ADDIS ABABAUNIVERSITY
SCHOOL OF GRADUATE STUDIES
SCHOOL OF INFORMATION SCIENCE
AND
SCHOOL OF PUBLIC HEALTH

DATA EXCHNAGE INTEROPRABILITY FRAMEWORK FOR LABORATORY INFORMATION SYSTEM (LIS) AND ELECTRONIC HEALTH RECORD (EHR) OF TWO HOSPITALS IN ADDIS ABABA

WONDWOSEN SHIFERAW ABERA

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A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES IN PARTIAL FULLFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN HEALTH INFORMATICS

BY
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_____	Examiner	_____	_____

DECLARATION

I declare that this thesis is my original work and it has not been presented for a degree in any other university. All the material sources used in this work are duly acknowledged.

_____

Wondwosen Shiferaw

May 2013

This thesis has been submitted for examination with our approval as university advisors.

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Dr. Fikre Enquselassie

_____

Ato Workshet Lamenew

DEDICATION

I dedicate this work to St. Marry, St. Habtemariham and My family who are always helping and motivating me to continue my education to the level possible.

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LIST OF ABRIVATIONS

AARHBs: Addis Ababa Regional Health Bureaus

CCR: Continuity of care record

CDC: Center for Disease Control

CDA: Clinical Document Architecture

CDISC: Clinical data interchanging standards consortium

CEN: Committee for Standardization in European Union

DEIFLE: Data exchange interoperability framework among LIS and EHR

eHealth: electronic Health

EHR: Electronic Health Record

E.C: Ethiopian Calendar

EHNRI: Ethiopian Heath nutrition research institute

FMOH: Federal Ministry of Health

GMP: Group Medical Practices

HIFIS: Health Integrated Financial Information System

HIS: Hospital Information System

HMIS: Health management information system

HL-7 V-3: Health Level 7 -Version 3

HSDP: Health Sector Development Programs

ICT: Information Communication Technology

IPD: Inpatients department

ISO: International standards organizations

ITU: International telecommunications union

LAN: Local Area Networking

LIS: Laboratory Information System

MHealth: Mobile Health

MRU: Medical record unit

OPD: Outpatient Departments

PHEMIS: Public Health emergency Management Information system

PFSA: pharmaceutical fund supply agency

TUTAPE: Tulane University Technical Assistant People of Ethiopia

WAN: Wide Area Networking

WLAN: Wireless Local Area Networking

WHO: World Health Organizations

US: United States

XML: Extensible Markup Language

ABSTRACT

Background: eHealth applications are key to facilitate the health care delivery by increasing access and quality. However, those applications are vary in design and structure. Interoperability between those applications is important that creates a bridge and facilitates the data exchange between two different eHealth applications. In Ethiopian hospitals, eHealth applications are characterized by small-scale in size with greater duplication of efforts. For instance, one of the gap has been the integration of applications such as Laboratory information system (LIS) and Electronic Health Record (EHR) due to limited interoperability in laboratory data exchange between these applications in the Hospitals.

Objectives: The objective of this study is to assess the existing LIS and EHR for data exchange interoperability and identify challenges with the view to explore the possibility of proposing and developing data exchange interoperability framework.

Methodology: In this study, an attempt is made to apply qualitative research method to explore the status of e-Health applications (LIS and EHR). Interviews were used tool for data collection. We have also collect the criteria from the literature on LIS and EHR application functionality testing. Finally, then constructive method helped for design data exchange interoperability framework on eHealth applications in the case of LIS and EHR. We used NVivo-10 software for coding the interview and analyze the data.

Results: In this study, lacks of interoperability and coordination cause for fragmentation of systems and data redundancy on eHealth applications which are the main challenges in the Hospitals. In order to overcome the data exchange interoperability problems in the Hospitals, the researcher suggested data exchange interoperability framework between LIS and EHR. The framework is tested by the developers and decision makers. The proposed and designed framework is encouraging for future change.

Conclusion: the study was designed to explore the current status of eHealth applications in the selected case. The investigator shown that there have been challenges in terms of data exchange interoperability, integration and coordination of the systems. The proposed data exchange interoperability framework is a possible solution to address the challenges.

CHAPTER ONE

INTRODUCTION

1.1. Background

The World Health Organization defined e-Health as "the combination of electronic communication and information technology in the health sector" [4]. It is a key area for improving health service delivery, promoting health, and easier information exchange on the health care organizations, assisting in decision making processes, and improving the effectiveness of operations [1]. In this regard, organizations need to invest a lot of resources to use e-health systems as a supportive tool for the effective and efficient delivery of Health services. Nowadays, e-Health is a cross cutting area which supports all functions and operations areas by facilitating the automation of various Health processes.

One of the challenges faced nowadays by health care and e-Health industry is interoperability between heterogeneous applications such as Electronic Medical Record (EMR) and Laboratory Information System (LIS). Interoperability is defined as the ability of different information technology systems and software applications to communicate, exchange data accurately, effectively and consistently to use the information that has been changed. There are three parts of interoperability: business process interoperability that deal with integrating business process by considering alignment and Harmonization; syntactic interoperability deal with only the structural alignment and integration; Semantic interoperability in particular on data exchange [25].

Semantic interoperability is the ability of e-Health system to share information and have that information properly interpreted by the receiving system in the same sense as intended by the transmitting systems that deal with concepts, meanings and data exchange issues [25]. There are technologies as solution on semantic interoperability such as semantic web (Web 3.0). Semantic technologies are emerging and several applications ranging from business process management to information security have demonstrated encouraging prospects of its benefits. Role of semantic is also very vital for achieving interoperability in sharing health records. For example: the role of Health Level 7(HL7) for clinical data exchange; Digital Imaging and Communication in Medicine

(DICOM) for imaging exchange; and other standards on semantic interoperability.

The Ethiopian Federal Ministry of Health (FMOH) has recognized the benefits of e-health as a tool to support the health sector and involved in a number of e-Health applications and services. These have been classified into the following major areas: Data Warehouse, Electronic Health Records (EHR), Laboratory information System (LIS), Logistic Management Information systems (LMIS), Geographical Information Systems (GIS), Tele-Education, Telemedicine, Human Resource Information System (HRIS), Health Integrated Financial Information System (HIFIS), Electronic Health Management Information System (e-HMIS) [1].

According to Ethiopian National e-Health Strategic Road Map, Laboratory Information Systems (LIS) and Electronic Health Record (EHR) are two major prioritized e-Health applications that enhanced data exchange, information use and reporting system at a national and hospital level[1].

According to William and Harsh [9], the Electronic Health Record is a computerized patient tracking, patient caring system that is an essential technology for health care and a necessary tool for improving patient safety and the quality of care. Availing quality and timely health information at various levels of decision points throughout the hospitals systems is very essential for the improvement of Health Care and overall Health System in Ethiopia. The benefits of using an EHR includes, increasing the quality and speed of access to Health Information exchange and the effectiveness of the Health System. In Ethiopia, the implementation of EHR is through software called Smartcare TUTAPE (Tulane University's Technical Assistance Program for Ethiopia) is developing the Smartcare software in partnership with Tulane University, CDC and the Federal Ministry of Health Ethiopia (FMOH).Smartcare was first developed, tested and deployed in Zambia by CDC for HIV/AIDS care and treatment. Besides the rich and advanced functionality and features, Smartcare has also been proven to work in entire hospital functionality especially in limited resources environment of developing countries particularly in Africa [1].

Jincy [2], clearly stated that, Laboratory information system (LIS) is a software-based laboratory information management system receiving, processing, and storing information generated by medical laboratory processing. In Ethiopia, the implementation of LIS was through software called Comp Pro Med's -Polytechnic. It is developed by private company in US and in partnership with CDC, the Federal Ministry of Health Ethiopia (FMOH) & Ethiopian Health and Nutrition research

institute (EHNRI). The EHNRI and CDC were involved in design and implementation of LIS [21].

FMoH ICT report [1], to identify major challenges on EHR and other systems like LIS in the Hospitals. In the report clearly stated that, redundancy and lack of interoperability exist in the between applications in the Hospitals and developed the eHealth Strategy Road Map [28] in collaboration with its technical partners that mainly proposed national level Health information exchange and overcome the existing eHealth application limitations (lack of integration and interoperability) on data exchange [8].

These eHealth applications give hope for some hospitals in Ethiopia to increase access to health care records, decrease cost and improving quality in the hospitals. But there are semantic particularly on data exchange interoperability problems still exist for example surveyed hospitals by researcher such as St. Paul Specialized Millennium Medical College and Zewditu Memorial General Hospitals.

St. Paul specialized hospital was established in 1961 E.c. it is located in Gulele sub city, Addis Ababa, it offer 24 hour general medical service and train medical professionals. Regarding the total number of employee, there are 600 admin staffs and 120 health professionals. The hospital provide emergency and non-emergency care delivery services further streamlining outpatient and inpatient services each of these services categorized in Laboratory Services, STD Treatment, Surveillance, TB Prevention, Voluntary counseling and testing, Blood safety, Health-facility based medical care, Prevention of mother-to-child transmission, Universal precautions, Information, education and communication, HIV/AIDS Research and it has 300 beds.

Zewditu Memorial hospital is a found in central Addis Ababa, Ethiopia it was built, owned and operated by the Seventh - day Adventist church. But it was nationalized during the derg regime about 1976 E.c. The hospital was temporarily closed down in 2007 after a serious leakage was found in the building. Regarding the total number of employee, there are 300 admin staffs and 89 health professionals. The hospital provide emergency and non-emergency care delivery services further streamlining outpatient and inpatient services each of these services categorized in Laboratory Services, STD Treatment, Surveillance, TB Prevention, Voluntary counseling and testing, Blood safety, Health-facility based medical care, Prevention of mother-to-child

transmission, and it has 214 beds. The two hospitals in Addis Ababa was the only hospitals implemented both LIS and EHR applications.

These researches addressed data exchange interoperability challenges between LIS and EHR in both Hospitals and suggest data exchange interoperability framework by qualitative method.

1.2. Problem statement

The major focus of the new five year strategic plan (HSDP-II, and HSDP-IV) is improving quality of health service delivery by increasing community mobilization through health information system. Based on this the Federal Ministry of Health started to implement eHealth systems in the hospitals [12].

According to FMoH (2010) Report, the Federal Ministry of Health and its technical partners were implemented e-Health systems at ten hospitals in Addis Ababa for improving quality of health service delivery, giving access for health service but the federal ministry identified and addressed some challenges (lack of standardization and coordination in health service delivery) by designing New Hospitals Reform as controlling mechanism in the hospital level. Some of the problems were not addressed currently such as lack information sharing between different e-Health system such as LIS and EHR, lack of information use at all levels (Hospitals, districts, regional and federal levels) for planning and decision making process [14].

The Federal Government in collaboration with Tulane University and Center for Disease Control, Ethiopia (CDC) implemented LIS and EHR at St.Paul Specialized Millennium Medical College and Zewditu Memorial Hospitals to enhance health service delivery more effectively and efficiently by increasing quality of service, access for health records and decrease health care cost [5]. On the other hand, most of the eHealth applications were implemented in pilot stages with fragmentation, lack of interoperability and integration between the eHealth applications such as EHR and LIS [12]. In St.Paul Specialized Millennium Medical College and Zewditu Memorial Hospitals, EHR was implemented in 2003E.C. EHR includes every point of Health service delivery, starting from Card Section to Pharmacy, in addition to IPD, wards and administrative works. Whereas, LIS was implemented one year after EHR, in 2004 E.C. LIS only focuses on laboratory functionalities based on the laboratory setup in the Hospitals that includes laboratory machine to computer communication that help to increase quality [8]. In Addis Ababa, both LIS and EHR were

implemented in laboratory department for improving laboratory service delivery. However, Laboratory technologists faced a number of Challenges [1] such as 1) Delay in data entry and exchange that created workload in the laboratory sections. 2) Wastage of time during laboratory service delivery that is because of doing both paper based and electronic system in the laboratory. This research mainly focuses on the gap of the two e-Health applications (LIS and EHR) in hospital by considering the data exchange and software functionality testing of both LIS and EHR applications that are working at St.Paul Specialized Millennium Medical College and Zewditu Memorial Hospitals so as to identify interoperability options. So the major questions explore in this research are:

1. What are the challenges in implementing eHealth applications in terms of interoperability?
2. How can we develop a framework to address interoperability on e-Health applications in St. Paul specialized Hospital and Zewditu memorial Hospital?

1.3. Objectives

1.3.1. General Objective

- ✓ To assess the existing LIS and EHR for data exchange interoperability and identify challenges with the view to explore the possibility of proposing and developing data exchange interoperability framework

1.3.2. Specific Objectives

- ✓ To investigate the clinical workflows particularly on data exchange interoperability between LIS and EHR.
- ✓ To assess challenges of users, decision makers and developers towards LIS and EHR applications.
- ✓ To propose data exchange interoperability framework.
- ✓ To evaluate the framework.

1.4. Scope of the Study

This study is going to be conducted in the context of LIS and EHR on identifying clinical work flow, limited to data exchange and its challenges of Zewditu Memorial and St. Paul Millennium Medical College Specialized Hospitals and proposed the data exchange interoperability framework on e-Health applications (LIS and EHR).

1.5. Significance of the Study

The findings of the research will benefit the Ministry of Health (MOH), Hospitals and Partners / stakeholders to the Health sector for planning and decision making process and Health information uses at all level.

- **Hospitals / eHealth System Users:** it will provide information about e-health applications (LIS and EHR) in Ethiopia in the case of Hospital and address some of the challenges on interoperability on data exchange; design data exchange interoperability framework between LIS and EHR that enable health care delivery more effectively and efficiently at the Hospital level. Make all the separation or fragmented e-Health systems look at one picture without any boundary that will help to prepare interoperability plan for sustainability of e-health systems at Hospitals.
- **Decision Makers at FMOH and Partners / Stakeholders:** the research will let the decision makers have more information about existing e-Health systems at the hospital level in relation to data exchange interoperability and propose data exchange interoperability framework among LIS and EHR. That will help them to make corrective actions and plan for sustainability of the existing e-Health Applications in Hospitals. Address interoperability issues on EHR and LIS for better decision making on implementation of e-Health Applications as well as guide for future selecting appropriate e-Health technologies on the Health sector.
- **Researchers:** This research also indicated future works on eHealth interoperability for researchers

1.6. Operational definitions

- **Data exchange:** it is the process of sending, transmission and receiving data between LIS and EHR.
- **eHealth applications**: refers to the two applications designed and implemented by TUTAPE and CDC in the laboratory section of the two hospitals in Addis St. Paul and Zewditu memorial hospitals
- **Integrated Laboratory Information System:** Polytech laboratory application that provides computer based recording, analyst and reporting to facilitates the laboratory activities by integrating all of the systems in a laboratory
- **Electronic Health Record:** Smartcare application, particularly a Laboratory Information System Module that provides computerized recording, analysis and reporting on laboratory activities to improve patient safety and the quality of care.
- **Laboratory section :** it is a department in the hospital that provide laboratory service and also the place where the two eHealth applications implemented
- **Semantic:** It focuses on the relation between signifiers, like words, phrases, signs, and symbols, and what they stand for, their denotation.
- **Interoperability**: Ability of a computer system to run application programs from different implementers, and to interact with other computers across local area network regardless of their physical architecture and operating systems.
- **Semantic interoperability:** the ability of computer systems to transmit data with unambiguous and shared meaning. Semantic interoperability is a type interoperability that mainly focuses on data with shared meaning and how the data exchange would be facilities between different applications.
- **Framework:** is a conceptual structure intended to serve as a support or guide for the building of interoperability between LIS and EHR that facilitate the data exchange in the hospitals

- **Hospital workflow:** refers to the path a patient should follow until he/she receives the medical service he/she needs. It is briefly represented in the following diagram.

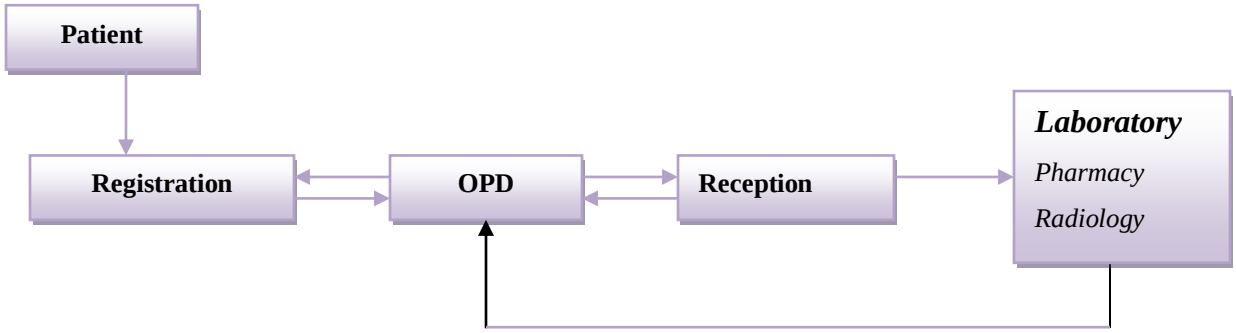

Figure1. 1Hospital Workflow

1.7. Organizations of the thesis

This thesis is organized in to seven chapters and discussed the following:

First Chapter: The background of the LIS and EHR applications and Problem statements, Objective, Relevance of the study and operational definitions clearly discussed in this chapter.

Second Chapter: This chapter is organized in to seven sections are introduces the reader about data exchange interoperability; that mainly covers Interoperability definitions, Semantic and Data exchange concepts, Explanation LIS and EHR applications in Ethiopia, organized some related works in other worlds. The related works are mainly addressing the options of interoperability framework.

Third Chapter: discusses the methodology employed to conduct this thesis and mainly address used hybrid methodology which is qualitative method with exploratory research approach and constrictive method.

Fourth Chapter: describes the analysis of findings in terms of results and discussions, strength and limitation.

