interoperability before implementation then take actions to control conformation of each required interoperability elements at the national level.

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Appendix I: Semi-structured Questionnaire

Addis Ababa University

College of Natural and Computational Science,

School of Information Science

Dear respondents,

Thank you for agreeing to take part to conducting the research: "eHealth Systems Interoperability Assessment Framework: case of FMoH healthcare institutions"

I am Yitayal, currently pursuing my master's in Information Systems at Addis Ababa University. By assuring you that your information will be used only for academic research purpose and confidentiality of your response is 100% granted, I kindly request you to answer the entire questions provided below by believing that the quality of this research findings highly depends on your honest and accurate information.

Thank you in advance for your time!

Researcher: YITAYAL CHANIE

Research Advisor: *GETACHEW HAILEMARIAM (PhD.)*

Mobile: +251913481711

Email: messimita@gmail.com

General directions

- ☐ Please check that the paper has two sections and 4 pages
- ☐ Please do not write your name
- ☐ Please put "X" mark on your choice

Section A: - General Information

1. **To which of the following organization you are working for?**

☐ FMoH
☐ NGO Partners

2. **Your job title** _____

3. **Your education level? Please tick (✓) on the box**

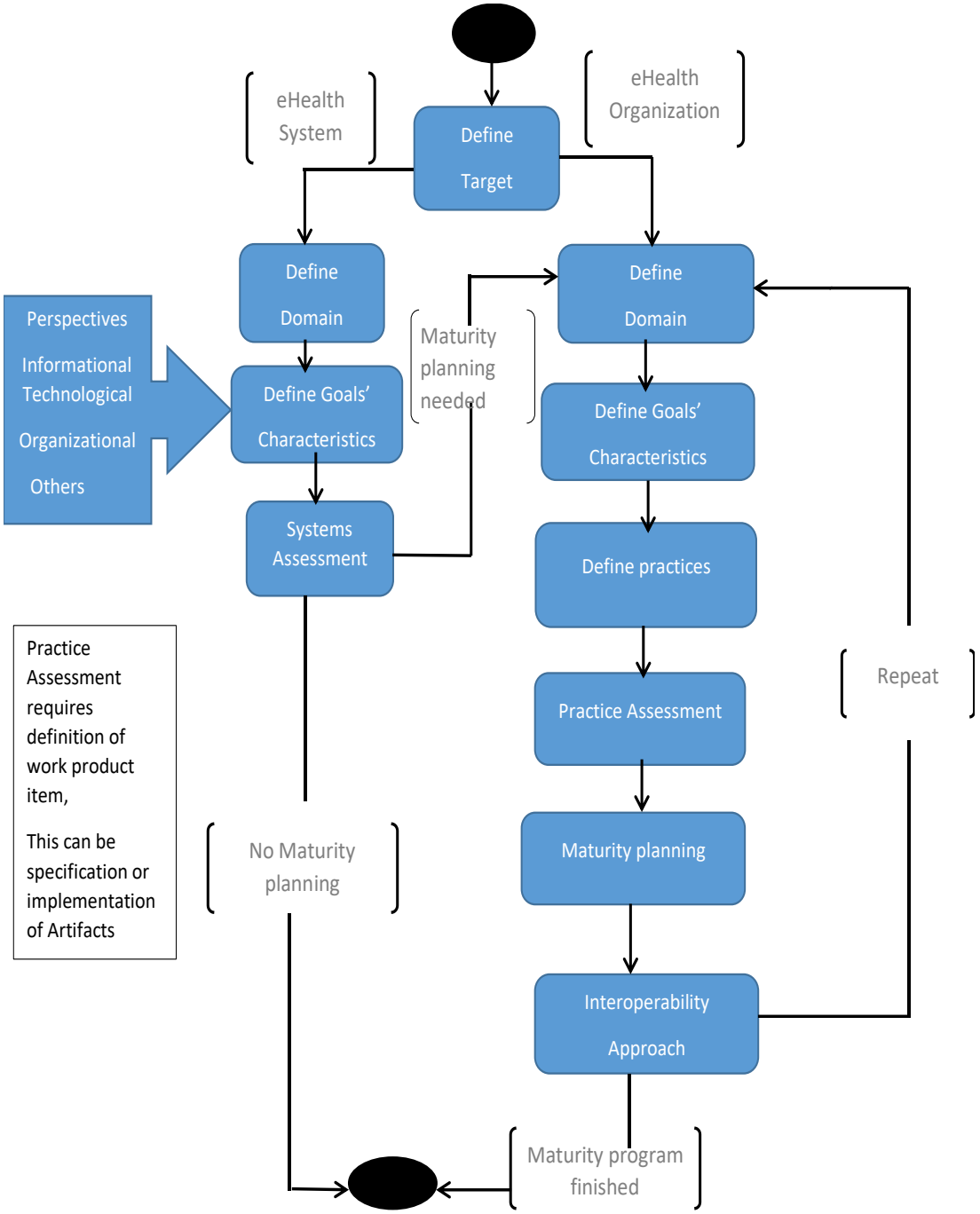
BA or BSc ☐ Masters ☐ PHD ☐ Other ☐

4. **Your years of experience**

Less than 3 years ☐ 3 to 5 years ☐ 5 to 10 years ☐ More than 10 years ☐

Section B: Questions used to evaluate the validity of proposed interoperability assessment framework

This section is seeking your opinion regarding the proposed frameworks' perspectives and the corresponding attribute (measuring items) are important and valid in the view of ehealth experts (you). Respondents are asked to give score values out of the pre-specified weighted measurement items (19 key elements) to indicate the extent to which you accept the validity of this research work.



No	**Interoperability perspectives and corresponding lists of key elements (25%)**	**Weights given to each sub key element (%)**	**Average response per each key element (%)**	**Points given by ehealth experts**														
