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Integrative Model for Effective Universal Health Care Information System

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Countries in Africa face an array of health care financing problems that leave their health systems far from achieving the objectives of good health status, equity, efficiency, acceptability, and sustainability. The main problem is simply a shortage of government budgetary resources for health care relative to increasing demand and need for care. One manifestation of the budgetary shortfall is deterioration in the quality and effectiveness of publicly provided health services (Barnum and Saxenian 1995). Other challenges fan from lack of interoperability in health care systems.

Rising costs, reduced Medicare reimbursements, increased pressure to improve the patient experience, and a shift to value-based care all mean that providers (and the entire healthcare industry) must move toward improved healthcare interoperability. Health information technology, those creating the information systems, other healthcare parties (including payers) and providers must be able to speak to one another to achieve an integrative healthcare system.

Healthcare as a whole must take on these challenges, but there are several major hurdles in the way. Until these are addressed, interoperability in healthcare might remain little more than a high-browed talking point. Here, we examine the four primary challenges that those of us in healthcare face.

Lack of Consistency When Identifying Patients

Currently, there is no consistent way of identifying a patient across the healthcare spectrum, throughout large healthcare systems or even across a network of providers. How are patients identified? By their name, date of birth, Social Security number, most commonly. The problem is that each instance of this information is stored in different ways in different systems meaning patient identification errors are possible.

According to many patient advocacy groups, one solution is the creation of a national, unique patient identifier. A patient identifier would be similar to an individual's Social Security number in that it is theirs throughout their lifetimes and would be used at every point of care. The benefits of a patient identifier are that it would be a code that sorts, categorizes, and identifies an individual no matter what system or provider used. As in all things "political," the efforts for moving such an effort forward seemed locked in a stalemate.

For years, organizations, including advocacy groups HIMSS and CHIME, have pushed for a national patient identifier. They reason that as health data exchanges continue to evolve, the need for a consistent, accurate way to identify patient health records is becoming more and more pressing. Thus, the lack of a nationally uniform patient identification system has resulted in increased healthcare facility costs, health data exchange inefficiencies and patient safety threats, among other pervasive problems.

The creation of the Health Insurance Portability and Accountability Act of 1996 (HIPAA) called for the creation of a unique patient identifier. Congress subsequently overruled this mandate because of patient privacy concerns. A highly vocal minority fear governments or industry will exploit patient data and that privacy might be even harder to protect if an identifier were to be used. However, without one, it's challenging to link disparate data to obtain a comprehensive picture of anyone patient's healthcare experiences. Thus, before industry-wide interoperability can become a reality, federal agencies will need to prioritize standardizing all aspects of patient health record exchange.

Lack of Standards for Sending, Receiving and Managing Information Between Health Systems

Currently, the healthcare technology offered by today's vendors makes it difficult to simply copy or share information from one electronic health record software or other healthcare technology to another. Mismatched fonts, external data fields, and proprietary formats mean that data has to be manipulated and sanitized before it can be imported into another system.

The adoption and use of health data standards form the basis for enabling interoperability across organizations and between electronic health record systems. According to the Office of the National Coordinator (ONC), "standards are agreed-upon methods for connecting systems together. Standards may pertain to security, data transport, data format or structure, or the meanings of codes or terms." With standards, health information exchanges, predictive analytics systems, and other information exchange efforts can be established, at least foundationally.

Throughout healthcare, a number of different standards development organizations (SDOs) create, define, update and maintain health data standards through collaborative processes that involve health IT users, but there is no single standard. With billions having been spent on EHR implementation, a health system must find more efficient ways to connect fragmented patient data, an effort that is increasingly relevant as the U.S. moves from a fee-for-service to a value-based health care system focusing on outcomes and populations. There is no interoperability standard. This lack of a common standard for capturing, transmitting, receiving, storing and managing patient data causes delays and inaccuracies – a major hurdle to interoperability efforts.

I. Background of the study

Health plays a vital role in virtually all the economies in the world. While, developed nation are putting in place measure to mitigate challenges arising from the health sector. Developing nations lag behind in this front, Kenya notwithstanding. Hammer and Berman (1995), argue that the challenge in many developing countries is exacerbated by a host of additional obstacles including inadequate tax collection system, corruption, weak management and oversight, insufficient skilled personnel and difficulties in identifying and reaching the most vulnerable citizens. High levels of waste and other forms of technical inefficiency also plague health systems in these countries. These problems are a threat to any gains that reforms to improve cost-effectiveness.

Challenges facing implementation of Interoperability in Health care systems

The implementation and use of DMS systems in Developing Countries has been explored for more than a decade and reported benefits of using this technology have included reduced waiting time for patients, reduced medication order errors, guiding healthcare protocols and simplified generation of mandatory reports to higher authorities (Douglas, 2009; Fraser et al.,2005; Rotich et al., 2003). Due to low healthcare budgets in Developing Countries, the use of Free and Open Source Software (FOSS) is particularly advocated for as a strategy to eliminate licensing costs for sustaining the systems (WHO, 2012). This has resulted in the development of various free and open source DMS systems (Fraser et al., 2005). Despite these efforts, the implementation and use of DMS systems in Developing Countries remains limited (WHO, 2012; Were et al., 2010a). Furthermore, existing implementations are biased towards hospitals in urban areas leaving rural primary care facilities marginalized from benefiting from this technology (Piette et al., 2012). Ironically, the majorities of the population in Developing Countries, like Kenya, lives in rural areas and obtain healthcare services from rural primary care facilities (NSO, 2012).