Fifth Chapter: describes and provides data exchange interoperability framework between LIS and EHR that possibly address gaps in the identified in chapter four.

Sixth Chapter: describes the validations of the framework from eHealth experts, software developers from CDC and TUTAPE.

Final Chapter provides the conclusion and implications in terms of recommendation for users, future work of the study.

CHAPTER TWO: LITRATURE REVIEW

INTEROPERABILITY FRAMEWORK ON eHEALTH SYSTEMS

2.1. Concepts and Definitions

The health care system are critical and demand high accuracy, prompt availability and interoperability. The right use of information and communication system can play vital role in achieving the said requirements; but unfortunately healthcare systems are used mostly as a replacement to manual patient logging. The manual healthcare data system is not only prone to error and loss but also it is not feasible to manage massive data and access any accessible, accurate and manageable data processing solutions. According to WHO [12], eHealth is the cost-effective and secure use of information and communications technologies in support of health and health-related fields, including health-care services, health surveillance, health literature, and health education, knowledge and research and it is one of the most rapidly growing areas in health today. According to Blobel [20], there is no doubt that the way to high quality, safe and efficient health service leads to distributed cooperative care (shared care) supported by information and communication technologies and defined e-Health (electronic health) – has been coined to describe applications of information and communication technology (ICT) in the health care sector.

Typical e-Health solutions are electronic medical records, applications in telemedicine, consumer health services (e.g., personal health records such as Google Health and Microsoft Health Vault), public health surveillance systems, and health decision support systems. Motivated by the assumption that e-Health interoperability will benefit patient care and increase efficiency of health services, developed countries worldwide have invested significant resources in the development of e-Health interoperability infrastructures [25-28]. (HSDP-IV and eHealth Strategy Road Map) [1], identifies the existing eHealth systems (initiatives) need to be much more strongly integrated, interoperability (technology and program)and data share (data exchange) without compromising the objectives of each sub systems [29].

[1] HSDP-IV: The National health sector development plan four form 2010/11 to 2014/15, and eHealth strategic road map (Under developed) which contain five year strategic plan and all partners involved in the design and implementation process

The ultimate goal of integrated eHealth system for everyone, everywhere to improve access, quality health services and allows better health being of all citizen [29].

According to Asuman D. and Tuncay N. et el, Interoperability is the ability of different information technology systems and software applications to communicate, to exchange data accurately, effectively, and consistently and to use the information that has been exchanged. Making Healthcare information systems interoperable will reduce cost of Health care and will contribute to more effective and efficient patient care [2, 10]. See the figure 2.1 below, how message exchange in the case of two different systems

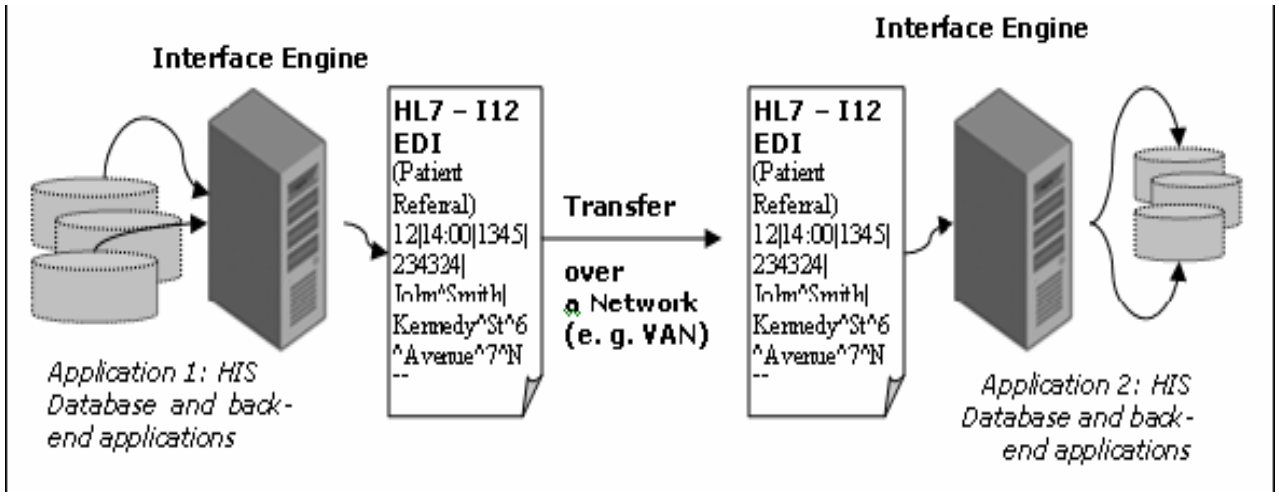

Figure2. 1Message exchange Between Heterogeneous applications

2.2. Interoperability in eHealth System

Asuman [10] stated that, Interoperability is important in the eHealth domain to increase the quality of healthcare and to decrease costs. There are several real life cases that will benefit from interoperability, such as being able to share lifelong EHRs of patients among different healthcare providers; providing clinical decision support through the use of clinical guidelines which require the interoperability of Electronic Health Record Systems (EHRs), laboratory information system (LISs) as part of EHRs and wireless medical sensor devices. In this regards, Interoperability with regard to a specific task is said to exist between two applications when one application can accept data (including data in the form of a service request) from the other and perform the task in an appropriate and satisfactory manner (as judged by the user of the receiving system) without the need for extra operator intervention.

To be interoperable, two applications need to agree on interfaces in each of the three layers of the "interoperability stack": the communication and transport layer; the document layer which involves the format of the exchanged messages and documents as well as the coding systems used and the business process layer which involves the choreography of the interactions. Bilateral agreements between two applications on these interfaces are not practical because it requires the implementation of a new interface for each application to be communicated with. Therefore standards have been developed to address the various layers in the interoperability stack [10].

However there are a variety of different competing standards that can be used for each layer of the interoperability stack and if applications conform to different standards, the interoperability problem continues. Profiling is used to overcome this challenge by predetermining the combination of the standards to be used and even further restricting them to ensure interoperability. Interoperability is the only sustainable way to help partners using eHealth systems that was developed and implemented from different vendors, to collaborate harmoniously to deliver quality healthcare [31]. At the very top of an "interoperability scale" are three levels, each one subdivided as: functional, syntactic, and semantic [21]. Extensive sharing and exchange of data requires that at least two levels of interoperability are reached [22]:

1. **Functional and syntactic interoperability**: the ability of two or more systems to exchange information through functionality and defined message structures so that this information is human readable by the receivers [23].
2. **Semantic interoperability:** the ability for information shared by systems to be understood at the level of formally defined domain concepts so that the information is computer process able by the receiving systems [23].

However, semantic interoperability is not an "all or nothing" concept. The degree of semantic interoperability depends on the level of agreement between sender and receiver regarding the terminology, and the content of archetypes and Ontologies to be used [24]. Semantic interoperability is essential for automatic computer processing which will enable the implementation of advanced clinical applications such as EHR (Electronic Health Records), laboratory systems, and intelligent decision support systems. In fact, healthcare delivery deals predominantly with information and knowledge management, and in terms of clinical information

dissemination, the aim here is not only exchanging data and information but reuse and process that data more intelligently [24].

2.3. Semantic interoperability framework on eHealth systems

In many interoperability frameworks, the semantic tools, namely, Ontologies are intended to be used as facilitators for the interoperability. However, it's very important to distinguish semantically supported interoperability from the semantic interoperability as the latter goes beyond mere data exchange and deals with its interpretation. Semantic interoperability of systems means that the precise meaning of exchanged information is uniquely interpreted by any system not initially developed for the purpose of interoperation. Thus, it is sometimes called "General Semantic Interoperability" [24]. It enables systems to combine and consequently process received information with other information resources and thus, to improve the expressivity of the underlying Ontologies and consequently – to increase the relevance of the data models which are formalized by those Ontologies [24].

Semantic Interoperability is also considered as a synonym for "Computable Semantic Interoperability" [24]. In this sense, it is the ability of computer systems to communicate information and have that information properly interpreted by the receiving system with the same meaning as intended by the transmitting system. Semantic Interoperability, in more general sense, refers to ability of receiving system to correctly interpret transmitted sufficient and necessary information, from sender, but also it is related to awareness and agreement of both actors about their behaviors for given interaction. Syntactic Interoperability is a prerequisite to semantic interoperability. It assumes that common data formats, languages and structures of the messages are defined, so receiving system may read, interpret and reason about the further processing of the message, based on its structure. In this sense, formats correspond to the protocols used for exchange; languages are related to formalisms used to describe the meanings of the messages; structures are related to conceptualization approach, used to describe the meaning of the concepts from these messages. The specification of this conceptualization, namely, ontology allows all interoperating systems to interpret meanings of terms with precision, by exploiting the message's terms used in specific contexts, to the ontology elements that describe the meanings of those terms in logical format. Some researchers suggest that upper ontology must be involved in reconciliation of the systems' semantics. This need is argued by the statement that no single ontology can describe

all possible terms related to all possible uses of the different information systems. However, limited set of basic (primitive) concepts may be combined to create the logical descriptions of the meanings of terms used in local or domain Ontologies. Beside that the issue of security and privacy is very crucial because in semantic there is information sharing and need patient or clinical data privacy and security [24].

2.4. Standards in eHealth systems

International Telecommunication Union [31] reported that, several organizations have been created to develop and evolve interoperability standards for the e-Health industry. For example, In European countries historical challenge is that many of these e-health standards are not interoperable with each other or directly coordinated with each other at an institutional level. This is not universally the case, and concluded the interoperability occurs at all levels starting from the physical layer, the data link layer, the network layer, the transport layer, the session layer, the presentation layer, and the application layer – there are also technically specific efforts at these various levels [31]. It is the extent to which these efforts interoperate between layers, as well as competition in specific areas of standardization, that will determine the future of e-health, as discussed in the conclusion of the report [31]. Committee for Standardization (CEN) in European Union, CEN primarily publishes standards that address application and content layer issues in e-health such as CEN/TS 15699: 2009 "Health informatics – clinical knowledge resources – Metadata" and CEN/TS 15212:2006 "Health informatics – Vocabulary – Maintenance procedure for a web-based terms and concepts database" [31]. the report also indicated that, there are other data exchange standards that are important for the health care industry such as Health Level 7 Inc. (HL-7), continuity of care record (CCR), Digital imaging and communications in Medicine (DICOM) - for Medical Images, Clinical data interchanging standards consortium (CDISC), and open EHR, are some of the standards discussed [31]. Among data exchange standards HL7 were clearly discussed below.

2.4.1. Health Level 7

Health Level Seven International (HL7) is a standard organization specifically devoted to the practice of developing standards related to the exchange, storage, and use of electronic health information such as clinical data and administrative information [31]. In this regard, HL7 provides

application-layer standards and the "7" in this organization's name correspondingly refers to the application layer, or layer 7, of the ISO/ITU Open Systems Interconnection (OSI) reference model for describing technical standards [31]. HL7 typically refers to both the standards organization and the HL7 family of standards and HL7 dates back to the mid-1980s, when it was formed to develop a standard for hospital information systems. It is a not-for-profit standards development organization involved in all aspects of standardization related to health information systems, electronic health records, and the communication, storage, and retrieval of this information. The scope of HL7's standards activities is quite large [31]. Some of the organizational members of HL7 include technology companies (e.g. IBM, Microsoft, Oracle); health providers (Quest Diagnostics, Kaiser Permanente); and pharmaceutical and laboratory companies (e.g. Novartis, GlaxoSmithKline) [31].

Lucas and Begoyan clearly stated that, the term HL7 is used both: I) as a name for the organization and ii) as a set of messaging standards (Version 2.x and Version 3.x). The HL7 organization focuses on the interface requirements that are needed by the entire health care organization, when communicating healthcare data within or outside its healthcare systems. HL7 standards are the most successful messaging standards in the healthcare industry. It is a protocol that consists of standardized grammar and vocabulary. The HL7 standard supports two message protocols: Version2 and Version3 [15, 18].

Eichelberg M. et el [18] indicated that, the most widely used HL7 Version2 protocol is limited to the exchange of messages between medical information systems. It was not developed following any methodology to ensure that all parts of the standard are developed consistently. HL7 Version2 does not support interoperability between healthcare applications very successfully. The main reason for this is the lack of a precisely defined underlying information model structure, plus definitions for many data fields are vague and overloaded with optional data fields [18]. However, by not defining a detailed information model, the HL7 version2 standard allows greater flexibility, which immediately triggers the problem of interoperability. Applications participating in communication using HL7 version3 must therefore have mutual agreements to achieve interoperability [15, 18].

HL7 Version3 is an improvement from the previousVersion2.x by being more focused on specific contexts, terminology, models and conceptual definitions and relationships. Its underlying

information model, called the Reference Information Model (RIM), is object oriented and the proposal for the Clinical Document Architecture (CDA) for exchanging clinical documents across healthcare systems uses Extensible Markup Language (XML) to encode the documents (HL7 2.5,2000) (Interface Ware). Thus the CDA defines the structure and semantics of medical documents that are to be exchanged and CDA documents use data types specified in the HL7 RIM. The CDA consists of 3 levels (HL7 CDA). Each of them takes the mark up of the previous level and adds more mark up to compose a clinical document. However, this does not change the clinical content of the document (HL7 CDA Release 1.0, 2000) (HL7 Standards).All the three levels in HL-7 listed below in the table 2.1 [15, 18].

Table 2. 1 The three levels of HL7 version 3.00

Level-1	Consists of a Coded Header and a Body. The Coded Header defines the semantics of each entry in the document. The Body contains clinical data in an unstructured test format or it can consist of nested data such as paragraphs, lists and tables.
Level-2	Models observations and instructions within each heading, thus making it possible to constrain the structure and content of the document through templates. This increases interoperability by using agreed templates between heterogeneous healthcare systems.
Level-3	Provides completely structured documents where each element of the document is adequately coded for machine processing. The CDA HL7 is not strictly an EHR standard, but forms its sub-component, that has already been harmonized with the equivalent structure in CEN13606and openEHR (HL7 EHR 2004).

2.4.1.1. HL7 message refinement process

According to Sartipi et el, [31], HL7 methodology uses RIM, HL7-specified vocabulary domains, and HL7 v3 data type specification and establishes the rules for refining these base standards to specify Message Types and equivalent structures in v3. The strategy for development of these message types and their information structures is based upon the consistent application of constraints onHL7 RIM and HL7 Vocabulary Domains, to create representations that address a specific health care requirement. Figure 2.2 illustrates the refinement process specified in HL7methodology, where the different parts are discussed below.

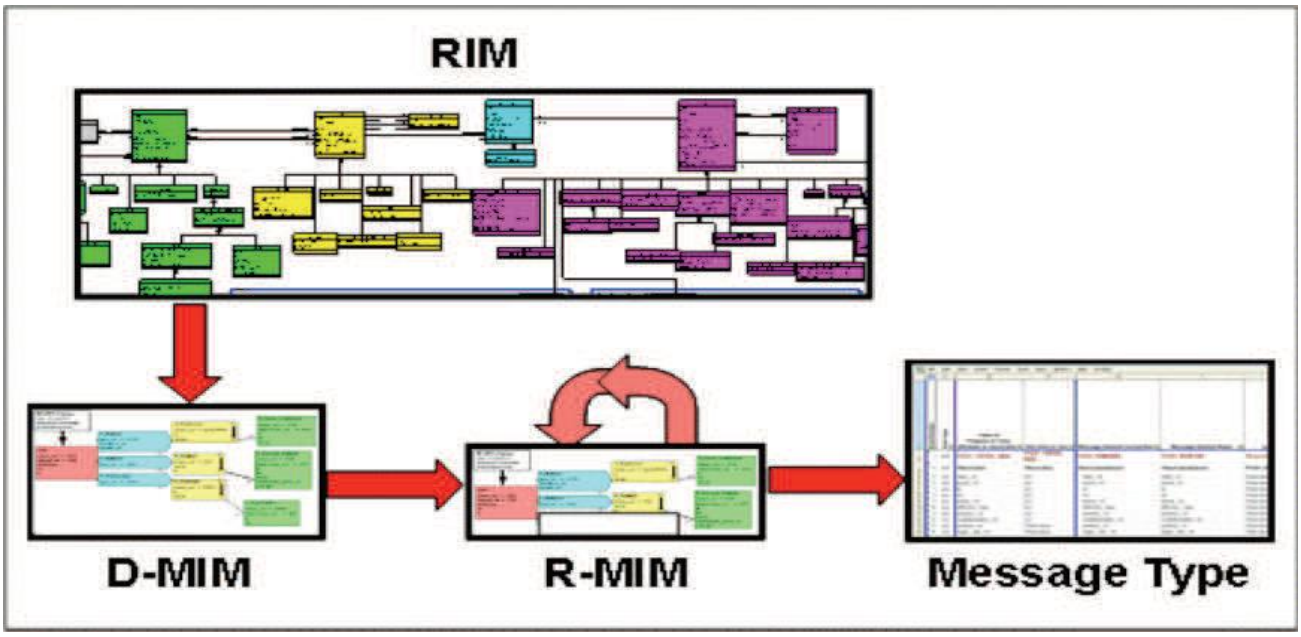

Figure2. 2Refinement process specified in HL7 methodology [35]

- **Domain Message Information Model (D-MIM)** is a subset of the RIM that includes a fully expanded set of class clones, attributes and relationships that are used to create messages for any particular domain (e.g., accounting and billing, claims, and patient administration)[35].
- **Refined Message Information Model (R-MIM)** is used to express the information content for one or more messages within a domain. Each R-MIM is a subset of the D-MIM and only contains the classes, attributes and associations that are required to compose those messages [35].
- **Hierarchical Message Description (HMD)** is a tabular representation of the sequence of elements (i.e., classes, attributes and associations) represented in an R-MIM. Each HMD produces a single base message template from which the specific message types are drawn [35].
- **Message** Type represents a unique set of constraints on message identification that are presented in different forms such as: grid, table, or spreadsheet [35].

