Transition to Cloud Computing in Healthcare Information Systems

by

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SUBMITTED TO THE DEPARTMENT OF SYSTEM DESIGN AND MANAGEMENT IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN SYSTEM ENGINEERING AND MANAGEMENT AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

FEBRUARY 2012

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ABSTRACT

This thesis is a study on the adoption of cloud computing in healthcare information technology industry. It provides a guideline for people who are trying to bring cloud computing into healthcare information systems through the use of a framework of tools and processes to overcome both technical and business challenges.

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Acronym

ACA	Affordable Care Act
AHRQ	Agency for Healthcare Research and Quality
ARRA	American Recovery and Reinvestment Act
CHC	Community Health Center
CHPL	Certified Health IT Product List
CLIA	Clinical Laboratory Improvement Amendments
CMS	Centers for Medicare & Medicaid Services
CONNECT	An open source software NHIN
EHR	Electronic Health Record
EPHI	Electronic Protected Health Information
EMR	Electronic Medical Record
FISMA	Federal Information Security Management Act
HCCN	Health Center Controlled Network
HHS	United States Department of Health and Human Services
HIE	Health Information Exchange
HIPAA	Health Insurance Portability and Accountability Act
HIT	Health Information Technology
HITECH	Health Information Technology for Economic and Clinical Health Act
NAMCS	National Ambulatory Medical Care Survey (NAMCS)
NCHS	National Center for Health Statistics
NwHIN	Nationwide Health Information Network

NwHIN Direct	Nationwide Health Information Network Direct
ONC	Office of the National Coordinator for Health Information Technology
PCAST	President's Council of Advisors on Science and Technology
PHI	Protected Health Information
PHR	Personal Health Record
PPACA	Patient Protection and Affordable Care Act
PRA	Paperwork Reduction Act
RHIO	Regional Health Information Organization
SCANNER	Scalable Nationwide Network for Effectiveness Research

1. Introduction

The focus of this thesis is to explore the current state of the art of applications of cloud computing in the healthcare information technology industry. The goal is to provide guidelines for people who are trying to bring cloud computing into healthcare information systems, through the use of a framework of tools and processes to overcome both technical and business challenges.

The healthcare industry has been slow in adopting the cloud computing model compared to some other industries. According to the CDW 2011 Cloud Computing Tracking Poll, only thirty percent of organizations in healthcare are implementing or maintaining cloud computing based systems (CDW LLC, 2011). Among those healthcare organizations who have adopted cloud computing, 39% of them are using Live Meeting, 24% are using Gmail, and 18% are using Google Docs. Therefore so far the dominant cloud services adopted in healthcare are still commodity applications, not yet the core applications with healthcare specialties or other cloud-based services, like storage.

During the course of the research for this thesis, I reviewed the latest literature, interviewed a number of professionals, researchers, and leaders in cloud computing and healthcare information technology fields, and used various analytical tools learned in the System Design and Management program, such as system analysis and business dynamics, to fully understand the dynamics and challenges in the transformation from conventional computing into cloud computing in healthcare industry.

A series of issues, including but not limited to security and privacy, government policies and regulations, and data handling are the major roadblocks for a rapid cloud computing adoption. There are much literature describing the existence of these issues, their consequences, and the urgency of solving these issues. But few have addressed the root causes and provided pragmatic solutions. This thesis is an attempt to reconcile the major issues that have been discovered in literature and in discussions with people in the field, and then provide practical guidelines on overcoming these roadblocks using analytical tools. Even though no one absolute solution works for all scenarios, at least we hope to reveal all the hidden blocks and spell out

the principles, so that the readers can get ahead of the curve when facing the transformation. Willingly or unwillingly, people in the field have to stand up to the transformation as it is coming at their way.

To make this thesis self-sufficient for all levels of readers, it will start with some background information on cloud computing and healthcare information systems, as well as related regulations. Healthcare is a huge industry and information technology plays an important role with many perspectives. In the context of this thesis, the discussions will be centered on the domain specific applications, e.g. the Electronic Healthcare Record (EHR) information systems, rather than the commodity application systems (e.g. Emails, Calendars, Web Meetings, Offices, etc.).

Then it will discuss in depth the state of the art cloud services and applications in healthcare domain and the known and unknown issues with these services and applications, in both technical and business arenas.

Following that, the thesis will analyze the issues using systems and business analytical instruments to fully understand the issues from different angles, as well as the forces and interactions with other critical factors in the business ecosystem.