Health information technology has developed around the globe. Different countries embrace different types of DMS systems. The manner in which the system is used varies from one country to another. There are numerous differences and similarities in the healthcare system of Kenya compared to other countries in the world. In the U.S., the HITECH Act, signed in 2009, gave healthcare providers incentives to implement DMS technology. The adoption of the technology in the U.S. was mainly aimed towards improving the quality of health services. Furthermore, the U.S. government, through the Patient Protection and Affordable Care Act, has increased health insurance to millions of uninsured Americans (Hsieh, 2016). Despite issues such as optimization, cyber security and interoperability that have thwarted the implementation of DMS technology, there has been a strong push in the U.S. for its implementation. Implementation in the U.S. has been given a higher priority as compared to Kenya. Its average adoption rate as at July 2013 was at 69%.

The HITECH Act succeeded in driving adoption of DMSs by creating financial incentives for their installation in medical facilities: today, virtually all U.S. hospitals have at least a basic system in place (fewer than 2% had one at the program's inception in 2009), as do around 75% of physician offices (versus around 4% in 2008). Data sharing, however, has proven to be a far more difficult challenge. The adopted EHR systems are almost all proprietary products with their own unique data models and representations of clinical concepts. Their ability to share data is limited.

Health information exchanges (specialized networks for health data sharing) have had difficulty finding a sustainable business model. Despite years of effort by the U.S. government and by Health Level 7 (HL7), the international standards-setting body for the sharing of health data among software applications, until quite recently no technical solution to the representation or sharing of health data (i.e., interoperability) was widely embraced. Moreover, most healthcare providers have historically had no economic incentive for sharing their data with other providers, whom they might even view as competitors.

To make matters more complicated, many EHRs have usability issues. According to *Computational Technology for Effective Health Care*, a 2009 National Research Council report, the electronic medical record systems that have been adopted "appear designed largely to automate tasks or business processes. They are often designed in ways that simply mimic existing paper-based forms and provide little support for the cognitive tasks of clinicians or the workflow of the people who must actually use the system."

As a result of these issues, EHR systems often frustrate physicians because using them takes too much time and data are often not displayed in a well-integrated manner that supports care decisions. The technical term for feeding back new medical knowledge to the physician, as envisioned in the learning health system, is *clinical decision support (CDS)*. CDS tools often offer advice on making the correct diagnosis and providing the best treatments for it. Historically, CDS tools were not widely used because they have been stand-alone applications operating outside the EHR environment; thus, they usually require duplicate entry of data already recorded on paper or in the EHR and are not well integrated into the physician's workflow and clinical processes.

The United Kingdom has also been in the forefront championing for the adoption of the technology. For instance, in 2002 the National Program for IT wanted to create a national electronic health record system to be used in the entire UK. The aim of the project was to eliminate the problems of interoperability between the different EHR systems (Stone, 2014). The UK government tried to implement the complex system by contracting four companies to create a national system that would allow the state attain interoperability in the system. However, the project was not adequately implemented, due to cost and time constraints, constant server breakdowns, and information overload stone (2014). Integrating data within different facilities or required a number of laws that needed to be passed in check on patients' security and openness in sharing data.

A case study of Denmark provides an ideal setting for further analysis in terms of attaining transferrable knowledge that can inform broader eHealth initiatives and implementation across the EU. The aim of this study is to examine the recent approach used by Denmark in their efforts to achieve interoperability after deployment specifically hospital electronic health records (EHRs). A case study approach was used to (i) assess how Denmark previously attempted to foster interoperability between EHRs, (ii) examine the newest strategies to foster interoperability and health information exchange (HIE) and (iii) evaluate the study's implications for other countries experiencing national eHealth fragmentation. The findings of this study can serve as

a learning opportunity for policymakers and health planners by providing them with further insight into broader aspects effecting interoperability after deployment such as the governance of implementation strategies.

The administrative structure of the Danish health care system consists of three levels: state, region and municipality. The state maintains the responsibility for overall regulatory and supervisory functions (e.g. legislation and providing overall guidelines). The regions and municipalities are responsible for providing health care services in the primary and secondary care sectors. The public hospitals, prenatal care centres and community psychiatric units are owned and run by the regions. The municipalities are responsible for post-hospital care, nursery homes, nursing homes and rehabilitation centres.

In the Danish health sector, eHealth is the primary tool of trade among Danish health care practitioners. A progressive approach to implementation and adoption via a series of key national IT strategies and regulations enabled an accelerated diffusion of technologies and their subsequent mandatory use Olejaz M, Juul A, Rudkjøbing A et al (2012). Initially, the diffusion of EHRs relied on a 'bottom-up' approach, where the former counties (now regions) were able to select their EHR systems, vendors and technical requirements.

The outcome of this approach resulted in a plethora of proprietary hospital EHRs that were not always fully capable of exchanging clinical data Kierkegaard P (2013). A report published in 2011 by the Danish National Audit Office also found that the regions were experiencing several significant technological and organizational challenges in connection with the implementation and adoption of EHRs Adler-Milstein J, Bates DW, Jha AK (2011).In India, the healthcare system is made up of both public and private hospitals. The country has a target of providing better healthcare. This is evidenced in some of the projects that the country has implemented in a bid to improve healthcare provisions. For instance, in 2011 the Integrated National Health system was started by the Indian government to provide universal quality health services by the year 2020 (Stone, 2014). The country, despite embracing the use of DMS, is behind other countries such as France and the U.S in interoperability systems. Their main concern is national, regional and municipal linkages while taking care of patients' data security.