				E1	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**	**E9**	**E10**	**E11**	**E12**	**E13**	**E14**	**E15**
1	**Key elements listed under Organizational interoperability**	**25%**																
1.1	Objective interoperability	**5 %**																
2.2	Rules and regulations interoperability	**5 %**																
3.3	Governance structure interoperability	**3**																
4.4	Service interoperability	**3**																
5.5	Process reengineering/standardization and modeling	**4**																
6.6	Enterprise Architecture Transformation	**5**																
2	**Informational perspective and corresponding lists of key elements**	**25%**																
2.1	Data Standardization	**10**																

2.2	Data access principles and Data Ethics	**5**																
2.3	Data life cycle	**5**																
2.4	Data Presentation and Format	**5**																
3	**Technical perspective and corresponding lists of key elements**	**25%**																
3.1	Hardware and Software specifications	**10**																
3.2	Messaging, Security and privacy Standards	**5**																
3.3	Technical protocols	**5**																
3.4	Physical and logical connectivity	**5**																
4	**Other interoperability perspective and corresponding lists of key elements**	**25%**																
4.1	Human resource interoperability	**5**																
4.2	Cultural/Language Interoperability	**5**																
4.3	Knowledge interoperability	**5**																
4.4	Interoperability Maturity Measure	**5**																

4.5	Interoperability Approach	**5**																
	Total points	**100%**																

APPENDIX II: DISCUSSION POINTS ON THE PROPOSED INTEROPERABILITY ASSESSMENT FRAMEWORK FOR FMoH

- **Discussion points**
  1. **Does this interoperability assessment framework solve all the main challenges and enables to attain different levels of interoperability between FMoH owned ehealth systems?**
  2. **Do you think the proposed interoperability framework provide valuable insight for decision makers how to approach healthcare service problems caused by lack of key interoperability elements?**
  3. **What is your feedback and recommendations?**