2.5. Potential Power of Interoperability in the Hospitals

The potential benefit of improved electronic data exchange is wide-reaching and managing hospitals data with semantics results in cost-effective, easily accessible, accurate and manageable data processing solutions. Interoperability has the ability of two or more eHealth systems to share

information and information properly interpreted by the receiving system in the same sense as intended by the transmission system. Health care standards (like HL7), that allow communication of health care systems sharing of data around the globe. Some of the Potential Powers of interoperability are the following [33];

First, patient safety and clinical quality are improved, as systems bring medical record information to the point of care, integrate health information from multiple sources and applications, and integrate decision support tools with guidelines and research results.

Second, patients can gain access to their own personal health information in the Hospitals, which empowers them to better manage their health. Third, the public health system benefits from improved reporting of communicable diseases and real time aggregation of data for bio surveillance and detection of emerging disease patterns. Fourth, aggregating electronic billing and payment data will facilitate better understanding of healthcare costs.

Finally, significant potential financial benefit may accrue from decreasing human involvement in information exchange and reducing redundant procedures. Interoperability is powerful because it leverages current technologies, such as hospital information systems, pharmacy systems, EHR, and CPOE, to reduce costs and improve quality.

2.6. eHealth Applications in Ethiopia (LIS and EHR)

According to Blobel [20], there is no doubt that the way to high quality, safe and efficient health service leads to distributed cooperative care (shared care) supported by information and communication technologies and defined e-Health (electronic health) – has been coined to describe applications of information and communication technology (ICT) in the health care sector. Typical e-Health solutions are electronic medical records, applications in telemedicine, consumer health services (e.g., personal health records such as Google Health and Microsoft Health Vault), public health surveillance systems, and health decision support systems. Motivated by the assumption that e-Health interoperability will benefit patient care and increase efficiency of health services, developed countries worldwide have invested significant resources in the development of e-Health interoperability infrastructures [25, 28]. (HSDP-IV and HISS)[1], identifies and clearly stated a number of projects as an enabler for improving quality of health care, reducing cost on health service and increasing access, among all the designed and implemented e-Health systems, the

major once are laboratory information systems (LIS) and electronic Health record (EHR) systems [5].

2.6.1. Electronic Health record/ Smartcare (EHR):

Electronic medical record is a comprehensive national Electronic Health record (EHR) and reporting and analysis system, designed to enable better patient care, enhance efficiency and to make the reporting and analysis system more accurate, timely and effective starting from community health workers to health facilities, to the level of health facilities, Woredas, Zones, regions and Federal ministry of Health to see informed decision support and also enhance health information exchange and information use at all level of health care. In 2002 E.C., EHR implemented one hospital at Federal (St. Paul hospital), five hospitals in Addis Ababa region, two hospitals in Oromia and one hospital each in Dire Dawa and Tigray Regions [5].

2.6.1.1. Ethiopian EHR Features

EHR has most attractive features include the ability of Smartcare to personalize Patient's medical record by using EHR. EHR are pocket/credit card sized plastic cards embedded with an electronic memory chip capable of storing Patient's information. Furthermore, EHR are used as a means of exchanging a Patient's Medical data between different points of services in the absence of online communication infrastructure [5].

EHR has the ability to function in either as a distributed (standalone) or as a centralized (client/server) mode. The distributed mode is used in the absence of online communication infrastructure were EHR are used to transport Patient data between different points of services. Further in this mode, Smartcare provides database merges by using any electronic data storage and exchange (e.g. flash disks, CDs) methods across all points of service [5].

In the centralized mode, Smartcare hosts the database on a central server and using online communications infrastructures (LAN/WLAN, WAN), enables all points of services to obtain real time access to Patient's information. Smartcare is developed using an Industrial standard modular architecture [5]. This provides the added advantage for simultaneous and phased development of various components of the application, without affecting the stability and integrity of the application. Other features of Smartcare include Role Based Security, Data merging, import/export,

backup /restore and Touch Screen technology for easy and very user friendly interface [5].

2.6.1.2. Network Logical architecture for EHR in Ethiopia

The selected logical network architecture is a single subnet peer-to-peer 802.11g wired-backbone wireless network with multiple access point and switches as described in Figure 2.3 below discussed, the network system will support 10-50 wireless desktop computers spread throughout the facilities' main departments [5]. All the access points are strategically placed to provide a minimum of 25% signal strength, in order to assure quality data streaming. Signal strength boosters have been used as required to further ensure the minimum signal strength. Further, all access points are UPS backed to ensure the continuity of network services during short power interruptions. The Figure 2.3 below is the EHR Network Diagram for General Hospitals [5].

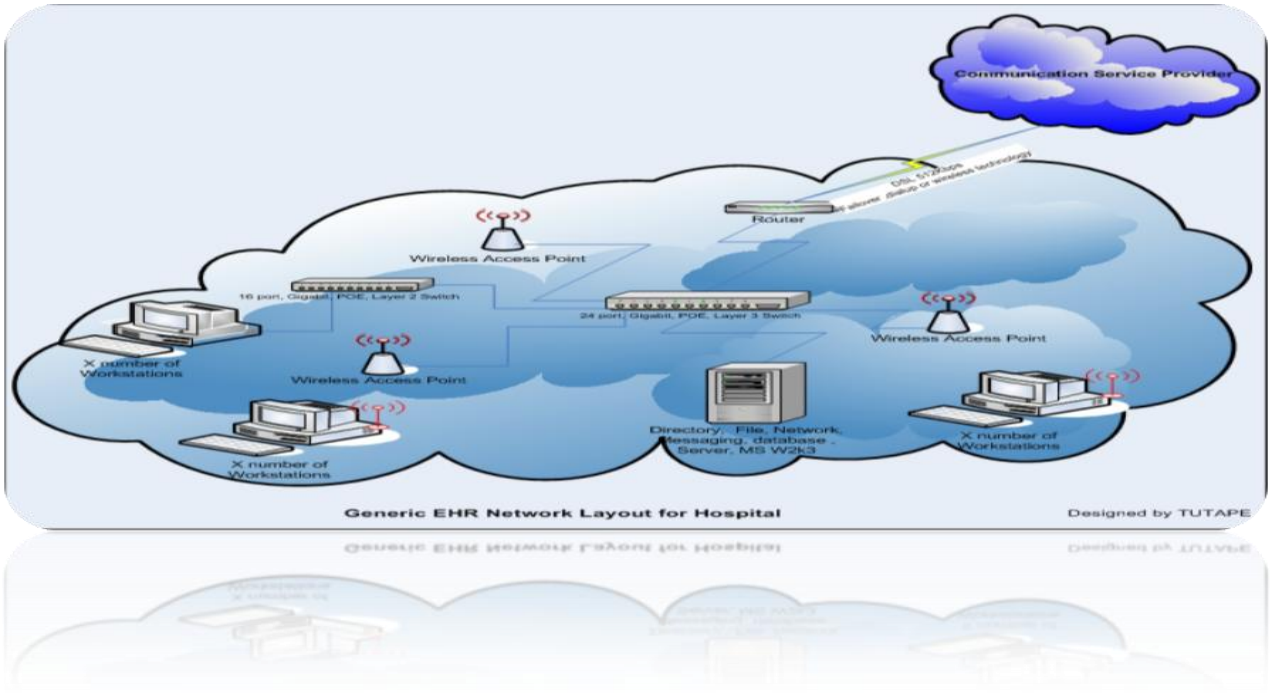

Figure2. 3Generic EHR System at the Hospital level

2.6.2. Laboratory information system (LIS)

Juncy [2]; defined laboratory information system (LIS) as a series of computer programs that process, store and manage data from all stages of medical processes and tests [2]. Physicians and lab technicians use laboratory information systems to supervise many varieties of inpatient and outpatient medical testing, including hematology, chemistry, immunology and microbiology. Basic laboratory information systems commonly have features that manage patient check in, order entry,

specimen processing, result entry and patient demographics. A LIS tracks and stores every detail about a patient from the minute they arrive until they leave and keeps the information stored in its database for future reference [2].

2.6.2.1. Ethiopian LIS Features

Laboratory Information System (LIS) is organized and implemented using the software called Comp Pro Med's designed by Polytech that is a fully featured, inexpensive Laboratory Information System that has all the features you want to streamline your laboratory workflow while being one of the easiest systems to use. Laboratory Information System (LIS) in Ethiopia supports work and information flow in all the steps of the laboratory testing process, including patient registration, test ordering, sample collection, testing, and reporting. This software organized by CDC Ethiopia and EHNRI[2] and implemented at 16 Regional laboratories, and two hospitals in Addis Ababa Hospitals [2]. Additionally, both the national clinical laboratories of Ethiopia use Polytech. Besides the CDC and two sub-Sahara African national reference labs; Polytech is also in use by Colorado State University Veterinary Teaching Hospital (the second largest Veterinary teaching institution in the world), Hawaii State Hospital, Mississippi State Hospital, Bronx Lebanon Hospital, University of Massachusetts and hundreds of critical care hospitals and Group Medical Practices (GMP) throughout the United States and Canada. The Figure 2.4 below show how the laboratory information system interface looks like and described how it works in the hospitals.

(2). EHNRI: the abbreviation stands for Ethiopian health nutrition and research institutions and it is mandated on establishing laboratories ,based on standards and serves as national laboratory for Ethiopian health sector, work on public health emergency .

Figure2. 4Overall laboratory information interface and architecture

In the above Figure 2.4 that show us the interface and architecture of LIS; mainly focused on the making the laboratory result more accurate and efficient by connecting LIS software to appropriate laboratory machine to make the laboratory results directly goes to LIS software [2].

2.7. Related works

In the previous literatures challenges eHealth and interoperability in data exchange were clearly stated then some of them provide eHealth road map and framework for their particular problems. Some of the previous works are discussed in this section.

World Health Organizations (WHO) [4], Recognizing that it is essential to make appropriate use of information and communication technologies in Health care to improve care, to increase the level of engagement of patients in their own care, as appropriate, to offer quality health services, to support sustainable financing of healthcare systems, and to promote universal access. The study deals with lack of a seamless exchange of data within and between health information systems hinders care and leads to fragmentation of health information systems, and realize the full potential of information and communication technologies in health system strengthening then propose through standardized electronic data: health workers can gain access to fuller and more accurate information in electronic form on patients at the point of care; pharmacies can receive prescriptions electronically; laboratories can transmit test results electronically; imaging and diagnostic centers have access to high-quality digital images.

According to Jalalkarim and Balachandran [36], clarify there are alarming barriers pertaining to eHealth applications development and implementations in particular to structure, contents and

communications. Standards are essential in communicating and sharing medical data between different applications. They also discussed barriers of connecting and implementing eHealth applications in the Hospitals: 1). adoptability of new systems and hence work procedure by doctors, 2). cost which need to be adhered through healthcare savings, governments, and motivations, 3). connecting vendors who need to be pressurized to make interoperable systems and 4). Standards that need to be set ensure communication and set catalysts to pursue them. The method used in this study mainly theoretical in nature with qualitative study that deigned in to three phased approach: 1st phase: described and explain the meanings and functionalities of eHealth applications as well as to understand the barriers. 2nd phase: understands the structures and deign. Once it was pinpointed that the main barriers in eHealth applications is interoperability, the next aim/phase of this paper was to assess how to bridge the gap by assessing interoperability solutions.

Abere et al [11]; stated that efficient service delivery and quality of data exchange depends on an integrated solution which is the result of coordination among eHealth applications and important to propose the required system's ability in information exchange, communication with other system.

Fun et al. [37]; have presented a conceptual model for information exchange in electronic (or digital) government infrastructure in our case like hospitals infrastructure. They figured out that application to application (A2A) information sharing model will aid in collaboration and understanding for the A2A information sharing and will assist the decision makers. They tested the proposed model by creating interoperability as a middleware.

Begoyan [18]; have presented interoperability standards for Electronic Health Records and described Models in five parts: first; the reference model mainly creating a model that described building blocks of EHR by representing the global characteristics of Health record components. Second; Archetype interchange Specifications that the wide scale sharing of EHR records and their meaningful analysis distributed computing sites requires that the equivalent clinical information represented consistently. Third; Reference Archetypes and Term lists that mainly addresses data objects for describing rules for distribution or the sharing of EHRs in whole or part by establishing general principle for the interaction of EHR with other components and mechanisms within EHR applications. Finally; Exchange model exchange model that presented message based and service

based models and HL-7 proposed a best for data exchange standards by describing each versions. (V-1.0 up to V-3.0)

Grabenweger and Duftschmid [38]; have presented a level of interoperability in two forms that is syntactic interoperability that guarantees the exchange of the structure of the data and semantic interoperability is the ability for information shared by systems to be understood at the level of formally defined concepts. They also clearly stated methodology that adopted from other researchers technical management information model and mainly contain four steps: 1st. planning of the analysis: render more precisely the aim of the system analysis, definition of the problem area and planning of the implementation of the analysis. A list of criteria to compare the different applications will also be a part of the planning of analysis. 2nd. Acquisition of information: in this thesis, acquisition of information will mainly be based on document and literature analyses. 3rd. Modeling: suitable representation of the results of the acquired information based on informal, semiformal or formal methods. 4th. Verification: reassessment of the generated models in consideration of correctness, completeness and adequacy. The reassessment shall be done in the course of verification sessions, where experts from the domain of EHR modeling will play the role of the evaluators.

Lorie Obal and Frank Lin [39]; have presented as many factors are driving an increased need for interoperability in medical information systems that Problems include: the growing cost of storing paper based records as required by law and double entry required at interfaces between electronic medical equipment and paper records. With little in the way of architectural guidance, systems developers are breaking new ground to design these systems. It may be necessary to re-examine the core process of architecture development in order to capture the diversity and evolutionary aspects of these systems. They also stated another literature was used to develop a meta-analysis to identify key problem concepts in large health records architectures. The review was conducted with articles on EMRs and Systems of Systems Architectures. Due to a lack of public information on large EMR architecture implementations, publicly available reports on US Government systems integration progress were included because they illustrated Secretary of State's development issues. An examination of these projects revealed massive failures in implementation as well as multibillion dollar losses in these systems. These failures lead to the drafting of the Clinger-Cohen Act (CCA)

in 1996 as a means of enforcing accountability in government IT projects. The methodology they used literature was reviewed to identify common issues which were then flagged and tabulated to discern possible issues and patterns. A sample group of 27 articles comprised the basis of the initial concept development. The articles were chosen by titles that indicated they focused on healthcare systems and large systems of systems. These articles were read in-depth and formed the basis for the keyword list. Keywords were chosen based on their relevance to healthcare systems and large systems of systems. In order to be chosen, a keyword was used by an author as a prominent systems concept within the article as opposed to being mentioned in passing

Zöllner and Caroline [40]; presented the interoperability between independent systems, to enable compatibility and consistency for health information and data, as well as to reduce duplication of effort and redundancies in the case of Germany public Hospitals and adoptedHL7 messaging standard that is used for the exchange of medical information between different communicating parties or devices. The most commonly used versions of HL7 are HL7 V2.xand HL7 V3. HL7 V 2.x is mainly focused on the transfer of message from sender to the receiver rather on interoperability. HL7 V3 focused on the shortcomings of HL7 V2.x and overcome those by targeting semantic interoperability. HL7 V3 is based on the standard model called Reference Information Model (RIM) that is very important for data exchange in Health services.

CHAPTER THREE:

METHODOLOGY

3.1. Study Design

This study was done at organizational level and qualitative research methods were used. On the study an exploratory research approach and a constructive method were applied to address the data exchange interoperability issues and to propose a data exchange framework between LIS and EHR.

3.2. Study Area:

The study was conducted from March to May, 2013 in Addis Ababa regional state. It is the capital city of Ethiopia which has 10 sub cities. There are 12 Public Hospitals, 37 Health Centers in Addis Ababa [12]. Electronic Health Records system (EHR) has been implemented in 10 hospitals and 26 health centers. On the other hand laboratory information system (LIS) has been implemented in 2 hospitals (Zewditu Memorial and St.Paul Specialized hospitals) [5]. This research is conducted on the two Hospitals (Zewditu Memorial and St.Paul Specialized Millennium Medical College Hospitals) that have been implemented both eHealth applications (LIS and EHR) in Addis Ababa regional state. The overall eHealth applications has initiated by the Federal Ministry of Health in collaboration with TUTAPE, and CDC. See below in the Table 3.1 the background of the LIS and EHR in Hospitals.

Table 3. 1Description of the study area

	St. Paul	Zewditu
EHR	EHR was implemented in 2003 E.c. the first phase of the implementation started from Medical Record Unit (MRU). Then with six months of time all the service delivery points including the laboratory section and Pharmacy units have started using EHR. In the process a total of 40 professionals were trained on how to use the system and for each service points computers were provided by Tulane University Technical Assistance People of Ethiopia (TUTAPE) including the established data centers (Server Room).	EHR was implemented in 2003 E.c. the first phase of the implementation was started from Medical Record Unit (MRU). Then with six months of time all the service delivery points including the laboratory section and Pharmacy units have started using EHR. In the process a total of 26 professionals were trained on how to use the system and for each service points computers were provided by Tulane University Technical Assistance People of Ethiopia (TUTAPE)
LIS	LIS was implemented in 2003 E.c in St.Paul specialized. This was the pilot sites in Addis Ababa. 2 no of Laboratory professionals trained in both hospitals. 4 no of computer distributed in Hospital in the laboratory sections. Other accessories like printers were provided that make the laboratory service more effective and efficient. The LIS is only system in the hospital working in the laboratory section just to connect the laboratory machine to the computer. That make the laboratory system, reducing errors during writing and	LIS was implemented in 2004 E.c in Zewditu Memorial hospital. This was the second pilot sites next to St. Paul specialized hospital. 2 no of Laboratory professionals trained in both hospitals. 4 no of computer distributed in Hospital in the laboratory sections. The LIS is only system in the hospital working in the laboratory section just to connect the laboratory machine to the computer. That make the laboratory system, reducing errors during writing and reading from the machine and the lab-technologies read the lab-result

	reading from the machine and the lab-technologies read the lab-result from one computer and fill the lab-form the in the EHR, laboratory module to send the lab-result to the physician from the any service point in the Hospital.	from one computer and fill the lab-form the in the EHR, laboratory module to send the lab-result to the physician from the any service point in the Hospital.