In Kenya, most healthcare service providers especially in rural settings, use the manual system of patient record keeping. Some facilities have only a partial DMS system with limited functionality. A large percentage of healthcare services are provided by public hospitals. In consideration of the increased benefits of DMS, Kenyan hospitals are being encouraged to implement the DMS. Public hospitals in Kenya have started adapting and implementing the DMS; however, connections between the different systems in these hospitals is missing, thereby making it difficult to link patient records (Hasanain, 2015). As a result, patients are unable to access a full and synchronized health record, because the record in Hospital A is different from the record in Hospital B (Ved and Tyagi, and Agarwal and Pandya, 2011). The lack of common patient databases is a problem for patients, who have to go through the long processes of filling out forms for information to different systems of each hospital they attend (Hasanain, 2015). As a result, this leads to repetition in records and results in patients having to undergo unnecessary tests already performed at previous visits to different hospitals.

Problem definition

Healthcare Data Records are stored in individual healthcare data pockets that make it impossible for that data to be accessed outside a specific healthcare facility which in turn limits the healthcare practitioners' ability to access information in a timely manner for timely and informed decision making (Iroju et al., 2013). Assuming that a patient visits two different healthcare institutions for treatment within a county, it is expected that each healthcare institution will have to open a file for the patient and conduct normal procedures. These procedures will be repetitive in those different hospitals. To a patient, this is costly and time consuming, (the Kisumu county all-cause referral mortality rate increased from 44% uncertainty interval [UI] 829·8–871·1 deaths per 100 000 in 1990 to 56% deaths per 100 000 in 2016. Under-5 mortality increased from 41% deaths per 1000 live births in 1990 to 43% deaths per 1000 live births in 2016). To a doctor, it causes inefficiency as time taken to redo the procedures slows down the entire process.

Justification of the study

Based on the current state of medical record information access and the push for greater technology adoption, this study was a basis for developing a design model for the universal health information systems in Kisumu County for an improved Digital Medical System (DMS) (remove). A standard platform will lead to more efficient methods for exchanging health information. The final findings of this research provides the Kisumu county government the guidelines for the implementation of interoperability through the Ministry of Health. The research finds lack of infrastructure, inadequate legislation and low budgets for the county which are the hindrances for the implementation of integrative systems. By adopting the solutions offered in this study, the health ministry will be able to provide high quality, more efficient services through advanced technologies in an updated IT platform. Therefore, there is a great need to establish a national DMS system through which any authorized healthcare provider and the patient can access medical records at any time and in any healthcare facility.

Universal Health Care UHC

Universal Health Care (UHC) means that everyone in the population has access to appropriate promotive, preventive, curative and rehabilitative health care when they need it and at an affordable cost. Universal care thus implies equity of access and financial risk protection. It is also based on the notion of equity in financing; this means that people contribute on the basis of ability to pay rather than according to whether they fall ill. This implies that a major source of health funding needs to come from prepaid and pooled contributions rather than from fees or charges levied once a person falls ill and accesses services. UHC involves judgments' about whom the potential recipients are, the range of services included within health care, and the quality of that care (WHO,2005).

The principles that should guide the formulation of a successful UHC include universality and social solidarity. Universality refers to the essential right to access health services and have financial protection from the costs of those services taking into consideration that all should have the same entitlements in relation to quality of health services. The second principle, social solidarity refers to common responsibilities and interests within society. Within the context of a health system, it particularly relates to the need for cross-subsidies in the overall health system. This includes both income cross-subsidies (from the rich to the poor, whereby individuals contribute to financing health services on the basis of their ability to pay) and risk cross-subsidies (from the healthy to the ill, whereby individuals benefit from health services on the basis of their need for services). Social solidarity is about equity. Income cross subsidies are required so that payments towards health service financing are in line with one‘s ability to pay. Risk cross subsidies ensure that use of health services is in line with individuals' need for health services (UNDP, 2009).

Health Information Systems

Information and Communication Technologies are being implemented in healthcare settings with the belief that they can contribute to improved efficiency, access and quality of healthcare services (Dzenowagis & Kernen, 2005; WHO, 2012). Among these technologies, Electronic Medical Record (DMS) systems are recognised as one of the prime transformers of healthcare and a central element in Health Information Systems (Chetley, 2006; Fitzpatrick & Ellingsen, 2012; WHO, 2012). From a care perspective, DMS systems are expected to: improve the accuracy of patient care information recorded in health records; support clinical decision-making; and improve accessibility of patients' healthcare information for continuity of care over space and time (Car et al., 2008; Chetley, 2006; Douglas, 2009; Fitzpatrick & Ellingsen, 2012). From a managerial perspective, DMS systems can generate health care statistics which are crucial in the management and planning of health services, thereby improving the quality of routine health data in health systems (*ibid.*).

Interoperability is a requirement for the successful deployment of digital medical systems (DMS). DMS improves the quality of healthcare by enabling access to all relevant information at the diagnostic decision moment, regardless of location. It is a system that results from the cooperation of several heterogeneous distributed subsystems that need to successfully exchange information relative to a specific healthcare process.

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Interoperability in Healthcare information System

Interoperability is the ability of an IT system component to work with other IT system components without special effort on the part of the user. Interoperability becomes a quality of increasing importance for information technology products as the concept that "The network is the computer" becomes a reality. In the government, interoperability has traditionally been viewed as the Department of Defense (DoD) and Department of Veterans Affairs (VA) capability to share electronic health information of wounded warriors, veterans, and shared beneficiaries. Many wounded warriors and other beneficiaries are also recipients of private sector healthcare so there is additional need to capture and share this data as well to optimize continuity of care. integrative systems are needed that are able to share or exchange data from the military, the VA, and from private sector providers. To promote and safeguard the health of populations, interoperability should be extended to include systems and databases used by federal or state agencies providing public health services, such as the Environmental Protection Agency's systems for monitoring environmental hazard exposures, the Centers for Disease Control's bio-surveillance activities, or data from state public health laboratories. This article summarizes the work of the interoperability team—a triple helix team of academic, government, and industry experts, brought together to focus on the complex issues of establishing electronic healthcare record interoperability.