APPENDIX III: EVALUATION RESULT FOR THE VALIDITY OF PROPOSED INTEROPERABILITY ASSESSMENT FRAMEWORK KEY ELEMENTS

No	Interoperability perspectives and corresponding lists of key elements (25%)	Weights given to each sub key element (%)	Average response per each key element (%)	Points given by ehealth experts														
				E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15
1	**Key elements listed under Organizational interoperability**	25%	23.5%															
1.1	Objective interoperability	5 %	4.7	5	5	5	5	5	4	4	5	5	5	5	5	4	4	5
2.2	Rules and regulations interoperability	5 %	4.3	5	5	5	5	5	4	4	4	4	4	4	4	4	4	4
3.3	Governance structure interoperability	3	2.6	2	2	2	2	3	3	3	3	3	3	3	3	3	2	2
4.4	Service interoperability	3	3.0	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
5.5	Process reengineering/standardization and modeling	4	4.0	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
6.6	Enterprise Architecture Transformation	5	4.9	5	5	5	5	5	5	5	5	5	5	5	5	4	4	5
2	**Informational perspective and**	25%	23.5%															

	corresponding lists of key elements																	
2.1	Data Standardization	**10**	**9.0**	**9**	**9**	**9**	**9**	**9**	**9**	**9**	**9**	**9**	**9**	**9**	**8**	**9**	**9**	**10**
2.2	Data access principles and Data Ethics	**5**	**4.8**	**5**	**4**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**4**	**5**	**5**	**4**
2.3	Data life cycle	**5**	**4.7**	**4**	**4**	**4**	**4**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**4**	**5**	**5**	**5**
2.4	Data Presentation and Format	**5**	**5.0**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**
3	**Technical perspective and corresponding lists of key elements**	**25%**	**23.3%**															
3.1	Hardware and Software specifications	**10**	**9.3**	**9**	**9**	**9**	**9**	**9**	**9**	**9**	**9**	**10**	**10**	**10**	**10**	**9**	**9**	**10**
3.2	Messaging, Security and privacy Standards	**5**	**5.0**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**
3.3	Technical protocols	**5**	**4.3**	**4**	**4**	**4**	**4**	**4**	**5**	**4**	**5**	**4**	**4**	**4**	**5**	**4**	**4**	**5**
3.4	Physical and logical connectivity	**5**	**4.7**	**5**	**4**	**5**	**4**	**5**	**5**	**5**	**4**	**5**	**4**	**5**	**5**	**5**	**4**	**5**
4	**Other interoperability perspective and corresponding lists of key elements**	**25%**	**22.6%**															
4.1	Human resource interoperability	**5**	**5.0**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**
4.2	Cultural/Language Interoperability	**5**	**4.1**	**4**	**4**	**5**	**4**	**4**	**4**	**4**	**4**	**4**	**5**	**4**	**4**	**4**	**4**	**4**

4.3	Knowledge interoperability	**5**	**4.7**	**5**	**5**	**5**	**4**	**4**	**4**	**4**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**
4.4	Interoperability Maturity Measure	**5**	**4.1**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**5**	**4**	**4**	**4**	**4**	**4**	**4**
4.5	Interoperability Approach	**5**	**4.7**	**5**	**5**	**5**	**4**	**5**	**5**	**4**	**5**	**5**	**5**	**4**	**5**	**4**	**5**	**4**
	Total points	**100%**	**92.9%**															

APPENDIX IV: SUMMERY RESULT OF THE VALIDITY OF PROPOSED INTEROPERABILITY ASSESSMENT FRAMEWORK AND THE CORRESPONDING FOUR PERSPECTIVES

	Interoperability Perspectives																	
		Organizational interoperability perspective (25%)						Informational interoperability perspective (25%)				Technical interoperability perspective (25%)				Others interoperability perspective (25%)				
	Key interoperability Elements	Objective interoperability	Rules and regulations interoperability	Governance structure interoperability	Service interoperability	Process reengineering/standardization and modeling	Enterprise Architecture Transformation	Data Standardization	Data access principles and Data Ethics	Data life cycle	Data Presentation and Format	Hardware and Software specifications	Messaging, Security and privacy Standards	Technical protocols	Physical and logical connectivity	Human resource interoperability	Cultural/Language Interoperability	Knowledge interoperability	Interoperability Maturity Measure	Interoperability Approach
	Respondent Average given point	4.7	4.3	2.6	3.0	4.0	4.9	9	4.8	4.7	5	9.3	5	4.3	4.7	5	4.1	4.7	4.4	4.7
	Respondents given point Per each perspective Commutative	23.5						23.5				23.3				22.6				
	Total Points	**92.9**																		