3.3. Study population

The source population was selected from three different groups. The first group consists of User of e-Health applications (EHR and LIS) and ICT support staffs of the two Hospitals. The second one is consists of e-health experts form FMOH (PHID and PPD who are fully involved on the e-Health project). Finally, software developers from partners (TUTAPE and CDC) which had developed and deployed the e-Health applications (EHR and LIS)

3.4. Sampling Techniques

Purposive sampling techniques were used to select the study population. This is due to the problem to access the experts in the study area during data collection at Hospitals and FMOH levels. Moreover in the process of data this study, few informants informed me to directly contact experts who would supply important information for the study. Initially, the study was divided into three categories: system user, project owner and eHealth application developer. The eHealth application users were St. Paul Specialized and Zewditu Memorial Hospitals which were the only hospitals that have implemented both EHR and LIS application; the project owners were at FMOH domain experts from the two directorates (Planning and Infrastructure) who were responsible for all eHealth initiatives as stated in the BPR document. The eHealth software developers are from CDC and TUTAPE who fully participated in designing the applications.

3.5. Sample Size

A total of 12 individuals were purposively selected based on working experience on using LIS and EHR at least more than one year then interviewed. A total of 12 individuals from study population, who are working more than one year from FMOH and Hospitals allocated as a sample size; St. Paul hospital (3), Zewditu Memorial general Hospital (3), CDC (1) , TUTAPE (1) and FMOH (PHID and PPD) (4)

3.6. Data Collection Procedure

Primary data were collected through qualitative methods using structured and pre-tested interview questions which was adopted from different previous research and developed by the investigator. The data was collected by interviewing eHealth application users, decision makers from hospital and FMOH as well as developers of the eHealth application from TUTAPE and CDC. The questionnaires were prepared in English. Moreover, one eHealth expert was assigned to test interoperability issues on LIS and EHR software system. The expert was used domain level interoperability standard software application testing checklist that have been developed by investigator and then the investigator were conducted an assessment on the eHealth applications (LIS and EHR). Secondary data were collected through reviewing of relevant documents and literature. See the interview questions in appendix (I, II, III, VI, and VII)

3.7. Interview

We conducted semi-structured interviews with open-ended questionnaires to the source of the population that include ICT support staffs at the Hospitals (ICT support technologist), eHealth experts, application developers, and users of the system (Electronic Health Record and Laboratory technologists/technicians). Twelve individuals were interviewed to understand the issue on data exchange challenges and recommendations between LIS and EHR application. In designing our interview questions, we borrowed from EMR software assessment checklist developed by FMoH. In addition, we used Azam and Hussain [7] study questionnaires to frame the interview questions. The modified questions were grouped into four categories that have been identified in the literature and problem areas. The questions that were used in the semi-structured interviews and the interview questions were attached at the appendix (I-VI). The first draft was presented to two experts on eHealth application at Government and Non Governmental Organization (NGOs). The refined draft was presented to three experts from different specialty areas. The experts provide comments and feedback that helped us refine the questions used in the study.

3.8. Application functionality Testing Criteria

Based on the collected criteria from the literature [1, 7], Application functionality testing was conducted to test the different functionalities of software for interoperability. It included reviewing the basic functionalities, requirements, integrity and interoperability of the software; and the standard applied for the development of the system. The software application testing checklist was attached in appendix IV.

3.9. Document review

Extensive review and close examination of literature, journals and documents dedicated to data exchange, eHealth, policy, strategy, and standards were conducted to triangulate the research findings. The system analysis documents of both eHealth application papers were reviewed to have better understanding of the subject matter that affects design, management, implementation and utilization of eHealth applications combining the review of subject area documentation and other data and the literature review provided understanding of the current operating environment of eHealth applications, providing different perspectives of potential factors they could impact the data exchange success.

3.10. Data Quality Control

The quality of data was guaranteed by proper designing and pre-testing of the standard questions. The pretesting for questionnaires was conducted on Federal Ministry of Health and some other Hospitals in Addis Ababa. The data questions were designed based on data collection technique employed by other as indicated in the related works [1, 7].

3.11. Data Processing and Analysis

All the interview questions were recorded and coded then entered into INIVO-10 software packages for analysis. The results were presented in the form of tables and finally data exchange framework will be proposed.

Steps to be used data processing and analysis

1. The response of the entire respondent entered in to the NVivo 10 software.
2. create main nodes based on the interview
3. put all related answers in to the node
4. Analyze the response by using quarry most frequently used words.
5. Create linkage of all words from all respondent answers.

3.12. Plan for Data Dissemination

The finding of the study will be disseminated to concerned bodies like decision makers at FMOH, development partners and Hospital manager. Furthermore, to make the findings available to a wider audience, an effort was made to publish the results of this finding on e-health journal.

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter was organized and presented in to two forms. Ones analysis of key informant interviews from FMoH, software developers, users of the systems and then, application functionality testing for both LIS and EHR to identify interoperability options. The interview respondent's demographic profiles were discussed in the table 4.1 below:

Table 4. 1Respondents Demographic Respondents

Name of institutions	Participants Age Range	Department Name	Positions
FMOH	27 – 38 years old	Health information Technology Team	eHealth experts
EHNRI	34- 37 years old	IT departments	LIS focal persons
St. Paul Millennium Medical College Hospital	27-37 years old	Laboratory technologist and IT experts	Laboratory and IT Heads
Zewditu General Hospital	25-34 years old	Laboratory technologist and IT experts	Laboratory and IT Heads

4.1. Results organized from interviews

The result was organized from 12 key respondents that mainly contribute to figure out the findings on the perspective of data exchange interoperability. The issues raised in these interviews are summarized into thematic areas. Those thematic areas were organized based on the respondent's answer that most frequently words used identified. The most frequently used words are list in Annex VI.

4.1.1. National eHealth Applications Status

Six key respondents out of twelve participants were interviewed: four from FMoH (eHealth experts in particular for EHR focal person and monitoring & evaluation experts) and two of them from EHNRI- (LIS project manager and system implementer). The Respondents clearly stressed that, there are ten eHealth applications exist at national level. The respondents also focused that Most of eHealth applications are not supported by national eHealth policy and strategy that linked with the national Health policy and ICT policy. They suggested that overall managements of eHealth applications should consider harmonization and alignment such as creating strong monitoring and evaluations system; avoid duplications and redundant eHealth initiatives at Hospitals levels. They also stated that, there is a draft eHealth Policy and Strategy designed by FMoH. The draft document should be finalized and workable in order to make effective and efficient data exchange interoperability.

There is also another issue raised by the respondents, there is five year strategic plan document in FMoH that integrated some of eHealth applications known by FMoH in the documents and its is working as working documents instead of eHealth policy and strategy. The eHealth policy and strategy create harmonization and alignment for all eHealth applications in the country. Finally respondents stated that because of the absence of eHealth policy and strategy or any monitoring and evaluations system most partners implemented eHealth projects in Hospitals by their own without asking recommendations from FMoH just by simply making negotiations with Hospital managers.

4.1.2. Design of EHR and LIS Applications

All respondents agreed that no single expert from the ministry were involved in the design and development of both LIS and EHR applications; nevertheless some officers were given training and participated in the implementation process such as network installation. Some experts explained that both EHR and LIS applications are technically sound and well designed; but some limitations still exist. They also said that, EHR is designed based on the clinical work flow of hospitals and EHR software divided in to five module: in the entry point there is registration module which capture patient demographic data and send to the appropriate department based on the patient's type of complain; then the physician will enter required data to the respective OPD module and other services in the Hospital and fill then send laboratory and drug request on laboratory and pharmacy

module respectively (if any); the lab result will be send back to OPD from the laboratory. Opposite idea was raised by two respondents, that health system is very complex and multidisciplinary in nature, thus it requires detail analysis before the design and development of eHealth applications with the involvement of clinical staffs.

From the developers' side, Tulane University and CDC were asked about the technologies used; they reported that, both applications are developed using C# and backend SQL data base. Most of the designed attribute and data type are the same but exist in different naming and styles.

4.1.3. Challenges and Recommendations on the usage of LIS and EHR

The experts at the ministry agreed that there are main challenges and recommendations on LIS and EHR, particularly on data exchange at Hospitals in relation with the FMOH plans and decision making processes. Table 4.1.below describes the main challenges and recommendations raised by eHealth experts.

Table 4. 2Challenges and recommendations of eHealth Applications

Main Challenges (LIS and EHR)	Recommendations (LIS and EHR)
Lack of interoperability between LIS and EHR; create fragmentations and data redundancy on between LIS and EHR.	Design and implement National eHealth policy and strategy with clear understanding of existing eHealth applications implemented in the Hospitals
Both applications managed by partners and called donors driven	Creating ownership at hospitals and avoid name donor driven by creating institutional and local capacity.
Lack of technical support on LIS and EHR at the Hospitals.	Propose one virtual team for strong support and controlling eHealth applications and for monitoring and evaluations of applications
Lack of awareness creation on LIS and EHR	Increase the involvement of users on the Hospitals during the design and implementation and also

Lack of ICT professional and poor management system in the Hospitals	Creating ownership at hospitals and avoid name donor driven by creating institutional and local capacity
Frequent power interruptions on hospitals that affect the EHR applications crate problems like backlogs and return back to paper based.	Provide alternative power source for hospitals

4.1.4. Data exchange and Interoperability in the Hospitals

The LIS and EHR users indicated that the data exchange issue considered as one of the major problems in the hospitals and also described as follows, the TUTAPE and CDC were implemented EHR and LIS applications respectively which are operational in laboratory to enhance the laboratory activity. However, applications create duplication of effort and burden for the laboratory technologist, because of poor communication between the two applications. The respondents also described how the LIS and EHR system communicates in the Hospitals.

The respondents recognized that, the physician uses the EHR application and sends the laboratory order with shared demographic data (Name, Age, Sex, address, and etc). Then the Laboratory technologist recorded in to LIS application for laboratory examination. However, the laboratory technologists should transfer the data from EHR to LIS manually as the laboratory module in the EHR and LIS don't interface in many ways, such as data naming style, data type, data format in general data structure. This is due to incompatibility that exists between EHR and LIS to handle laboratory cases.

The respondents also indicated that because of delay in EHR and LIS applications create problem in service delivery, increase health care cost and proposed interfacing. Integration and interoperability are proposed as the best solution in the Hospitals that the respondents acknowledge LIS and EHR are important enhance the hospital system to facilitate the service delivery. However, Lack of interoperability between LIS and EHR; data lost, fragmentation are the main challenges.

The respondents stated that one of the possible causes of the delay in service delivery, increase patient waiting time and reporting system. In order to identify the major issues on data exchange and it is important to discuss in to two categories based on the perspective of users and ICT support in the hospitals.

4.1.4.1. Hospital ICT Support Staffs on LIS and EHR

In both systems (LIS and EHR), ICT support team agreed that they didn't know about LIS application but they were trained about EHR and work as a system administrator. They stressed that, there is continuous workload in the laboratory sections. Moreover, laboratory technologist couldn't enter patient data on time because of that EHR was currently being terminated and users turn into paper based communication. But the situations falls to reduce duplication reduce cost and unnecessary error during patient to doctor interaction.

ICT support team also reported that beside the advantage of both systems. However, Hospitals didn't have sustainability plan for future expansion and maintenance for system failure. They assume that those things are the donor responsibility.

Finally the ICT support technologist clearly figured out the main challenges and their recommendations were depicted in Table 4.2 below.

Table 4. 3Challenges and Recommendations Raised by Hospitals ICT Team

Challenges	Recommendations
Lack of awareness creations among physicians towards EHR applications	Awareness creation to all physicians and health professionals towards eHealth applications.
Power interruption that affect LIS and EHR applications	Provide alternative power source for eHealth applications in the hospitals
Slow network connectivity and slow performance.	Increase the performance of the applications.
Lack of basic computer skills and lack of on the job training on LIS and EHR	Provide on the job training for all users in the hospitals and continuous follow up.
Lack of system maintenance equipment's (power outlet, swatch, wireless devices and cables)	Design plan for sustainability and consistency of the system.

4.1.4.2. Laboratory technologist towards LIS and EHR

Laboratory technologists clearly discussed the issue towards LIS and EHR applications from the perspective of four categories: I) Training, II) Utilization, III) Major issues in data exchange, IV) Challenges and Recommendations

Training: The laboratory technologist stated that they were trained on both LIS and EHR applications from CDC and TUTAPE experts starting from basic application training up to a master trainer and system implementation focal persons in both Hospitals. However, no one involved in the design and implementation of the applications and the training time was very short and not enough; the implementers gave training for 3 days and 1week for EHR and LIS, respectively. In addition to that, there are also guidelines and user manuals for both applications in the hospitals and they always refer those documents on daily bases.

Utilization: The laboratory technologist at Zewditu Memorial Hospital mainly stressed that they have used EHR application for 2 years and no more use it now because of hospital building renovation created damage on EHR network system. However, LIS application was in promising result than EHR in the laboratory activities.

On the other hand, laboratory technologist at St. Paul Specialized and Millennium Medical College Hospital stated that they have been using both EHR and LIS applications since from 2003 E.C and 2004 E.C respectively. The laboratory technologists also explained on how to use the LIS and EHR applications in the Hospitals on the perspective of data entry, data analysis and reporting systems. The laboratory technology also indicated some of challenges that hinder data exchange between LIS and EHR which create duplications of effort and workload for laboratory technologists. We can discuss in two ways:

> "For EHR, there are five EHR modules in the hospitals which are liked with services such as OPD, Pharmacy laboratory and Registration. The EHR-LIS module help to facilitate the laboratory activates and create linkage with other service areas. EHR-LIS module gives all patient demography data and laboratory orders come through EHR laboratory module. However, the EHR-LIS shared all the demographic data and laboratory requests to LIS systems then LIS systems created barcode for the sample then after diagnosis finalized the result printed and go back to OPD and also entered in to EHR- LIS module and send to the physicians."

> "There are two ways in data entry for LIS applications that were designed based on the nature of the laboratory service and laboratory standards instrumental (like microscopic diagnosis), one way is enter data in to the software by reading the instruments. The other one is machine interface with LIS applications that is able to read the result from the machine automatically then the laboratory technologist verified the result and finally printed the result"

Major issues in data exchange: the respondents figured out, data exchange between LIS and EHR applications is an issue in the Hospitals and identified some of the challenges that may create any disturbance such as dissimilarity in attribute naming. They also identified that, standards are very important tool for data exchange.

The respondents compared the standards used on EHR and LIS applications while LIS applications designed and developed based on laboratory standards like International laboratory standards, American laboratory standards and national laboratory standards of Ethiopia. Whereas, EHR module not well designed like LIS for the laboratory services which is missed some laboratory quality issues in Laboratory. They also suggested the EHR application was designed for OPD and other service points except laboratory. They also stated that EHR incorporates clinical standards like international classification of Disease (ICD-10) and other national standards like HMIS that is important for Health service delivery in the hospitals.

The laboratory technologist were recommended that it will be good if there is means to connect both applications and working in as one application in the Hospitals. They also stated some standards used during design and development of the LIS and EHR that the table 4.3 below discussed the standards used on LIS and EHR applications.

Table 4. 4Standards used in both LIS and EHR

Standards used		
LIS	**EMR**	**Remark**
Clinical standards like ICD 10 and other	International disease list (ICD-10) and HMIS new reform	Each applications have their own focus area: EHR mainly focused for OPD and other hospitals services and LIS for Laboratory
HL7 V3 for data exchange	NO	Plan to use HL7 V3 for data exchange with LIS system
Laboratory quality control standards	NO	

The laboratory technologists also identified that workload; errors in writing results and resource wastage paper are the main challenging issues in the laboratory and also stated possible recommendations to overcome the above gaps on data exchange by considering interoperability as the best ways to make linkage between the LIS and EHR applications.

The laboratory technologists recognized that issue of data exchange is their day to day challenge in the laboratory. Table 4.4 below discussed main challenges and their recommendations in data exchange in the Hospitals

Table 4. 5Main challenges and recommendations in data exchange

Main Challenges	Main Recommendations
There is workload in the laboratory because of lack of interoperability between LIS and EHR	Developers should consider the applications interoperable and interfacing.
Network and power interruption that create delay in Health service such as delay in searching patient profile, laboratory order etc.	
Lack of barcode printing paper, result lost, transcription errors because of manual work	

4.2. Application functionality testing for LIS and EHR for interoperability options

In this section the functionality are tested based on the criteria set as discussed earlier in the methodology section. Investigator figured out the major challenges on data exchange interoperability by testing basic LIS and EHR functionalities then identifying the data exchange interoperability options between the applications. The application functionality testing checklist is attached in the Annex VIII.