Interoperability can be achieved at different levels. At the highest level, data are in a format that a computer can understand and operate on, whereas at the minimum type of interoperability, the data are in a format that is viewable, so that information is available for a human being to read and interpret. Paper records can be considered integrative in that they allow data to be read and interpreted by a human being. In the remain-der of this article, however, we do not discuss interoperability, in this sense; instead, we focus on electronic interoperability, for which the first level of interoperability is unstructured viewable electronic data. With unstructured data, a clinician would have to find needed or relevant information by scanning uncategorized information. The value of viewable data is increased if the data are structured so that information is categorized and easier to find. At the highest level the computer can interpret and act on the data.

Over the last few years, there has been an increasing awareness by both the private and public sectors of the ability to improve the quality and safety of healthcare with integrative healthcare information technology (IT) systems Markle Foundation, (2003). Some of these health information technologies include electronic health records, personal health records, health information exchanges, evidence-based medicine, and comparative effectiveness research (Hersh, 2009). As health care systems are increasing the adoption of health IT, a growing amount of data is being gathered. One of the ultimate goals in using health information technology is to evaluate and provide information to providers and patients on the most appropriate treatment options based on scientific comparisons of the effectiveness of treatments, including factors such as quality, risk, benefit, and cost (Congressional Budget Office, 2007). Data standards and interoperability are currently a bottleneck for seamless exchange and use of data to derive the maximum benefits of health IT. In order to be able to share health information, interoperability across software from multiple vendors is critical (California HealthCare Foundation, 2005). When interoperability is lacking, it impedes access to data, which in turn leads to inefficiencies, increased cost, and poor quality (Stiell, Forster, Stiell, and van Walraven, 2003; Smith, Araya-Guerra, Bublitz, Parnes, Dickinson, Van Vorst, Westfall, and Pace, 2005; Shapiro, Kannry, and Kushniruk, and Kuperman,2007). A core requirement for interoperability is the need for both data and messaging standards. Interoperability of healthcare information systems and the lack of consistent data standards has been a problem in healthcare for many years. Interoperability problems in healthcare include gaps in data standards, several overlapping standards, multiple data standard development organizations, and no overarching mechanism for ensuring the development and usage of data standards.

Barriers to Interoperability in HealthCare

There is no doubt that interoperability has a major positive impact on healthcare. However, the lack of interoperability in healthcare systems and services has long been identified as one of the major challenges in healthcare. For instance, a practitioner in a private practice may have difficulty obtaining complete information about a patient who is currently being hospitalized; also, a practitioner may repeat tests and procedures because he or she does not have prior information about the patient. Consequently, this section appraises the barriers impeding interoperability in healthcare.

Complexity of HealthCare Domain

The healthcare domain is a very complex one because it involves a lot of actors such as doctors, radiologists, nurses, pharmacists, laboratory technicians who collaboratively participate in the treatment of patients. Each of these actors generates information that is needed by one another. The information in the healthcare domain is also enormously complex, because it covers different types of data such as patient administration, organizational information, clinical data and laboratory/pathology data Ryan (2006). However, safe and effective healthcare relies heavily on the ability to exchange data from one software to another, and from one person to another, and also on the ability to understand that information so that it can be used. However, care givers may be unwilling to share health-related information, but even when they agree to share information; individual entities may have their customized or vendor-driven software that is incompatible and not integrative with other systems.

Standardization Problems in HealthCare

The operational goal of standardization is to provide sets of consistent specifications called "standards" to be shared by all parties manufacturing the same products, or providing the same services Groen and Wine (2009). Standards are agreed-upon specifications that allow independently manufactured products, whether physical or digital, to work together, or in other words, to be integrative. The major goal of standards in the healthcare domain is to improve patient care by allowing interoperability among disparate systems. However, standards are often too general and subject to local interpretation and implementation. For instance, there is a "standard" that every patient admitted to a U.S. hospital undergoes nursing assessment processes which are not uniform or standardized from one hospital to the other. A serious error or omission in this process can lead to the untimely death of a patient Bock, Carnahan, Fenves, Gruninger, Kashyap, Lide, Nell, Raman and Sriram (2005). In addition, abbreviations are barely standardized within the healthcare domain. Moreover, there are a lot of standards used in healthcare. These include the Health level 7 standards, OpenEHR, Digital imaging and communications in medicine (Dicom), CEN/ISO EN13606, International Classification of Disease etc. Healthcare institutes however do not conform to a single standard, and the use of multiple standards breeds confusion Bock, Carnahan, Fenves, Gruninger, Kashyap, Lide, Nell, Raman and Sriram (2005). Thus, the pursuit of high patient care and safety is futile in the absence of uniformity or standardization of the basic means of communication.

Use of Incompatible clinical Ontologies

Existing efforts aimed at achieving semantic interoperability within the healthcare domain rely on agreements about the understanding concepts stored in terminology systems such as nomenclatures, vocabularies, thesauri, or ontologies. This is based on the fact that all computer systems would understand one another perfectly if they use the same terminology or ontologies, or mutually compatible ones Groen and Wine (2006). However, the growth of incompatible terminologies and ontologies within the healthcare domain is exponential. Thus, the use of incompatible and heterogeneous terminology and ontologies in healthcare contribute to the problem of interoperability. This is because heterogeneous terminologies and ontologies consist of multiple representations for the same clinical concept.