Finally, based on the facts and analysis, it will propose a framework of a set of process steps and characteristics that can be applied at different stages during the transformation from conventional computing to cloud computing. A case study on cloud based EHR adoption will be used to demonstrate the application of the proposed framework.

2. Background Information

2.1 Cloud Computing

Cloud computing has been coined as an umbrella term to describe a category of sophisticated on-demand computing services initially offered by commercial providers, such as Amazon, Google, and Microsoft (Rajkumar Buyya, 2011). The key concept of Cloud Computing is to deliver computing resources through a global network when and where the customer requests. The "cloud" in the term is a metaphor for computing resources (hardware and software) that companies and users access without the need to know exactly where that hardware and software is physically located. It is also used as a graphical symbol for the Internet in diagrams of computer networks to depict the varied technology infrastructures the cloud conceals (Hugos & Hulitzky, 2011).

The technology advancement in grid computing and virtualization with efficient cluster management has made it possible for cloud computing to provide large scale computing services to massive user bases. Cafaro and Aloisio (Cafaro & Aloisio, 2011) gave a clear explanation on the relationships among grids, clouds and virtualization. In short, grids provide the distributed infrastructure and promise to deliver computing power on demand, clouds provide computing services, business applications and functions through grid, and virtualization decouples cloud services from physical locations by hiding the physical characteristics of computing resources. They work together to achieve dynamic resizing of the infrastructure, balance of workload, server consolidation, and on-demand resource provision.

Cloud computing is a type of network computing. Network computing is not new, but compared to the conventional network systems, cloud computing is unique in the following areas.

Design principles & architecture

Many cloud service providers evolved from traditional IT companies. Traditional IT products (software, hardware, or integrated systems) are typically designed to meet specific

requirements in the traditional network environment. Even though many traditional IT products also support distributed computing, cloud based products (software, platform, or infrastructure) emphasize the use of grid computing and virtualization technologies, and face a different set of challenges in terms of scalability, security, and flexibility. For example, in cloud computing, user data is usually saved in data centers that are independently located, and are shared by many users. The cloud service provider may save storage by allowing different users access to the same disk drives, but in turn they have to make sure users are not allowed to access other user's data without permission.

For cloud service users, taking Software as a Service (SaaS) applications as an example, the design and development of the application is usually done in a web environment that is provided by the cloud hosting company. Design is generally limited by the capabilities of low-level programming that a traditional Software Development Environment (SDE) usually has, but instead, cloud-based SaaS provides pre-defined high-level components or objects to speed up the development. An example is the development of customized Customer Relation Management (CRM) applications on SalesForce.com or Force.com. Because of the widely expanded range of applications sharing on the same cloud, the design principles and architecture of the cloud varies significantly from traditional software applications.

Security & data storage considerations

One of the core design principles of cloud computing is dynamic scalability, or the ability to provision and decommission servers or services on demand. To the cloud user, dynamic scalability can be achieved by using third-party data storage or web service clouds on a subscription basis. However, doing that requires them to store data in the cloud. Because the data is physically stored at an unknown location, extra caution is needed to ensure the security and reliability of the data storage.

Sometimes regulations and government policies require different level of security on different data sets. For example, in the healthcare industry, the HIPAA Security Rule posed a bigger challenge to safeguarding protected healthcare information. Meeting the security and privacy rules is critical to a successful cloud computing system.

Service delivery & deployment methods

Whether the cloud is provided as an internal corporate resource (private cloud), as a service hosted by a third-party (public cloud), or as a hybrid of these two models, the traditional software package installations through CD or other mediums, are changed to instant subscription and pay as you go. Most cloud services are delivered through web browsers, or in some cases a thin-client with very simple functions to serve as the user interface – which is also called "Ubiquitous Network Access" – services are made available over the network using standard mechanisms which support a wide range of client devices (e.g., desktop, laptop, PDA, phone). The new service delivery and deployment methods give users the maximum flexibility and portability on the use of the services they paid for to meet the business volatility requirement. However, the designer and the developer should also know the limitations of a web browser or a thin-client they are restricted to.

New pricing & business models

The ability to scale operations up and down smoothly as market conditions and business environments change is one of the key elements for companies to stay agile and successful in today's world. IT expenditures as one of the biggest capital investment to a business are always under scrutiny when it comes to financial planning or cost reduction. Use of clouds helps companies of different sizes to change from a fixed cost model to a variable cost model in terms of IT operating expenses. It is very attractive to small businesses or startups that are starved for cash when they are expanding. It also gives enterprises competitive advantage when they have the luxury of scaling up and down quickly. However, while the benefit is obvious, many companies are reluctant to move because either their capital expenditures have been done or their new spending model has yet to be built into the overall business processes in the company.