4.2.1. Data entry

Both applications (LIS and EHR) were developed in different software interface form, attribute name and different style on data entry, but both considered the paper based system in the hospital. Besides through there are differences in attribute name, both applications have similar meanings and data types that may create confusions for laboratory technologists

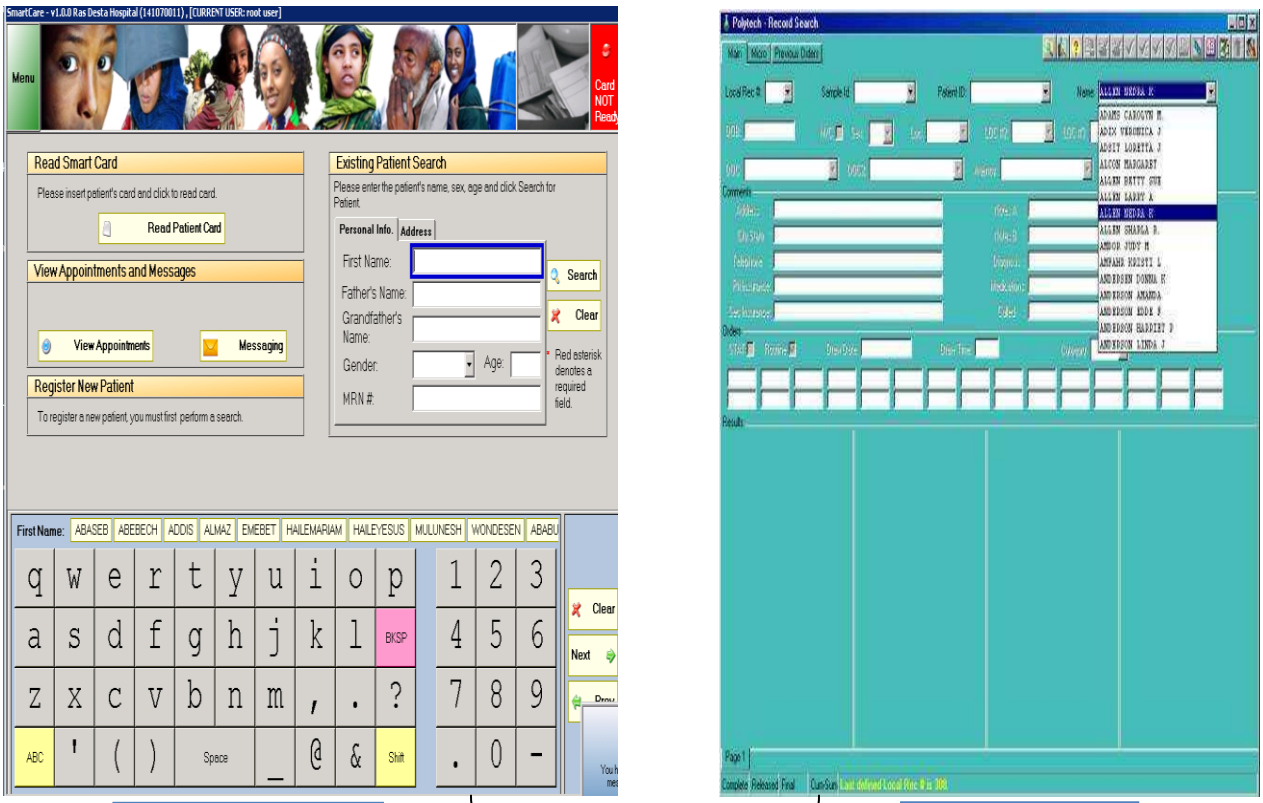

Figure4. 1: Data entry format

Table 4. 6Data entry main issues on EHR and LIS applications

No.	EHR Applications	LIS applications
1	As compared with LIS application with EHR which have some challenges in the laboratory: - It is not designed based on the standards laboratory request - It doesn't indicate instructions, Normal values.	All the data entry attributes the same as paper based systems. The laboratory order and result organized based on national clinical standards, user-friendly compared as EHR in the laboratory easy entry Dropdown list. Level the normal value and strong error directions mechanism
2	In EHR data entry, user interfacing not easy formatted for the laboratory technologist. Lack of validation mechanisms.	Easy data entry format understood by laboratory technologists. Standards validation rules were integrated including an option recheck again and again.

Note: **Sample ID** and Some other laboratory attributes are the important attributes exist that only in LIS and generated automatically after registrations.

4.2.2. Laboratory Request Order Entry

Only EHR application allows the physicians to write laboratory orders that make a linkage between EHR-OPD module and EHR-laboratory Module through electronically. The EHR-laboratory module and LIS applications only works at laboratory section; however, there is a space in both applications to writing all the necessary data. LIS system only start working at the laboratory sections so no LIS software in other service points and not allowed to write and send in electronic formats. In this case the laboratory technologists write copy the laboratory order from paper based to LIS software. The LIS automatically diagnosis the result and send in paper based.

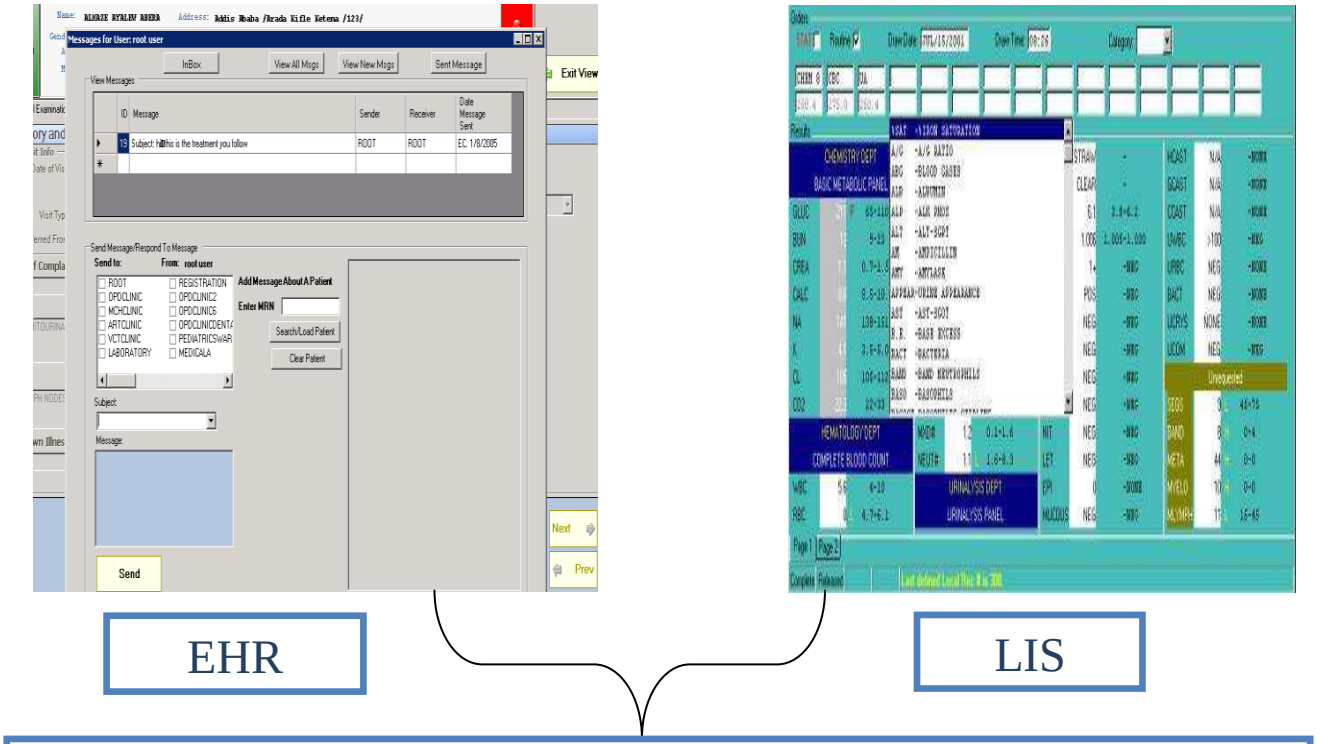

Figure4. 2: Laboratory order form

Table 4. 7 Laboratory Request Order Format

EHR Applications	**LIS applications**
All the laboratory orders come from the physicians electronically and goes to laboratory and editing note is allowed for the laboratory technologist on laboratory order	All the laboratory orders come from the physicians on paper based and laboratory technologist register the lab-order to LIS software.
Null	After registering patient's demography information and laboratory order the LIS automatically generates Sample ID and Print the Sample ID. Then after, the laboratory technologist tagged the sample ID in to real Sample.

Attribute field size and data type don't have validation rules e.g. RBC….. 1280000 (Big Number)……. Accept without giving any alert and in some functionality give alert but if you save will accept.	All the attributes and data types clinical laboratory standards laboratory and also the application designed with some features like Good validations mechanisms like not accepted and color indications. That applied both forms of result data entry. There are two ways of data entry in LIS - Manual Data entry with after diagnosis for microscopic or instrumentals diagnosis like Malaria - Automatically Data transfer to LIS software for machine based diagnosis interfacing with the machine and directly pull the lab result like Hematology and serum Chemistry

4.2.3. Laboratory Result entry and Display

Electronic Health Record (EHR): in this case the result of the laboratory order come through laboratory technologist by simply reading the result from the machine & instrumentations and writing to the EHR software if there is any unexpected result occurred, the laboratory technologist order the laboratory before send to Physician after conformations. They were sends the result to physician, no validation rule is processed because of the manual work.

Laboratory Information's Systems (LIS): the result comes in two ways: the first, to enter the data from instrumentation based like microscopic result and validate the result then entered manually to LIS software that is called manual system. Second, LIS software automatically collect result that means the machine and LIS software interface each other and the result can directly be displayed without data entry. Before sending to the physicians, the laboratory technologist

rechecks again for validating the result and requests multiple laboratory orders without any data entry errors.

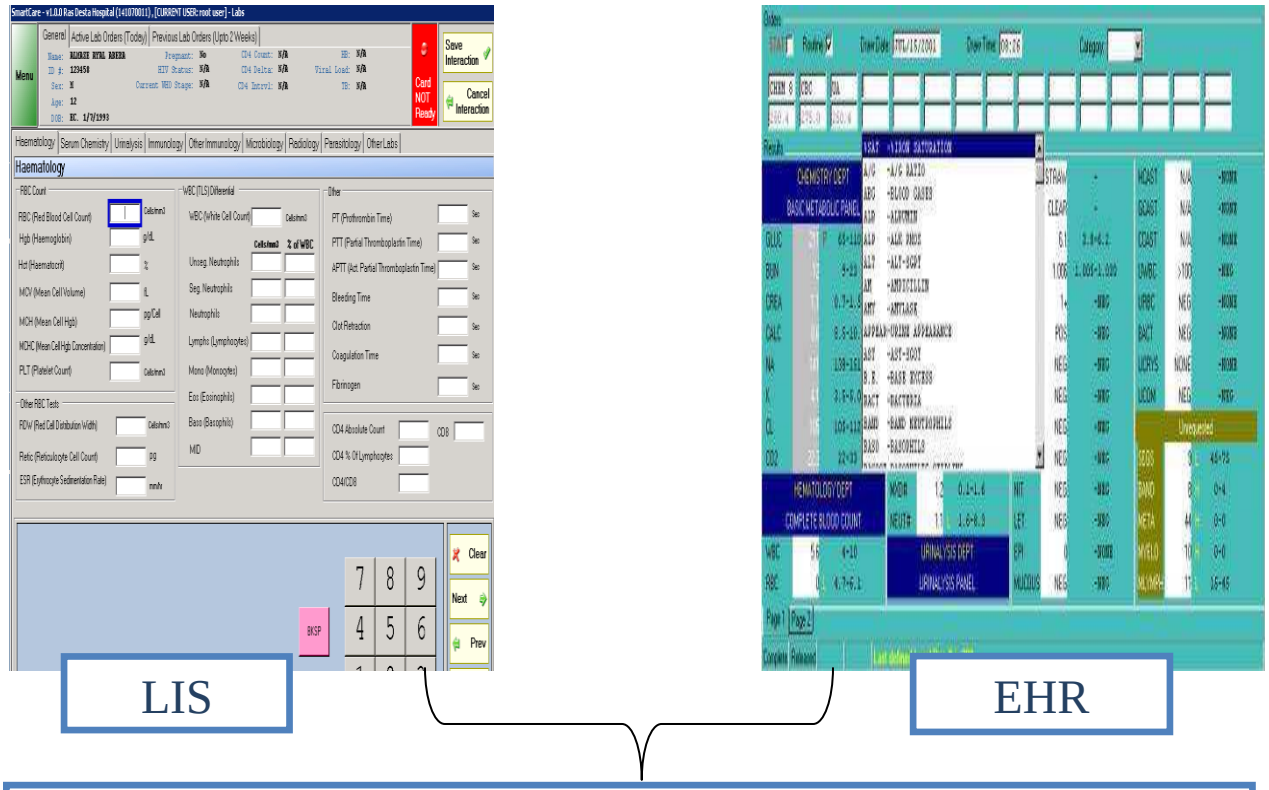

Figure4. 3: Result displayed and result entry format

Table 4. 8Result displayed and result entry format

EHR Applications	LIS applications
All the laboratory result checked by laboratory on tally sheet and expected to send by writing the result in to LIS modular software and finally send the result to the Physicians	All the laboratory results checked through interfacing with machine and another one is instrumental checking like microscope and write in to LIS and send to physician
result goes electronically in the hospitals	Result in print out format from EHR
All attributes are equivalents to what is ordered	All attributes are equivalents to what is ordered

4.2.4. Strength and Limitation application of functionality

4.2.4.1. Strength

- ✓ LIS Application are designed based on laboratory standards but EHR not
- ✓ All laboratories order attributes were well designed and exist in both applications compared with paper based.
- ✓ Both systems enable easy to access to the list of laboratory tests (all laboratory order list exist as compared with the paper one)
- ✓ Ability for system expandability and interoperability.

4.2.4.2. Limitation

- ✓ Lack of laboratory standards only for EHR application
- ✓ The EHR system was slow to retrieve data but LIS system relatively fast in the laboratory system.
- ✓ EHR system have too many laboratory orders because disease list used the full ICD 10 is loaded with out customization
- ✓ The EHR has low error detecting capability which includes: it doesn't alert physicians if they prescribe overdose drugs, it doesn't detect if 40 years old patients assigned to pediatric clinic, the field size is not limited, etc.
- ✓ The attribute existed in LIS occurs in EHR in different name but similar meaning
- ✓ EHR doesn't show the normal values of laboratory result for the physicians

4.3. DISCUSSIONS

This study tried to investigate on eHealth applications (LIS and EHR) particularly those complemented in hospitals in Addis Ababa. No previous study has been conducted, which deals with data exchange interoperability between LIS and EHR in Health institutions. The study reports new information on the data exchange interoperability challenges and recommendations. Interview result of the study is compared with both the result of application functionality testing and also the studies made in the rest of the world.

As shown in the results section, this study focuses on results of both applications functionalities testing and compiled challenges & recommendations on data exchange interoperability from the users, decision makers and eHealth experts towards eHealth applications in particular LIS and EHR. The study identified issue of data exchange at national eHealth applications, standards used on LIS and EHR. The discussions are presented as follows:

4.3.1. LIS and EHR Software functionality testing

The study finding in the table 4.5, EHR and LIS application functionality testing is aligned with previous study results in the eHealth applications such as lack of interoperability and fragmentations of software applications that create increase cost of Health care. The literature reviewed are few mention to align with the results and also suggested interoperability is the only options that cost-effective and secure use of information and communications technologies in support of health and health-related, real life challenges involved in moving a data exchange system from the less interoperability or no interoperability among heterogeneous applications than more interoperability [16, 32].

As clearly stated in result section 4.1.2, supported by the previous literature on EHR; it is expected to reduce patient waiting time by decreasing the time elapsed to search records, to document, transfer investigation results and to communicate between sections through another applications LIS, That is because the LIS designed for process, store and manage data from all stages of medical processes and tests [2, 30]. The result also shows, the major issue that the two applications make difference was in their objectives, EHR designed for entire Hospital activity including Laboratory and major concern about treatment of patients that may lack laboratory activity which was sensitive for laboratory section and LIS applications addresses all the laboratory activities

including machine interfacing with automatic diagnosis system that make better (Stated Section 4.1.2). But both applications play important role in the Hospitals and most of the respondents agreed that creating interoperability between LIS and EHR is very crucial.

In section 4.1.4, the study shows timely data entry in the Hospitals that interoperability has a potential power to solve challenges on data exchange among LIS and EHR by improving data exchange in wide-reaching and managing hospital data with cost-effective, easily accessible accurate and manageable data processing solutions [33].

The Study finding in table 4.6, on LIS and EHR applications functionality testing which indicated the dissimilarity of attribute field size and data type but the same descriptions and meaning that may hinder the data exchange among applications. The previous studies show us there is such kinds of challenges exist Abu Dhabi [36] by identifying the major barriers in the data exchange that is the same as result shown in table 4.6, they propose standards like HL-7 and interoperability as best solutions. Finally, In order to overcome the challenges making Healthcare information systems interoperable will reduce cost of Health care and will contribute to more effective and efficient patient care [2, 10, and 30].

4.3.2. Data Exchange between LIS and EHR and its Interoperability

According to laboratory technologists (section 4.1.4.2); lack of data exchange interoperability between LIS and EHR were leads to another solution in the laboratory section. According to the literature [2, 3, and 10], "interoperability creates linkage among two or more applications that facilitate the data exchange process in the enterprise". And also there is a previous study which indicated the semantic interoperability options in data exchange are the best solution [18]. Semantic interoperability issues, the semantic tools, namely, Ontologies are in-tended to be used as facilitators for the interoperability and however, it's very important to distinguish semantically supported interoperability from the semantic interoperability as the latter goes beyond simple data exchange and deals with its interpretation. Semantic interoperability of systems means that the precise meaning of exchanged information is uniquely interpreted by any system not initially developed for the purpose of interoperation. Thus, it is sometimes called "General Semantic Interoperability". It enables systems to combine and consequently process received information

with other information resources and thus, to improve the expressivity of the underlying Ontologies and consequently [24].

According to results shown in the table 4.3, the respondents clearly stated that standards used in both LIS and EHR applications. It is similar with to the previous literature [15, 18, and 40] such as the proposed HL7 Version3 is focused on specific contexts, terminology, models and conceptual definitions and relationships. Its underlying information model, called the Reference Information Model (RIM), is object oriented and the proposal for the Clinical Document Architecture (CDA) and there also a possibility to link with ICD-10 for exchanging clinical documents across healthcare systems uses Extensible Markup Language (XML) to encode the documents (HL7 2.5,2000) (Interface Ware). Thus the CDA defines the structure and semantics of medical documents that are to be exchanged and CDA documents use data types specified in the HL7 RIM.