Legacy Systems

Legacy systems (usually electronic medical record systems) with limited interoperability capabilities are those systems implemented prior to the introduction of common national standards. These systems are still in use today. Their data storage, input, and inventory of data items are unique and often proprietary. The problem associated with legacy systems is that they are designed for a particular task or facility. Moreover, many of these systems are designed to prevent interoperability with other vendors' applications to protect market share and to encourage purchases by hospitals or clinic chains.

Resistance to Change

The healthcare industry unlike most industries (e.g. banking industry) still relies on piles of papers/ handwritten notes (paper records) for patients care. This is because most healthcare providers are resistant to change from their traditional paper-based system to electronic health system because of the following reasons which were emphasized in Rosati, Lamar (2005).

Large number of physicians in individual or small group practices with very limited administrative support for IT and related practice changes;

The lack of uniformity and interoperability of IT systems from different vendors; Regulatory limitations on hospital funding of IT for physicians;

Lack of trust and other legal concerns with respect to joint IT solutions; and Privacy and security concerns.

Thus, the transition from a paper-based system to an electronic integrative system in healthcare still remains a challenge for healthcare providers. The paper-based process is inherently error-prone, as the multiple actors involved in the patients' care may not communicate complicated results appropriately, leading to medical errors. The paper-based system also adversely affects the management of medical information and the secure sharing of information across the continuum of care Groen and Wine (2006).

Ontology theory

Ontology is the theory of objects and their ties. It provides criteria for distinguishing different types of objects as concrete and abstract, existent and nonexistent, real and ideal, independent and dependent and their ties which can be relations, dependencies and predication.

Information technologies have a strong impact on the organizational structure of governments, hospitals, healthcare centers and private companies. These organizations rely upon this technology for collecting, producing, representing, processing and exchanging information. They increasingly depend on information technology standards and protocols to guarantee the mechanism for information management that forms the basis of collaborative work. As a result, how data are collected in information systems has a direct impact on the potential to process and exploit information within an organization. The HTI field involves professionals from multiple knowledge areas such as medicine, engineering, economics and law. The large number of different backgrounds in this relatively new field necessitates consensus on the concepts used. During the development of the IHIS information system, we detected discrepancies between professionals with respect to the semantics of several terms and taxonomies. As a result, there arose a need for a mechanism to represent knowledge based on consensus between the relevant parties.

In order to deal with this highly variable kind of patient records, we need mechanisms to personalize the knowledge describing both the hospital in which the patient has been treated or diagnosed, the zone to which the hospital belongs and the patient. Once that is done. Then the diagram bellow can be used to explain the manner in which the hospitals in various zones will relate with each other across to the national level without information loss or mix up.

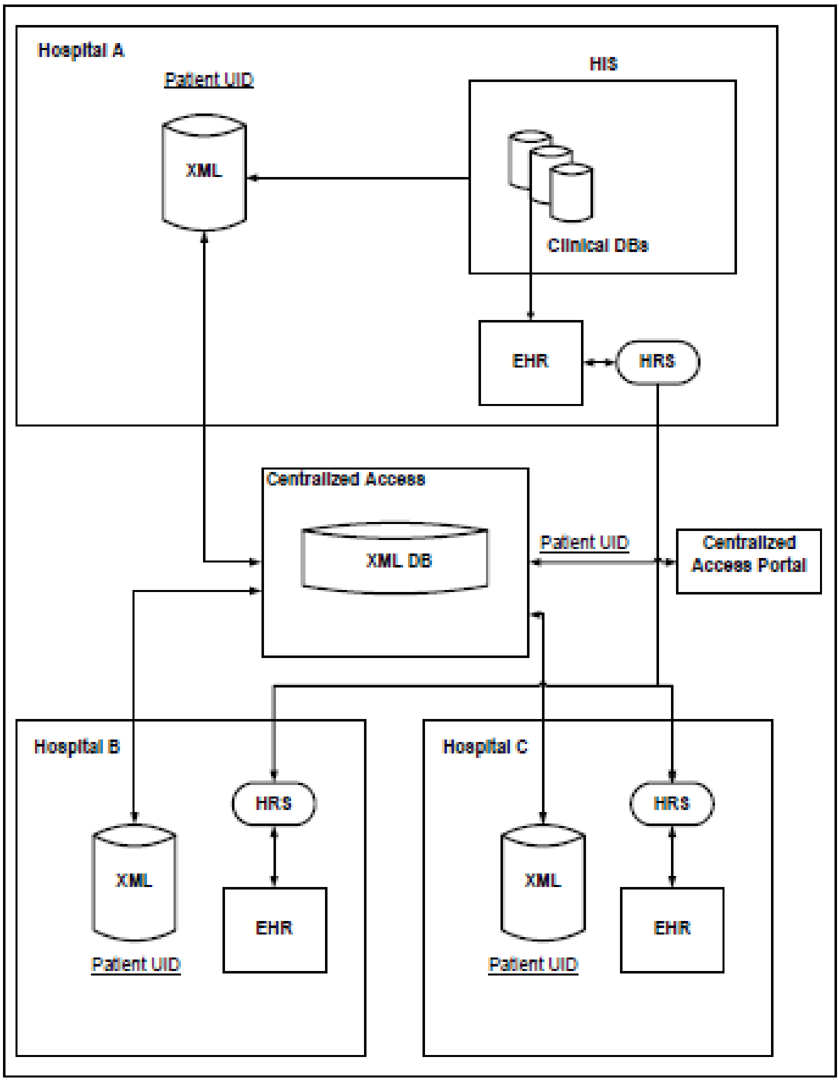
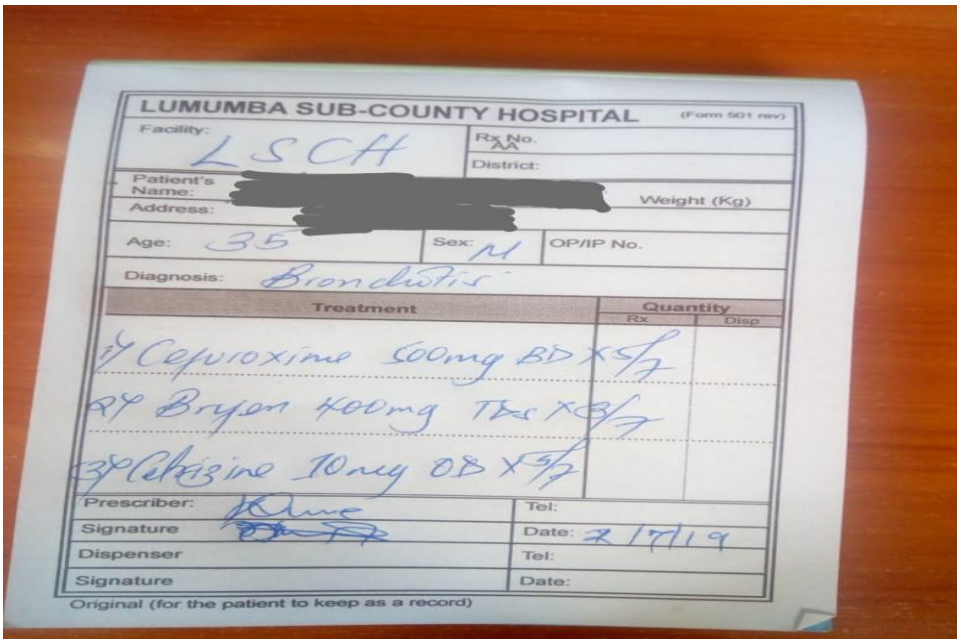