Benefits of Cloud Computing

In a report on public sector cloud computing published by the Federal CIO Council (Kundra, 2010), the benefits of cloud computing are summarized into six areas:

- *Economical.* Cloud computing is a pay-as-you-go approach to IT, in which a low initial investment is required to get going. Additional investment is incurred as system use increases and costs can decrease if usage decreases. In this way, cash flows better match total system cost.
- *Flexible.* IT departments that anticipate fluctuations in user load do not have to scramble to secure additional hardware and software. With cloud computing, they can add and subtract capacity as its network load dictates, and pay only for what they use.
- *Rapid Implementation.* Without the need to go through the procurement and certification processes, and with a near-limitless selection of services, tools, and features, cloud computing helps projects get off the ground in record time.
- *Consistent Service.* Network outages can send an IT department scrambling for answers. Cloud computing can offer a higher level of service and reliability, and an immediate response to emergency situations.
- *Increased Effectiveness.* Cloud computing frees the user from the finer details of IT system configuration and maintenance, enabling them to spend more time on mission-critical tasks and less time on IT operations and maintenance.
- *Energy Efficient*. Because resources are pooled, each user community does not need to have its own dedicated IT infrastructure. Several groups can share computing resources, leading to higher utilization rates, fewer servers, and less energy consumption.

Technology Adoption Curve

Due to these unique characteristics, many companies and organizations that have had extensive experiences with conventional network systems are tempted to maintain current technology in order to avoid switching risks or "unknown" risks. Very often it falls onto the shoulder of their consultants or contractors (vendors) to build the business case and defend the benefits of cloud computing. While cloud computing is a well-established concept and encompassed by the academic community, pioneer technology developers, and all major IT service providers, there is still considerable gap between them and the rest of the business

world, especially in the traditional sectors such as manufacturing, finance, healthcare, governmental departments, etc. It could be an extra burden to the vendors to demonstrate and deliver the benefits.

While it is unclear if and when all conventional information systems will transition into cloud computing, there is a clear trend that more and more companies and organizations are moving towards to cloud computing. Just like any other new technology or innovation, this transition follows the typical technology adoption curve (Figure 1). In March 2011, Avanade commissioned a survey of 573 C-level executives in 18 countries. The research finds cloud computing has reached it first milestone as a mature technology (Avanade, 2011). According to the survey, 74% of enterprises are using some form of cloud services.

The Technology Adoption Curve
As captured by Everett Rogers in his book <<Diffusion of Innovations>>.

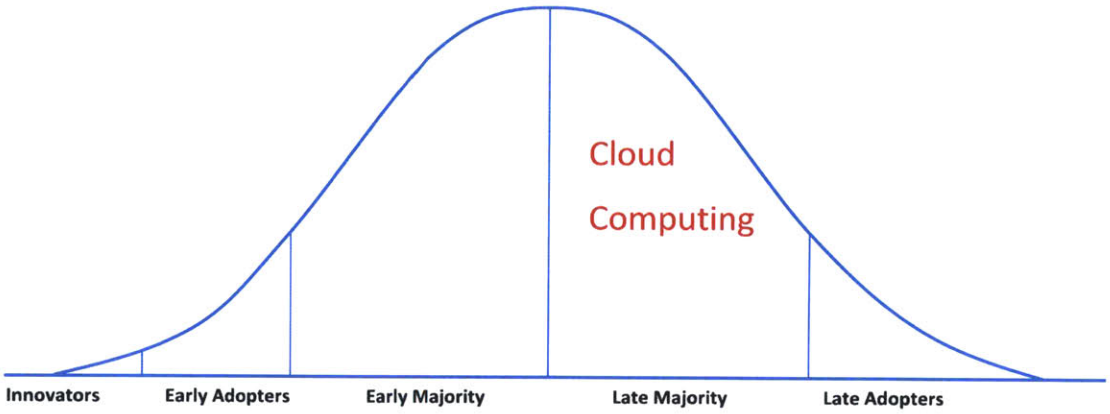


Figure 1 Cloud Computing Technology Adoption Curve

Different business sectors may fall into different categories. It is noticed by experts in Cloud Computing that cloud adoption is stronger in small businesses and big enterprises, while it stays very low in middle sized companies. The explanation is simple. Small companies often have IT infrastructure shortages and limited IT budgets. IT is considered a pure cost instead of a valuable resource. Cloud computing allows them to use sophisticated tools without the trouble of acquiring and managing a complicated technological infrastructure, and pay at a price that is metered from real usage. For big enterprises, cloud computing can be