The results shown in the table 4.4 indicated that there is workload because of working in both in paper based and electronic system. The workload was due to network interruption, result lost and power interruption in the hospitals. Those challenges are also happened in other countries [36, 39] that were driving forces to use interoperability. Interoperability has benefits that able to solve those challenges:

First, patient safety and clinical quality are improved, as systems bring medical record information to the point of care, integrate health information from multiple sources and applications, and integrate decision support tools with guidelines and research results [33].

Second, patients can gain access to their own personal health information in the Hospitals, which empowers them to better manage their health [33].

Third, the public health system benefits from improved reporting of communicable diseases and real time aggregation of data for bio surveillance and detection of emerging disease patterns. Fourth, aggregating electronic billing and payment data will facilitate better understanding of healthcare costs [33].

Finally, significant potential financial benefit may accrue from decreasing human involvement in information exchange and reducing redundant procedures. Interoperability is powerful because it

leverages current technologies, such as hospital information systems, pharmacy systems, EHR, and CPOE, to reduce costs and improve quality [33].

The next chapter will discuss the data exchange interoperability framework between LIS and EHR. The framework helps for system developers as a guide for interoperability in the Hospitals and also help for decision makers to plan for the sustainability and scalability of LIS and EHR applications.

CHAPTER FIVE

DATA EXCHANGE INTEROPRABILITY FRAMEWORK BETWEEN LIS AND EHR

This Chapter described the proposed and developed data exchange interoperability framework between LIS and EHR. The framework is developed based on the results of the study, experience from the literature and linked with the national eHealth strategic road map framework components.

5.1. Introduction

To date, comprehensive computer-based patient records are commonly used in developed countries, and are rare and nonexistent in the developing world. However, in this era of information, there is a considerable interest of developing and using eHealth applications (EHR and LIS) especially in developing countries like Ethiopia, with the intension to obtain the expected advantages of EHR and LIS in the Hospitals. As a result, the FMOH and EHNRI developed EHR and LIS respectively. First implementation was started in St. Paul specialized and Zewditu memorial Hospitals in Addis Ababa. Since then, a total of 10 hospitals implemented the full package of EHR and a total of 2 hospitals implemented LIS systems in Addis Ababa City Administrations at St. Paul specialized and Zewditu memorial hospitals. The Federal Ministry of Health stated in the Health Sector Development Plan (HSDP IV) to implement LIS and EHR applications in to all 116 hospitals within the next five year [11].

It is expected that EHR and LIS systems are to create an overall improvement in the workflow of clinical operations, specifically, to reduce medical error rates, increase efficiency, and in general improve the process of health care delivery and management. Both systems were independently designed and implemented at two hospitals in Addis Ababa without considering the data exchange between the two applications.

5.2. Method Used in Design data exchange interoperability framework between LIS and HER

There are two considerations to design data exchange interoperability framework between LIS and EHR applications:

First consideration is literature: Data exchange interoperability framework becomes a best solution as already stated in the literature by Jalalkarim and Balachandran [36], clarified the method how to develop a framework based on alarming barriers pertaining to eHealth application development and implementation in particular to structure, contents and communications. The study conducted to identify the challenges of physicians on eHealth application and interoperability between hospitals. In the research used qualitative study method with the phased approach to develop a framework:

1st. phased: describe and explain the meanings and functionalities of eHealth applications as well as to understand the barriers.

2nd Phased: understand structure and design of eHealth applications: once it was the pinpointed the main barriers in eHealth applications in interoperability, the next aim assess how to bridge the gap eHealth applications by assessing the interoperability solutions by considering standards

Second consideration is existing eHealth strategic direction: The national eHealth strategic road map document also consider in designing data exchange interoperability between LIS and EHR. The applications and presentation layers in the strategic road map are directly linked with proposed framework in this study.

Finally, this research is more similar with the literature [36] and the eHealth strategic road map was considered in the design of data exchange interoperability framework.

5.3. Data exchange interoperability framework between LIS and EHR

Federal ministry of Health (FMoH), identified some of common challenges that is similar with this study and design national level eHealth strategy road map based on Health Matrix network framework designed by world health organization, discussed below in Figure - 5.1

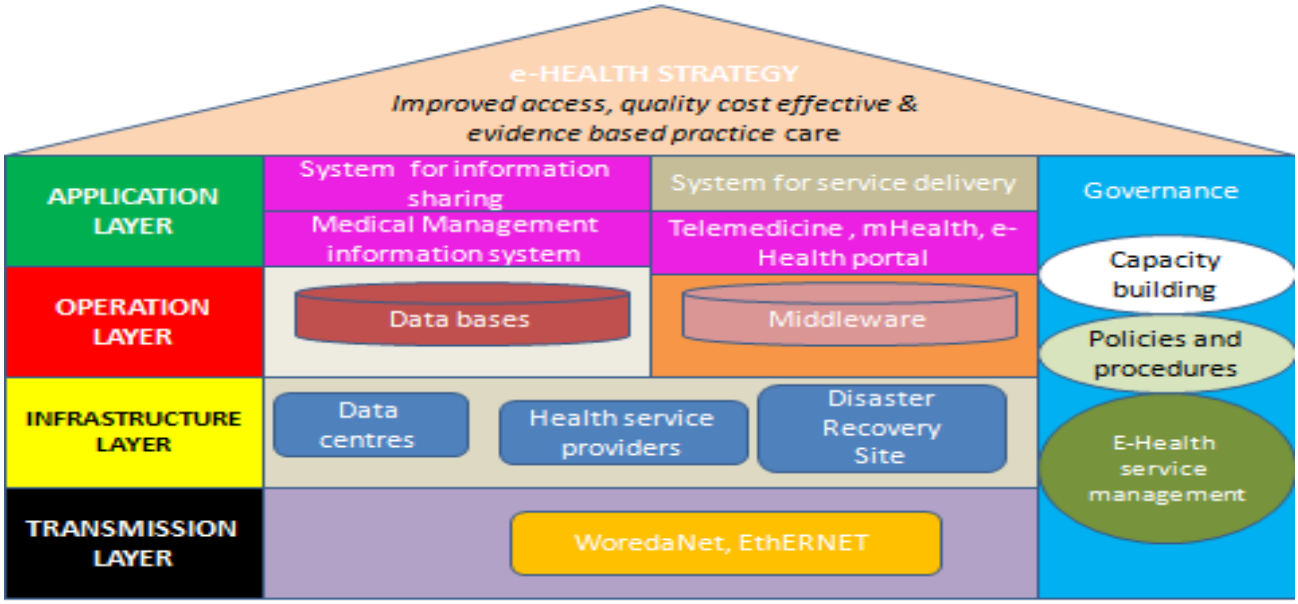

Figure 5. 1National level eHealth strategic road map framework in Ethiopia

The major issue in the eHealth National strategic documents and that is mainly related to our study is the applications and operational layers.

Application layer: on the principle of information sharing and information use between different applications that the applications have special role to enhance the health service at all level starting from hospitals up to FMoH. The eHealth strategic road map have list of plans to make one integrated and interoperable system at national level. All applications have a plan to link with the health data warehouse that is the main repository clearly represented on operational layer in the name of database. In this layer there are two components that are linked each other, system for information sharing like eHMIS, LMIS and PHEMIS are the main application. System for Health service delivery: mainly discussed on enhancing the quality of health service delivery by increasing access like Tele-medicine, mHealth, eHealth portal Laboratory Information System (LIS) and Electronic Health Records (EHR).

Operation layer: it is mainly deal with how the applications works and database system that each application have their own database and linked with main repository called Data warehouse at federal ministry of health data center. The middle ware is the application lay on operational layers help to link different database format in to one then store in to the data ware house that is important for planning and decision making process at national level. It is also important for public health emergency preparedness and research in the health care of Ethiopia.

The Federal Ministry of Health is expected data from hospitals through eHealth applications. Nowadays the public hospitals have an opportunity to have LIS and EHR within the next five year (HSDP -IV) and need national to facility level data exchange. Then based the above findings on the national level information sharing is so vital in the health sector for many reasons. The proposed data exchange interoperability framework between LIS and EHR create an option to solve those challenges at each level. These framework work only hospitals level and mainly consider the national level eHealth framework. Figure 5.2 below describes the data exchange interoperability framework between LIS and EHR. That basically answers the challenges related on data exchange in the hospitals which implemented LIS and EHR.

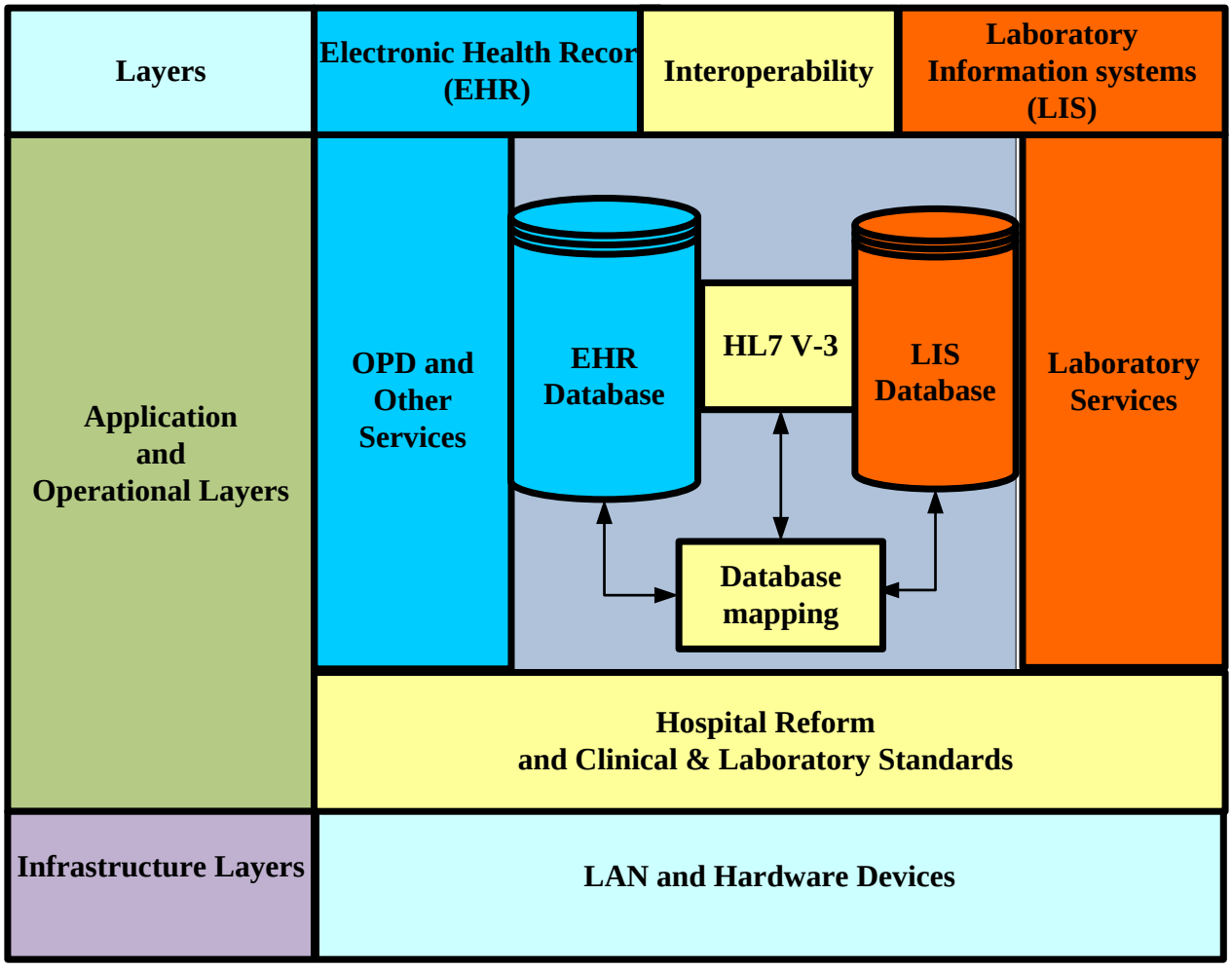

Figure 5. 2Data exchange interoperability framework for LIS and EHR (DEIF)

The DEIF is designed based on two pillars I) Operational layers and Applications layers and II) infrastructure layers. Figure 5.2 discussed below in two pillars.

5.3.1.Infrastructure layers

5.3.1.1. LAN infrastructure and Hardware devices

In order to make data available at real-time to all points of service within the Hospitals, EHR and LIS are installed in a centralized mode (client/server) then accessed with shared computers, printers and ICT accessories. This mode operates on an online communication infrastructure within the Hospitals. Local Area Network (LAN) including Wireless Local Area Network (WLAN) and demonstrated as the appropriate technology for building the communications infrastructure. The major advantage of LAN and WLAN that make data exchange more effective

and efficient includes improve easy, fast, and affordable networking solution for Hospitals.

EHR and LIS applications are installed at the Medical Record Room and the Triage Room were the bulk of data encoding takes place followed by other Clinics including Out Patient, In Patient, MCH, Pharmacy, ART, VCT and TB and laboratory for only LIS application and used one shared infrastructure in the hospital that also include training both on job and off job training for Health professionals.

5.3.2.Applications and Operational layers

5.3.2.1. Electronic Health Record (EHR) Applications

In the centralized mode, EHR hosts the database on a central server and using online communications infrastructures (LAN/WLAN), enables all points of services to obtain real time access to Patient's information. EHR is incorporate using an industrial standard modular architecture that important for data exchange like HL-7. This provides the added advantage for data exchange interoperability among LIS and other eHealth applications, without affecting the stability and integrity of the application. Other features of EHR include Role Based Security, Data merging, import/export, and backup/restore and address user friendly interface for easy to use.

5.3.2.2. Laboratory information system (LIS) applications

Laboratory Information System (LIS) organized and implemented by considering fully featured, that includes and supports work and information flow in all steps of the laboratory testing process, including test ordering, and sample collection, testing, and reporting. Finally Physicians and lab technicians use laboratory information systems to supervise many varieties of inpatient and outpatient medical testing, including hematology, chemistry, immunology and microbiology. Basic laboratory information systems commonly have features that manage patient check in, order entry, specimen processing, result entry and patient demographics. A LIS tracks and stores every detail about a patient from the minute they arrive until they leave and keeps the information stored in its database for future reference. In addition, we should enforce to use standards for EHR to develop and use HL7 v3 and HL-7 v3 used for data exchange LIS applications.

5.3.2.3. Health Level 7(HL7 V-3)

HL7 Version3 is an improvement from the previousVersion2.x by being more focused on specific contexts, terminology, models and conceptual definitions and relationships. Its underlying information model, called the Reference Information Model (RIM), is object oriented and the proposal for the Clinical Document Architecture (CDA) for exchanging clinical documents across healthcare systems uses Extensible Markup Language (XML) to encode the documents (HL7 2.5,2000) (Interface Ware). Thus the CDA defines the structure and semantics of medical documents that are to be exchanged and CDA documents use data types specified in the HL7 RIM.

There are segments in HL7 V-3; the first segment is the message header segment with the three-letter code MSH, which defines the intent, source, destination, and some other relevant information such as message control identification and time stamp. The other segments are event dependent. Within each segment, related information is bundled together based on the HL7 protocol. A typical message, such as patient admission, may contain the following segments:

- MSH—Message header segment
- EVN—Event type segment
- PID—Patient identification segment
- NK1—Next of kin segment
- PV1—Patient visit segment

Segments in HL7 –V -3 have important role in data exchange between LIS and EHR applications

5.3.2.4. HL7 Message Refinement Process

According to Sartipi.et.al [35]; HL7 methodology uses RIM, HL7-specified vocabulary domains, and HL7 v3 data type specification and establishes the rules for refining these base standards to specify Message Types and equivalent structures in v3. The strategy for development of these message types and their information structures is based upon the consistent application of constraints onHL7 RIM and HL7 Vocabulary Domains, to create representations that address a specific healthcare requirement. Figure 2.2illustrates the refinement process specified in HL7methodology, where the different parts are discussed below.

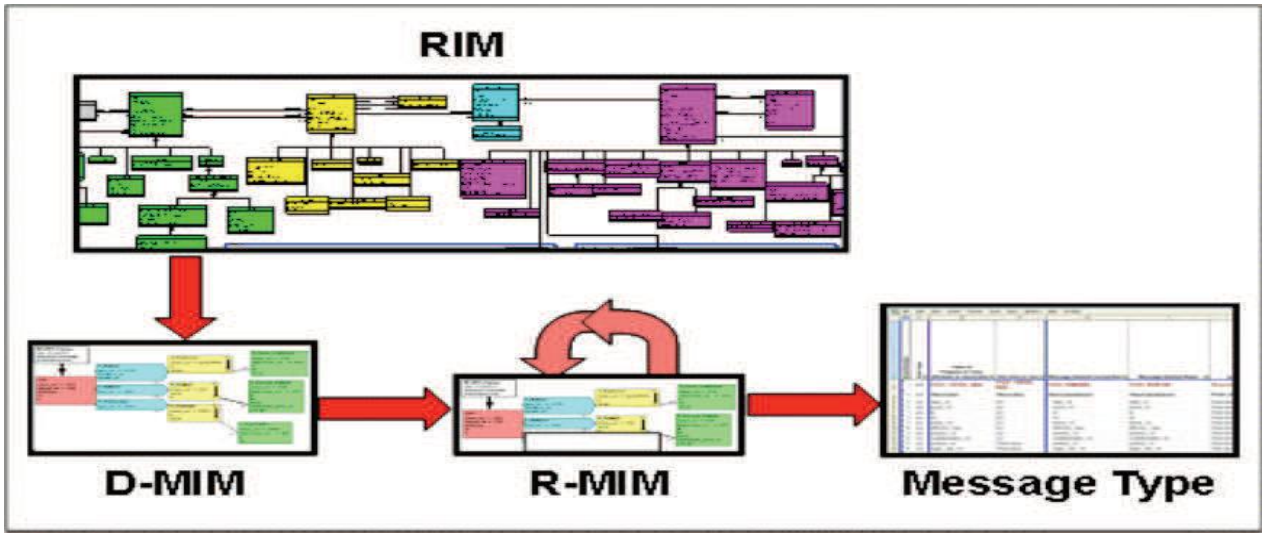

Figure2. 5Refinement process specified in HL7 methodology [35]

- **Domain Message Information Model (D-MIM)** is a subset of the RIM that includes a fully expanded set of class clones, attributes and relationships that are used to create messages for any particular domain (e.g., accounting and billing, claims, and patient administration)
- **Refined Message Information Model (R-MIM)** is used to express the information content for one or more messages within a domain. Each R-MIM is a subset of the D-MIM and only contains the classes, attributes and associations that are required to compose those messages.
- **Hierarchical Message Description (HMD)** is a tabular representation of the sequence of elements (i.e., classes, attributes and associations) represented in an R-MIM. Each HMD produces a single base message template from which the specific message types are drawn.
- **Message** Type represents a unique set of constraints on message identification that are presented in different forms such as: grid, table, or spreadsheet.