Figure 1 ontology theory for the integrative health information system

Level of interoperability

In the literature review, the researcher, looked at the various levels of interoperability in the current setup of our hospitals, this coupled with a pre-research, revealed that all public hospitals are still using physical level interoperability, where information is still passed manually using filled forms. Below is a sample of a prescription done at Lumumba hospital. This document is scanned then saved on a flash disk, CD or computer's hard disk, from this point the patient is required to carry a copy of the document to another facility, for example Kisumu east sub county hospital. This is tamed as a Level 0 and is described as isolated interoperability in a manual environment. The key feature of Level 0 is human intervention to provide interoperability where systems are isolated from each other. Level-0 systems need to exchange data or services, but cannot directly interoperate. The lack of direct, electronic connectivity may exist solely due to differing security or access-control policies, or it may be a lack of physical connection between the two systems.

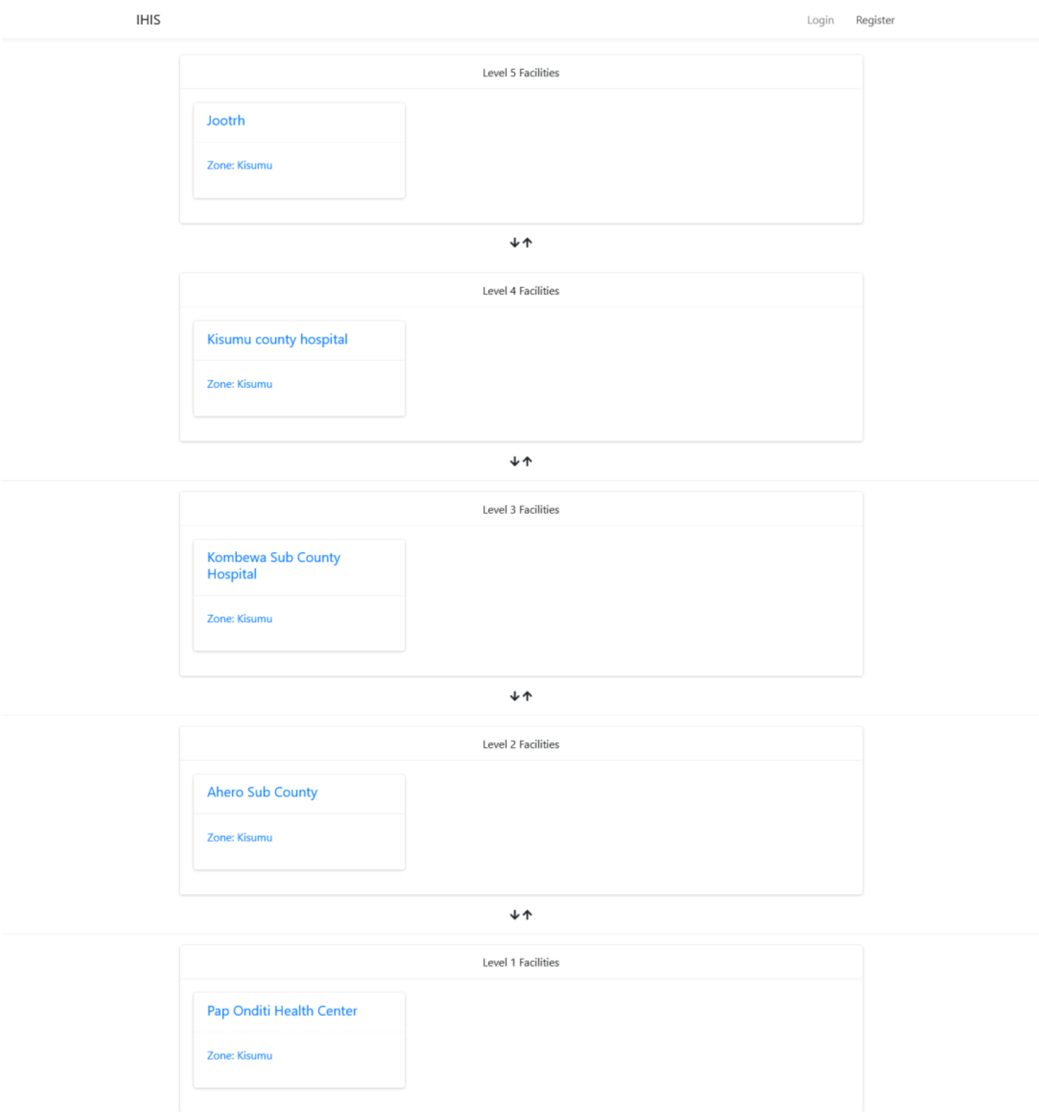

LUMUMBA SUB-COUNTY HOSPITAL (Form 501 rev)

Facility: LSCH
Rx No.
District:
Patient's Name: [redacted]
Weight (Kg)
Address: [redacted]
Age: 35
Sex: M
OP/IP No.
Diagnosis: Bronchitis

Treatment	Quantity Rx	Quantity Disp
1) Cefuroxime 500mg BD x 5/7		
2) Bryon 400mg Tds x 3/7		
3) Cetrizine 10mg OD x 5/7		

Prescriber:
Tel:
Signature
Date: 2/7/19
Dispenser
Tel:
Signature
Date:
Original (for the patient to keep as a record)

Figure 4 1: Prescription sheet



Test database design

Being a system to be used with other already existing databases, the researcher came up with the following consolidated database schema that has the tables that can be found in the existing systems such as the user table that will be from the NIIMS systems and the health and medical practitioners system. These holds data about patients and health service providers

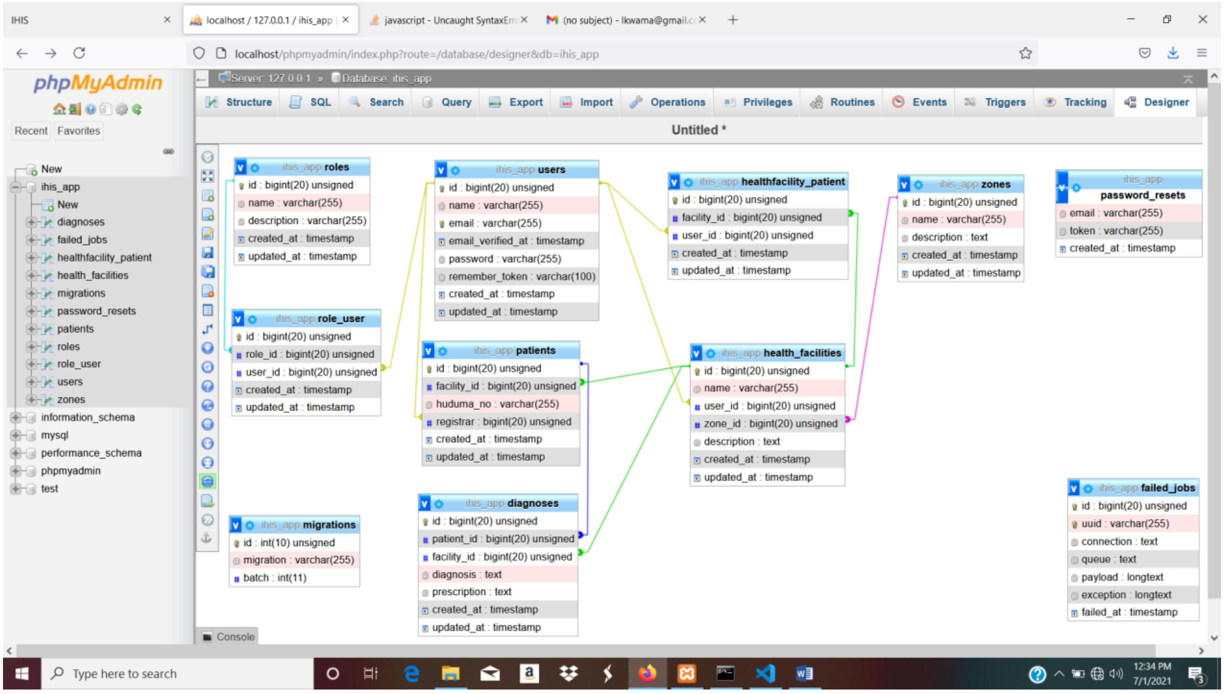


Figure 2 National Database structure

Current health care models informing the design of the existing health care system.