5.3.2.5. Laboratory clinical standards

According to Hospital reform guideline [14], all hospitals and service areas expected to follow the new hospitals reform and implemented at all levels of care. The expected national hospitals laboratory service standards, clearly stated and using those standards help for fast, efficient and effective that mainly address in storage analyze and result related challenges.

The following diagnostic tests should be provided by Hospital Laboratories that mainly standards raised by the government of Ethiopia that also considered in the data exchange interoperability framework among LIS and EHR:

1. Haematology
    - CBC with Automated Differential
    - CBC – Manual
    - Blood film
    - CSF Cell Counts
    - CD4 (absolute)
2. Clinical Chemistry
    - Chemistry Panel
        - Liver function tests (ALT, bilirubin)
        - Serum electrolytes
        - Renal function tests (Creatinine, urea, nitrogen)
        - Lipid profile
        - Serum amylase
        - Glucose
    - Whole Blood Lactate
3. Microbiology
    - AFB Smear
    - India Ink Stain
    - Gram Stain
    - Microbiology culture and sensitivity
    - Wet Mounts – Direct Microscopy
    - Serology
    - HIV Serology Rapid Test
    - Cryptococcal Antigen Test
    - Hepatitis B
    - Hepatitis C
    - TPPA/ TPHA/ RPR
4. Parasitology
    - Malaria Rapid Test
    - Malaria smears microscopy (Blood Film)
    - Stool examination: Direct microscopy and concentration techniques

- Urine tests
- Urine Dipstick with Microscopy
- Urine Pregnancy Rapid Test

5.3.2.6. Database of EHR and LIS Applications

Based on the findings section 4.2, the database systems of both applications are organized and introduced independently that already installed in to different server but the applications database designed through SQL server 2003. This study proposed the two applications as exist and through interoperability that create one database table and linked with the databases then the applications give access for all health professionals. That is similar with RIM- RMIM the next subtitle discussed how the database system interchanges the data from LIS to EHR applications.

5.3.2.6.1. Database Mapping

The proposed database system linked with HL7 v-3 have Reference information model that already facilitate the data exchange process and the database of the two applications. The mapping database has the ability to communicate in attribute level mapping and act as a middle ware that accepts any request from the EHR and communicate with LIS and LIS to EHR.

Each EHR attribute have linked with the same meaning but different naming style in LIS that mainly solve the problems in data exchange through database mapping; the database mapping checks validation of each requested attributes and stored if it's new. The table 5.1 below described how the database mapping works with some known attributes working in both applications.

No.	***Patient Personal information in both Applications (Format based system testing)***		***Descriptions***	***Database Mapping***	***Data type***	***Ontology (vocabulary)***
	EHR Database Format	***LIS Database Format***				
1	Medical Record Number (MRN #) E.g. In EHR unique identifications # (Abebe MRN# RSH/123566/05)	Patient ID (PID #) In LIS unique identifications # (Abebe MRN# RSH/123566/05)	Unique identifier for patients	MRN# = PID #	Varchar	The attribute have the same meaning but name that expressed ***MRN# = PID #***
2.	First Name, Father Name, Last Name E.g. EHR attribute Abebe (First Name) Bekele (Father Name) Ayele (Last Name)	Patient Name Attribute Patients Name contains Abebe (First Name) Bekele (Father Name)	Description of the Patients Name	First Name + Father Name + Last Name = Patient Name {describes : (Abebe = Abebe), (Bekele in EHR = Represented as x +Bekele in LIS), (Ayele in EHR = Represented as x +	Varchar	Both attributes, are the same meaning but in different attribute name and that Simply expressed (***First Name + Father Name + Last Name) for EHR = Patient Name (First Name +''+Father Name +''+ Last Name) for LIS***

		Ayele (Last Name)		Ayele in LIS)		
3	Sub City (Zone), Woreda Kebele E.g. Attribute sub City and Kebele for the name Abebe contain: Gulele, Woreda = 07 Kebele = 08/16, House Number = 1009	Address Attribute sub City and Kebele for the name Abebe contain: Gulele, Woreda = 07 Kebele = 08/16 House Number = 1009	Description of Patient Address	Sub City (Zone) +Woreda+ Kebele = Address:{describes (Gulele = Gulele) , (07 in EHR = Represented as x + 07 in LIS), (08/16 in EHR = x + 08/16), (1009 in EHR = Represented as x + 1009 in LIS)	Varchar	The attribute have the same meaning but difference in attribute name: expressed mathematically in (***Sub City (Zone) + Woreda + Kebele + House Number) for EHR = Address (Sub City (Zone)+ ''+ Woreda + '' + Kebele + '' + House Number) for LIS***
4	Gender (Abebe Gender = M)	Sex (Abebe Sex = M)	Indicate gender of the patients	Gender = Sex	Varchar	The attribute have the same meaning but name that expressed ***Gender = Sex***
Note X in database mapping and '' in ontology: indicate that the single space between each attributes.						

Table5 1Attribute level matching and attribute Descriptions

CHAPTER SIX

EVALUATION OF DEIFLE

This part of the study intends to make analysis of the data exchange framework between LIS and EHR. This is based on evaluation from discussion conducted with three different groups of experts at Federal ministry of Health Particularly on Health information technology (HIT), implementing partner's staffs from LIS application manager; and partner's staffs from EHR software developers. All the responses were analyzed and compiled. The final recommended suggestions mainly address challenges on data exchange interoperability among LIS and EHR in the Hospitals. Most of the respondents are working in application software / projects which are involved on the design and implementations of each application and health informatics at the ministry. The researcher sent the proposed framework to all the group experts two days before the discussions were conducted. Two hour discussion was conducted through consultative meeting at the Federal Ministry of Health, Public Health Infrastructure directorate office with each of the group. They assessed the proposed data exchange interoperability framework between LIS and EHR based on the challenges they faced during their work. After the discussion all the experts forwarded three thematic points. The issues and their corresponding discussions on the three thematic points are presented bellow in three groups:

6.1. Validations of framework by the EHR Developers

Tulane software developer and project manager (Mr. Hiwot Tesfaye), recognized that the study shows the major challenges which were identified before and the researcher proposed a good data exchange interoperability framework between LIS and HER as solution that addresses local interoperability challenges in the hospitals and improve health service delivery. Tulane software developer and project manager also provided comments on the framework that were already proposed by the researcher.

According to Mr. Hiwot, all the layers on the framework clearly displayed and placed properly and represented the major applications data exchange issues and infrastructure issues. But there was an comments, for instance to change the concept ***database mapping*** to ***field matching*** since database

matching needs resources. Planning to implement interoperability based framework is one of the challenge since data exchange interoperability between the LIS and EHR applications will require additional investment on resources like Memory, Processor, etc. It's also proposed to add a layer which depicts how a user accesses the systems that helps to clarify the proposed data exchange interoperability framework among LIS and EHR. Generally it's agreed that the framework is important to implement the designed interoperability options in the Hospitals and it's also planned to access the hospitals and address interoperability issue with LIS applications in the laboratory. The findings on this research provide solutions on how to create interoperability and make the data exchange process efficient.

6.2. Validations of framework by the LIS Developers

CDC information system analyst and project manager (Mr. Aklilu Asrate), acknowledge that the study shows how our system linked with any other system in the hospitals like EHR and identified the major challenges which were stated before and the researcher proposed data exchange interoperability between LIS and EHR solution framework. The proposed framework on hospital data exchanges clearly addressed the problems that laboratory technologist faced on their day to day activities. The proposed framework somehow look like Health Matrix Network (HMN) framework developed by World Health Organizations. It was agreed that the framework was well designed with easy to recognize for both technical and hospital staffs and create a bridge between LIS and EHR applications; that it is direct implication to improve health care delivery by increasing access for patients and increase patient's satisfaction.

According to Mr. Aklilu ,in the application and operational layers of the framework the research clearly demonstrated the data exchange standards like HL-7 V-3 which is popular and a key solution on data exchange issue between LIS and EHR that were already used during LIS development on creating machine interfacing. However, HL-7 v-3 Standards is a big document and requires customization which needs the approval of standards organizations like the Food Medicine and Health Control authority of Ethiopia. In the Infrastructure layer, the proposed framework of shared infrastructure in the hospitals make the eHealth applications more effective and efficient in the hospitals level with the objective of improving quality and access by reducing workload and cost.

Finally, the expert accepted the proposed data exchange interoperability framework which depicts interoperability between LIS and EHR which were discussed. He also commented that the major data exchange challenges were clearly addressed by the proposed framework.

6.3. Validations of framework by the eHealth Experts

Federal Ministry of Health, Biostatistics & Health informatics expert and Team Leader of Health Information Technology team (Ms. Yemsrach Kifelew), commented on the data exchange interoperability framework done by the researcher. According to her, the also clearly identifies the major challenges like EHR and LIS data exchange interoperability and interfacing then proposed a good framework with a potential to address major challenges on eHealth applications. The proposed framework is easy to recognize the defined layers which are application, operational and infrastructure layers. She also discussed on the layers and raised the following issues:

Applications and operational layer: In this layer, the researcher proposes three basic components that make the framework easier to implements and technically sound. The standard used on the framework HL-7 V-3, is an important one on data exchange between LIS and EHR. In this layer database mapping is used as data exchange bridge between LIS and HER applications and interoperable. This layer considers attribute level mapping and session level matching. To explain this, once a laboratory order reaches in the LIS; the database mapper considers time of order and request before performing the task just like actual work performed.

Infrastructure layer: the proposed framework address challenges of infrastructure in the Hospitals. So she strongly agreed that the proposed data exchange framework mainly considers the existing ICT devices that are the challenges of infrastructure at the Hospitals.

Finally, she explained the data exchange interoperability framework is excellent and it's one means to create a deigned solution on data exchange between LIS and EHR with the consideration of existing infrastructure in the Hospitals.

6.4. Validations of framework by the LIS and EHR users

St.Paul Millennium Medical College Hospital laboratory department (Mr. Ephraim Tesfaye) commented on the data exchange interoperability framework done by the researcher after one hour discussion about the proposed framework designed by the investigator. According to Mr. Ephraim, the findings and the suggested framework have a capacity to make the two applications integrate and interoperable that is essentials in improving the Health care delivery in our hospitals.

According to Mr. Ephraim, explained about major problems in data exchange and linked with the proposed data exchange interoperability framework and raised the following ideas:

1. In the proposed framework the investigator clearly stated; laboratory standards and new hospitals reform, which make the health information system (data exchange) more integrated and coordinated. This solves the major data exchange problems between LIS and EHR in the hospitals by putting middleware applications working as converter of the data by accepting the two database formats.
2. In addition; the proposed framework also indicated new infrastructure setting in the Hospitals that is more effective and efficient than the existing independently working systems. The proposed system also stated shared LAN system that makes LIS and EHR applications as one system in the hospitals.

Finally, the proposed data exchange interoperability framework between LIS and EHR is excellent option.

6.5. Strength and Limitations of the Study

Strengths

- In addition to interview questionnaire and applications functionality testing use that make the study a bit strong.

- The present study assessed the data exchange challenges between LIS and EHR applications in St. Paul Millennium Medical College and Zewditu Memorial General Hospitals.

- By considering multiple challenges in data exchange the study proposed data exchange interoperability framework help to use the limited resources more effectively and efficiently.

Limitations

- The proposed data exchange interoperability framework could be expressed elaborately by demonstration how the data exchange among LIS and EHR looks like; however the software developers who developed the applications are not willing to give the source code and design documentations since their policy does not allow them to do so. Therefore; this study lacks some complimentary information such as how interoperability works between LIS and EHR system.

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATION

7.1. CONCLUSIONS

Nowadays in the public Hospitals, eHealth applications have common solutions to improve patient safety, increase access and quality and decrease health care cost. However, these are standalone applications which don't interface and exchange data among themselves. eHealth applications in the hospitals should consider on how to make them communicate and in order to address major challenges such as Lack of interoperability, create fragmentations and data redundancy on eHealth applications, Laboratory result lost and Transcription errors, it also create workload because working in both in paper based and electronic through EHR and LIS. Based on the findings the of this research work, data exchange interoperability framework between LIS and EHR applications is developed as a solution. The framework takes in to consideration the new Hospitals reform guidelines, that indicate how standardized hospital workflow looks like and data exchange standards HL7 V-3 and interoperability options that fit to software applications. This framework solves data exchange challenges between LIS and EHR applications which are being used in public hospitals.

7.2. RECOMENDATIONS

The study showed that a number of solutions and recommendations have been proposed to overcome main challenges on data exchange interoperability between LIS and EHR in Hospitals. National eHealth Strategy roadmap provides the national level guideline for future interoperability. Moreover this study provided data exchange interoperability between LIS and EHR that will be helpful for developers and eHealth experts at FMoH that create better understanding of data exchange interoperability between LIS and EHR for better planning and decision making on eHealth application sustainability. Major recommendation which categorized in two three group discussed below:

1. **Recommendation for Decision makers**
    - Provide alternative power source for Hospitals
    - Awareness creation to all physicians and health professionals
    - Increase the performance of the systems
    - Provide on job training and continuous follow up for users on both basic computer & system related
    - Create strong monitoring and evaluation on data exchange in the hospitals
2. **Recommendation for Software developers**
    - Developers should consider the applications interoperable and interfacing that also clearly indicated in the draft eHealth strategy.
    - Design plan for sustainability and consistency of the system
    - Increase the use involvements in the development and implementation of eHealth applications
3. **Recommendation for users**
    - Create virtual team to support the sustainability of LIS and EHR in the Hospitals

Those recommendations are directly and indirectly affect the data exchange interoperability between LIS and EHR. Finally, this study provided data exchange interoperability framework that create harmonized data exchange interoperability environment among LIS and EHR without reformulating the LIS and EHR applications that guide for designed a Middle ware that facilitate two applications to communicate as one system in the hospitals and that provide solutions for some challenges that clearly stated in this study that mainly incorporate feedback from decision makers.

7.3. FUTURE WORK

Our research is the effort to solve the issues of interoperability between LIS and EHR. We think that our suggestions will be helpful for implementation of interoperability among the eHealth applications. We analyze many things by our interviews and applications functionality testing and we think there are may be deficiencies in the study and it needs more detailed research and work for the better of interoperability among eHealth applications and beneficial for the people of the county. In future there is a need to work on Smartcards and also options in the EHR systems in eHealth fields. We think that there also a study area on:

- Data exchange in trans-institutional among Hospitals eHealth applications just to facilitate referral system.
- Business process level of interoperability area is also one of the future works.
- Comparative study between LIS and EHR-LIS modular software applications in terms of usability testing.

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Annex I.

Interview questionnaires with FMoH and EHNRI

I. Background Information about the study

Objective of the Study: To provide data exchange interoperability framework on EHR and LIS applications

II. Important operational definitions:

1. ***Electronic Health Record (EHR):*** Smartcare application, particularly a Laboratory Information System Module that provides computerized recording, analysis and reporting on laboratory activities to improve patient safety and the quality of care.
2. ***Laboratory Information System (LIS):*** Polytech laboratory application that provides computer based recording, analyst and reporting to facilitates the laboratory activities by integrating all of the systems in a laboratory
3. ***Data exchange:*** it is the process of sending, transmission and receiving data between LIS and EHR.

III. Background Information about the participant

1. Respondent Name :
2. Interview # :
3. Age :
4. Sex : M= ☐ F= ☐
5. Respondent profession / position /title :
6. Work experience
7. Higher level of education :

IV. System related questioners

1. What is your specific role in FMoH / your Directorate?
2. How many eHealth initiatives exist at the national level? Where did you implement and which partners or involved in the implementation process?
3. What policy or strategy you have followed during the period of identification and implementation of eHealth projects in the Hospitals?

4. Are you involved during the implementation of the two EHR and LIS applications (eg. training, design and installation, etc)?
5. In your view; is the current EHR/LIS well designed and technically sound with smooth data exchange? If not, what do you think the system looks like?
6. What are the main challenges of e-Health Applications during implementation at national level in terms of Technology, Human resource and Project management?
7. Have you ever evaluated the applications or the system if so what are the main findings?
8. What is your recommendation for the future on both applications (LIS and EHR)?

V. Data exchange related Questionnaires

1. Did you aware in the issue related to know data exchange between different eHealth applications and what were the main challenges exist for the operational of eHealth applications at Hospitals?
2. How it affected the Health information reporting system at FMOH?
3. What is your recommendation regarding to challenges data exchange and eHealth applications?

Annex II.

Interview questionnaires with Laboratory Technologist

i. Background Information about the study

Objective of the Study: To provide data exchange interoperability framework on EHR and LIS applications

ii. Important operational definitions:

Electronic Health Record (EHR): Smartcare application, particularly a Laboratory Information System Module that provides computerized recording, analysis and reporting on laboratory activities to improve patient safety and the quality of care.