This being the second objective, it capitalized on the strength gained in chapter two under literature review. Based on literature review, Multi-tier client–server architectures were picked as the best architecture for designing this model to keep up with the pace of change required to deliver a compelling software product and to leverage emerging technologies, a three-tier architecture provides numerous benefits. It allows a developer the opportunity to extend, modularize, and be able to configure their application. Two standards also stood out when it comes to matters healthcare standardization and these are semantic and syntax standards. Semantics is aimed at the documentation of the system whereas syntax aims at managing the actual system development process. The architectures discussed in this study include master-slave, two-tier client-server, multi-tier client server, distributed components, peer-to-peer and service-oriented architectures. This standards and architectures were important to this study in the sense that they allowed for ease of design and implementation of the model through simulation in order to demonstrate its applicability.

Objective three of the study sought to have the model designed and developed with respect to all the combined literature review which was quite elaborate. Based on the research findings, users are more reliant on a web-based system that is accessible from anywhere in the organization.

II. Recommendation

Interoperability in healthcare is vital as it allows for faster processes on the part of the healthcare institutions while helping reduce costs on the part of the patients. With the automation levels seen in most healthcare institutions, the study recommends the full standardization of both syntax and semantic standards. Most importantly, is the use of distributed component architectures, the layered approach organizes processes into layers such that each layer is implemented as a distinct logical server. The limitations to this approach are its lack of design flexibility that should be done for each layer and the demand to plan for its scalability to accommodate more clients. Distributed component architecture structures the system as a set of interrelating components or objects that make available an interface to a series of available services. These services are available to other components via middleware that is facilitated by method or remote procedure calls. Distributed component architecture relies on middleware which manages object interactions, resolves variances between parameter types handled between object, and provides a series of shared services that application object use. Some of the existing middleware include CORBA (Orfali et al., 1997), .NET and Enterprise Java Beans (EJB).

The following are the advantages of using a distributed component model:

- It lets the designers to delay decisions on how and where services ought to be provided. The components that provide services can execute on any node on the network.
- Being an open system architecture, it allows for required resources to be made available if and when needed without causing major disruptions on the existing system.
- It is flexible and scalable i.e. new components can be added with increase in the system load without halting other system services.
- The system can be reconfigured dynamically as the components or objects move across the network as expected. This is an important aspect especially where demand on services keeps fluctuating. To improve a system's performance, a component that provides a service can move to the same processor as the service that is requesting components.

This architecture can be implemented as a logical model that allows one to organize and structure the entire system (Erl, 2005). This can be achieved by providing the functionality of an application either as a service or a combination of services which can be provided by a set of distributed objects. For example, in a healthcare application there may be application objects dealing with patient management, pharmacy, and imaging among others. This architecture would best illustrated in data mining systems which look for data associations stored in a set of databases. Data associations are arrived at by separating the databases, conducting intense process computations and graphically representing the results (Erl, 2005).

The advantage of this architecture over the layered one is that there is minimal disruption with the addition of new databases as each added database is made accessible by adding another component which simplifies the interfaces that control data access. These databases may be hosted on different hosts. Having new integrator objects allows for the mining of new forms of relationship.

There are two major disadvantages of this architecture that include its design complexity when compared to the client–server model that makes it hard for one to envision and comprehend and the lack of acceptance of standardized middleware by the users arising from its complexity, though if users are well trained, then it becomes the best model to run in an environment where population is large. Although service-oriented architectures offer solutions to these problems, distributed component architectures perform better and have high throughput since message-based interaction are slower than RPC communications. Figure 18 represents Level-2 interoperability. Level 2 is described as functional interoperability in a distributed environment. The key feature of Level 2 is the ability of independent applications to exchange and use independent data components in a direct or distributed manner among systems. Level-2 systems must be able to exchange and process complex (i.e., heterogeneous) files. These files consist of items such as annotated images, maps with overlays, and multi-media or hyper-linked documents. The systems are generally connected to multiple systems on local net-works. A key capability provided by systems or applications, at the top end of this level, is the ability to enable and provide web-based access to data.

The primary enabler of Level-2 interoperability is ***applications***. The applications must be able to read, write, and process the information that is exchanged.

Figure 2 1:Level 2 Functional Interoperability in a Distributed Environment

Procedures**:** Level 2 of the *procedures* attribute is characterized by program types of procedures. These procedures include such things as training, staffing, and planning in a program environment so that other systems within the same program environment will have similar procedures in place. In addition, other procedures are based on adherence to a common operating environment.

Applications**:** Level-2 systems are identified by their increasing level of sophistication and complexity and by their ability to provide a heterogeneous understanding of the data being exchanged. E-mail at this level includes the successful exchange of attachments. Software necessary to parse formatted messages such as office automation is associated with this level, and is characterized by software products such as word processing applications, spreadsheet applications, desktop data base applications, presentation graphics applications, and image and map viewers. Web browsers and their associated "helper" applications complete Level 2. Mohan (2002).

***Infrastructure*:** The primary change in *infrastructure* capabilities from Level 1 to Level 2 is the transition from a peer-to-peer connection to a many-to-many connection, as represented by LANs. This need to work with multiple systems is driven by application functions such as e-mail. This form of collaboration requires connections to more that one system before it is truly effective. The ability to establish connections to multiple systems without reconfiguring hardware or the infrastructure is a major characteristic of this level. Support for protocols that can be used to establish even larger networks also comes into play. The TCP/IP protocol is used to exchange information on a LAN through such functions as a web browser. The TCP/IP protocol also has the capability to support more complex infrastructures that are seen at Level 3. Level-2 infrastructures support moving information locally between multiple systems. The differentiation between the particular systems is supported by the infrastructure with minimal need for user involvement. Hardware and communications protocols are designed to move information between multiple systems. Some examples are Network Interface Cards (NICs), and LAN protocols such as Ethernet or Token Ring.

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