Laboratory Information System (LIS): Polytech laboratory application that provides computer based recording, analyst and reporting to facilitate the laboratory activities by integrating all of the systems in a laboratory

Data exchange: it is the process of sending, transmission and receiving data between LIS and EHR.

iii. Background Information about the participant

Respondent Name :
Interview # :
Age :
Sex : M= ☐ F= ☐
Respondent profession / position /title :
Work experience
Higher level of education :

iv. System related Questionnaires

1. What is your specific role in the laboratory sections?
2. Do you know about EHR and LIS?
3. Are you involved in the deploying the EHR or/ and LIS? In which part of the implementation (eg. Training, design and installation, etc)

4. Did you use EHR and LIS for laboratory information's system? How long you have used the applications and how you classify your general knowledge and skill for the use of the Applications?
5. Did you have any training on the EHR or LIS applications that you are currently using?
6. Do you have any reservation about the implementation of EHR/LIS and about the data exchange?
7. How do you insert data in to EHR and LIS?
8. How do you get results/report from both EHR and LIS?
9. Do you feel that data exchange is major issue in EHR/LIS?
10. What are the major problems you face and expected to face on data exchange?
11. What concerns do you have about any data exchange?
12. Is the current EHR/LIS well designed and technically sound with smooth data exchange? If not, what do you think the system looks like?
13. Did the EHR and LIS have import and export features? If so for what purpose you are used?
14. What challenges you have faced on data exchange (timeliness, accuracy, and consistency) provide for patients and hospital staff?
15. Are there any guidelines, operating procedures, and user manuals for each application? If so how you frequently referring?
16. Do you think EHR/LIS is helpful to your day to day activity? Please describe?
17. What is your recommendation to improve the use of EHR and LIS?

v. Data exchange related Questionnaires

1. Do you know what standards have applied or considered to develop the EHR /LIS?
2. When/ why do you need to exchange data between LIS and EHR?
3. What type of data do you need to exchange data between the two applications? How frequent per a day/weekly/monthly?
4. What are the challenges you faced while you exchange data between EMR and LIS? How did you solve the problem? (By yourself or by request help)?
5. If Q-4 is on Solved the challenge by request help; what solution has been provided? Was addressed all your concern?
6. Are you recording your data exchange challenges in your day to day activity?

7. Do you prefer a solution to consider without affecting each application but only plays as a middle application between LIS and the EHR that facilitate data exchange?
8. How do you expect the data exchange policy should be? (Input /process /output)?

Annex III

Interview questionnaires with ICT support Technologist for

Background Information about the Study

Objective of the Study: To provide data exchange interoperability framework on EHR and LIS applications

Important operational definitions:

Electronic Health Record (EHR): Smartcare application, particularly a Laboratory Information System Module that provides computerized recording, analysis and reporting on laboratory activities to improve patient safety and the quality of care.

Laboratory Information System (LIS): Polytech laboratory application that provides computer based recording, analyst and reporting to facilitate the laboratory activities by integrating all of the systems in a laboratory

Data exchange: it is the process of sending, transmission and receiving data between LIS and EHR.

Background Information about the participant

Respondent Name :
Interview # :
Age :
Sex : M= ☐ F= ☐
Respondent profession / position /title :
Work experience
Higher level of education :

System related questionnaires

1. What is your specific role in the Hospitals?
2. Do you know about EHR and LIS?
3. Do you have any reservation about the implementation of EHR/LIS?
4. Did you aware the issue related on both EHR and LIS working in laboratory section? What do you understand from both applications?

5. Can you benefit of both EHR and LIS in the hospital? Explain how?
6. If Q-5 benefited, what is their importance for management (information use decision making, analysis and reporting) of eHealth Applications (LIS and EHR) in the hospital?
7. Do you explain for us what your plan for the sustainability and scalability of LIS and EHR in the hospital?
8. What are the main challenges for EHR and LIS in terms of technology, user friendliness and training?
9. What is your recommendation for LIS and EHR as well as general development of eHealth applications?

Annex IV

Interview questionnaires with Software Developers

Background Information about the study

Objective of the Study: To provide data exchange interoperability framework on EHR and LIS applications

Important operational definitions:

Electronic Health Record (EHR): Smartcare application, particularly a Laboratory Information System Module that provides computerized recording, analysis and reporting on laboratory activities to improve patient safety and the quality of care.

Laboratory Information System (LIS): Polytech laboratory application that provides computer based recording, analyst and reporting to facilitate the laboratory activities by integrating all of the systems in a laboratory

Data exchange: it is the process of sending, transmission and receiving data between LIS and EHR.

Background Information about the participant

Respondent Name :
Interview # :
Age :
Sex : M= ☐ F= ☐
Respondent profession / position /title :
Work experience
Higher level of education :

System related questionnaires

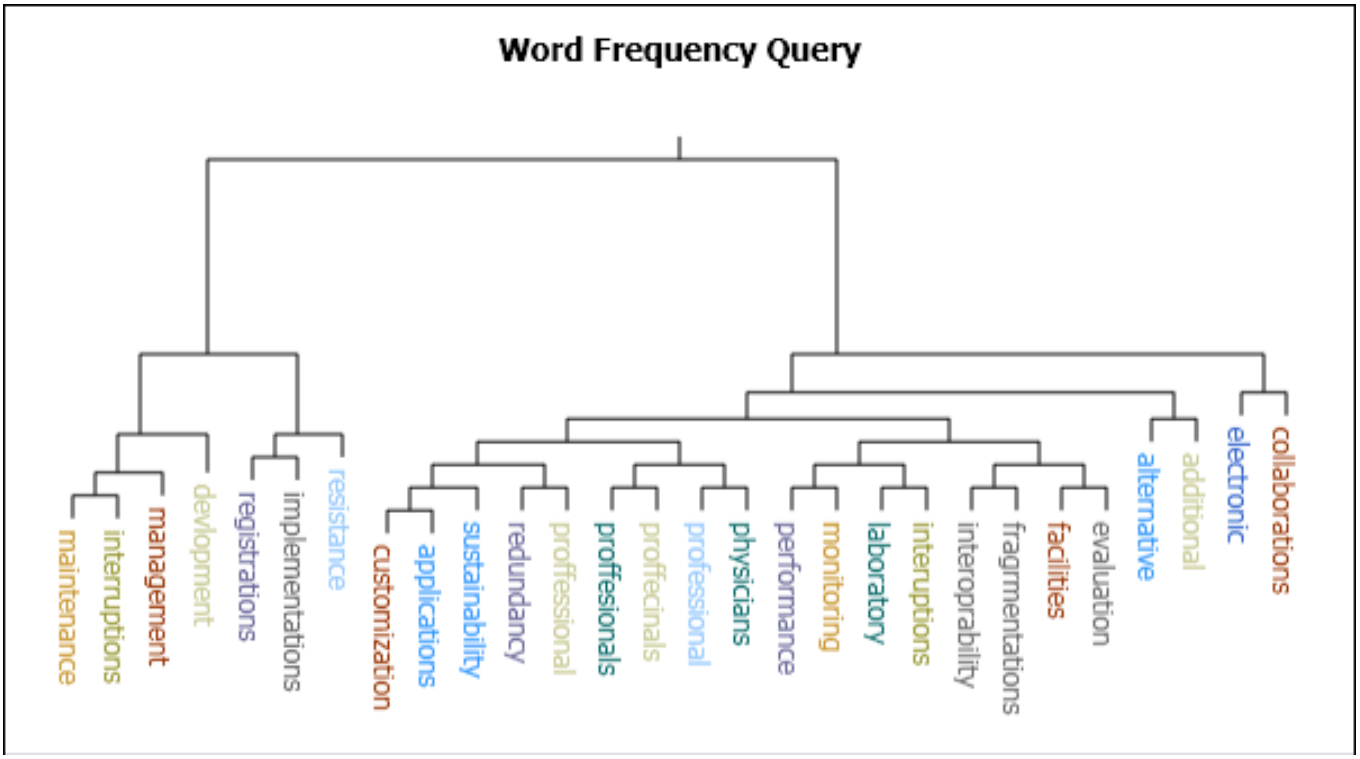
1. What is your specific role in your organizations especially during the implementations?
2. What does your EMR or LIS does in the hospitals? Describe Functionality based (like Laboratory modules)?
3. What is your specific role on EHR or LIS development?
4. Do you know other eHealth applications other than you EHR/LIS?

5. Did you follow any policy or guide lines that make you applications workable? (Input /process /output)?
6. What Software engineering method you follow during the development of EHR or LIS?
7. What are the standards follow in your EHR or LIS?
8. Is there any request for help from the hospitals with your application exists?
9. Did you have support disk for users in your office?
10. Have you ever evaluated or upgrade EHR or LIS based on the feedback you received from users?
11. If Q-5 yes, what are the possible feedback from the users?
12. Does the EHR or LIS have User Manuals procedural while using the system?
13. Did you develop user manual and technical analysis documents (software development documentation and technical documentations for maintenance) by your own or customized from other?

Data Based related Questionnaires

1. What programming language did you use during design your database?
2. Did all functionalities have import and export features on any other database?
3. What concerns do you have about any data exchange?
4. Do you feel that data exchange is major issue in EHR/LIS?
5. What are the major problems you face and expected to face on data exchange?
6. What do you recommend on e-Health Applications (EMR or LIS) in data exchange with the other e-Health Applications (EMR or LIS)?

Annex V:



Word	Length	Count	Weighted Percentage (%)	Similar Words
applications	12	23	2.21	application, applications
professionals	13	17	1.63	professional, professionals
implementation	14	9	0.86	implementation, implementations, implemented, implementing
interoperability	15	9	0.86	interoperability
alternative	11	8	0.77	alternative
laboratory	10	8	0.77	laboratory
resistance	10	8	0.77	resistance
interruptions	13	7	0.67	interruptions
considered	10	6	0.58	considered, considering
electronic	10	6	0.58	electronic
facilitate	10	6	0.58	facilitate
physicians	10	6	0.58	physicians
developers	10	5	0.48	developers, development, developments
interoperability	16	5	0.48	interoperability
management	10	4	0.38	management, managements
professionals	14	4	0.38	professional, professionals
redundancy	10	4	0.38	redundancy, redundancy

consistence	11	3	0.29	consistence, consistency
incorporate	11	3	0.29	incorporate, incorporation
initiatives	10	3	0.29	initiatives
interaction	11	3	0.29	interaction, interactions
interfacing	11	3	0.29	interfacing
interruptions	12	3	0.29	interruptions
performance	11	3	0.29	performance
professionals	13	3	0.29	professional, professionals
registrations	13	3	0.29	registration, registrations
sustainability	14	3	0.29	sustainability
technology	10	3	0.29	technologies, technology
transcription	13	3	0.29	transcription
additional	10	2	0.19	additional
calculating	11	2	0.19	calculating
collaborations	14	2	0.19	collaborations
communicate	11	2	0.19	communicate, communication
customization	13	2	0.19	customization, customizations
duplications	13	2	0.19	duplications
evaluation	10	2	0.19	evaluation, evaluations
facilities	10	2	0.19	facilities
importance	10	2	0.19	importance
information	11	2	0.19	information
initiatives	11	2	0.19	initiatives
institutional	13	2	0.19	institutional
institutional	12	2	0.19	institutional
integration	11	2	0.19	integration, integrations
international	13	2	0.19	international
involvement	11	2	0.19	involvement
maintenance	11	2	0.19	maintenance
monitoring	10	2	0.19	monitoring
professionals	12	2	0.19	professionals
activities	10	1	0.10	activities
alignments	10	1	0.10	alignments
appreciated	11	1	0.10	appreciated
capacitate	10	1	0.10	capacitate
commitment	10	1	0.10	commitment
continuous	10	1	0.10	continuous
controlling	10	1	0.10	controlling
curriculums	11	1	0.10	curriculums
demography	10	1	0.10	demography
development	10	1	0.10	development
equipments	10	1	0.10	equipments
especially	10	1	0.10	especially
fragmentations	15	1	0.10	fragmentations
harmonization	13	1	0.10	harmonization
implemented	10	1	0.10	implemented
impossible	10	1	0.10	impossible
incentives	10	1	0.10	incentives
integration	12	1	0.10	integration
maintenance	10	1	0.10	maintenance

operational	11	1	0.10	operational
professionals	13	1	0.10	professionals
professionals	11	1	0.10	professionals
scalability	12	1	0.10	scalability
stockholders	12	1	0.10	stockholders
successful	10	1	0.10	successful
sustainability	13	1	0.10	sustainability
technician	10	1	0.10	technician
understanding	13	1	0.10	understanding

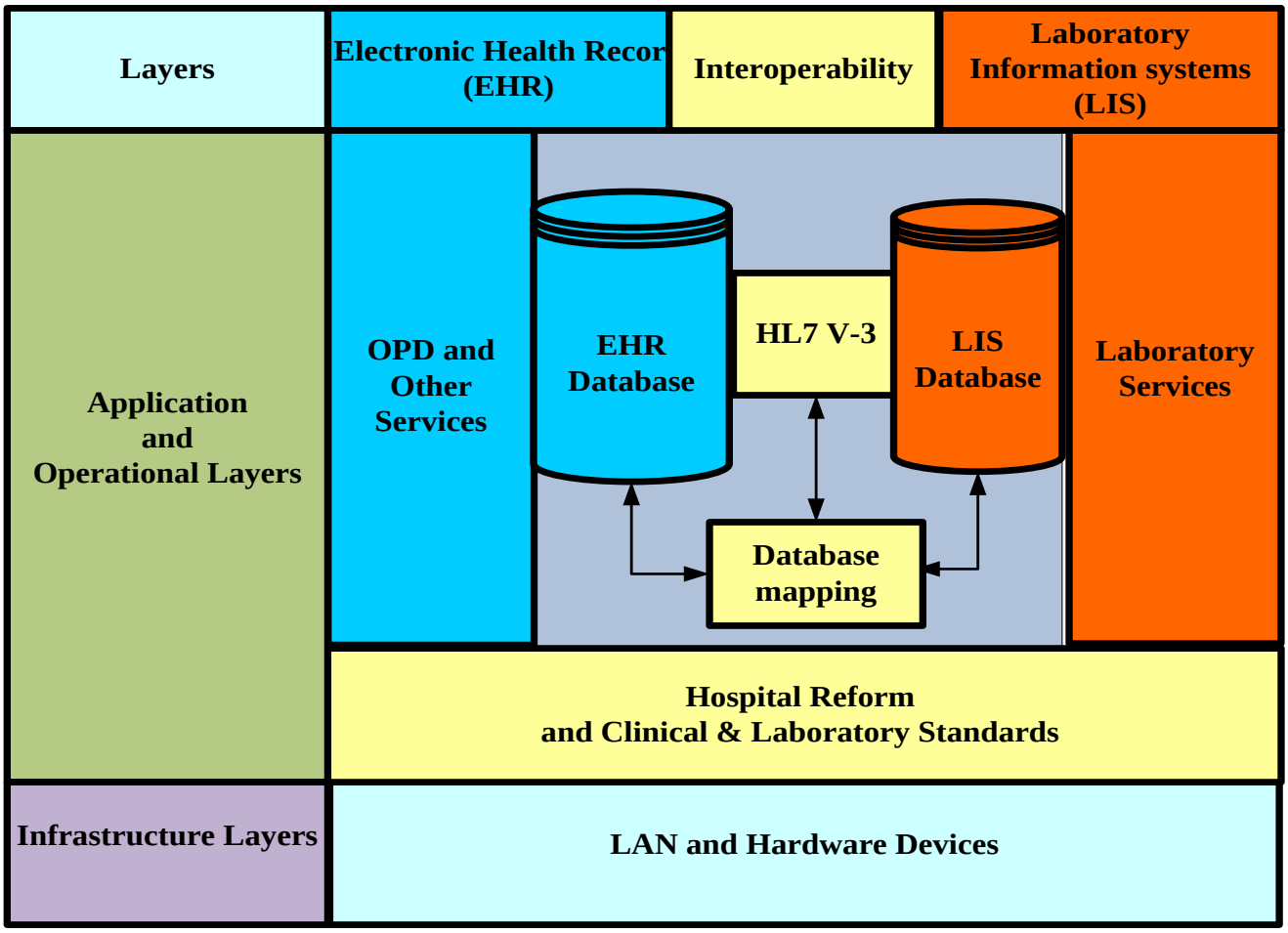
Annex V:

Assessment Checklist of EHR and LIS applications software

Assessment Checklist of EHR and LIS applications software, FMoH, April, 2013				
	Laboratory Module			
No.	**Software Version Basics**	**LIS**	**EHR**	**Remark**
1	Is a data entry form has the necessary constraints in terms of:			
2	Field Size			
3	Data type			
4	Does the system enable to write detail history and physical examination of Clients? (Does it have adequate place)			
5	Does the system have any validation mechanism when error occurs			
6	If a Physician wrongly order lab, does it allow editing?			
7	Does it send the lab request successfully (take the MRN & the tests ordered to check in lab)			
8	Does it display the lab result with the normal value?			
9	Does it have alarm when the lab result becomes abnormal?			
Data exchange b/n the two eHealth Applications (LIS and EHR)				
1	How data is exchanged from one point of care to another (from all departments to the laboratory)?			
2	In what programming language the software developed and standards			
3	Check the database of the software (DBMS language tables)?			
4	How the software interact with the laboratory Machines (MRI, Chemistry, Hematology and CD4.)			
5	Data entry to the MRI, Chemistry, Hematology and CD4 machine			
6	Data receive to the MRI, Chemistry, Hematology and CD4 machine			
Comment				
1	What weakness do you observe from the software in data exchange?			
2	What strengths do you observe from the software in data exchange?			

Annex VI:

Evaluation of data exchange framework between LIS and EHR that implemented in Hospitals



Discussion points:

1. What is your role in your organizations?
2. Does the framework solved all the main challenges on data exchange in the Hospitals
3. What is your feedback and recommendations?