leveraged in a different way: the cloud is considered a solid way to deal with variable workload and to delegate services, a viable alternative to outsourcing. More and more private clouds are used internally and interact with public clouds to exchange data and services in a more or less transparent way when needed. Medium size companies typically, have a real IT budget including human and material resources, but resistance to change and outsourcing make cloud computing a less favorite choice.

The anticipated business benefits in terms of business case, financial value, strategic direction and flexibility provided are appreciated by organizations worldwide and the current adoption curve confirms that cloud computing is here to stay and has a potential to transform business and IT. From a vendor side, there is still work required to improve the understanding of cloud computing as the market is missing a clear and universal understanding of what cloud computing is, the different types and the different services. Both business and IT departments need to be involved. As maturity increases and offerings get broader and clearer, organizations will further expand their cloud sourcing and vary the models they use.

2.2 Healthcare Information Systems

Just like in all other industries, healthcare information systems have gone through many changes to evolve from verbal descriptions and paper based manual processes to modern computer based data collection and information process systems. Healthcare information is sensitive to both patients and physicians who create the information and scientists who use the information to conduct research. Privacy and security are the top concerns. In recent years, there has been increasing demand from both the healthcare community and the government for more advanced and easy to use Healthcare Information Technology (HIT) systems, in order to meet the regulations and rules established.

Overview of Healthcare Information Systems

The definitions of the types of health care information vary by different organizations. According to (Wager, Lee, & Glaser, 2009), there are mainly two types of healthcare information: the administrative information, and the clinical information. Focusing on these two types of healthcare information, HIT systems are also centered on administrative systems or clinical systems.

Type	Clinical	Administrative
Patient-Specific Information	*Identification Sheet* *Problem List* *Medication Record* *History* *Physical* *Progress Notes* *Consultations* *Physicians' Orders* *Imaging and X-ray results* *Lab results* *Immunization Record* *Operative Report* *Pathology Report* *Discharge Summary* Diagnoses Codes Procedure Codes	*Identification Sheet* *Consents* *Authorizations* Pre-authorization Scheduling Admission/Registration Insurance Eligibility Billing Diagnoses Codes Procedure Codes
Aggregate Information	Disease Indexes Specialized Registers Outcomes Data Statistical Reports	Cost Reports Claims Denial Analysis Staffing Analysis Referral Analysis

	Trend Analysis Ad hoc Reports	Statistical Reports Trend Analysis Ad hoc Reports
Information Systems	- Contains clinical or health-related information relevant to the provider in diagnosing, treating and monitoring the patient's care	- Contains primarily administrative or financial data - Used to support the management functions and general operations of the health care organization
Application Examples	- EMR/EHR systems - Ancillary information systems (laboratory, radiology, pharmacy, etc.) - Telemedicine and telehealth systems - Medication administration systems - Mobile health monitoring systems	- Patient administration systems (registration, scheduling, billing, etc.) - Financial management systems (payroll, personnel management, accounts payable, inventory management, etc.) - Supply chain management systems - Office administrative systems (emails, document editing, web conference, etc.)

Table 1 Healthcare Information and Information Systems

History of Healthcare Information Systems

The history and evolution of HIT is intertwined with the health care environment changes and information technology development. The major advances in information technology and significant federal initiatives had enormous influence on the evolution of healthcare information systems. For example, in 1980s the unveiling of affordable and powerful PCs promoted the use of HIT in small healthcare organizations, and in 2000s the federal stimulus money caused fast pace adoption of EHR systems.

Time	Healthcare Environment	State of IT	State of HIT
1960s	- Enactment of Medicare & Medicaid - Cost-based reimbursement - Focus on financial needs and capturing revenues - Building mode	- Mainframe computers - Centralized processing - Few vendor-developed products	- Administrative systems - Used primarily in large hospital and academic medical centers - Developed and maintained in-house - Data processing was primarily centralized on mainframe computers

1970s	- Hospital growth and expansion - Medicare and Medicaid expenditures rising - Need to contain health care costs	- Mainframes were still in use - Minicomputers became available and more affordable	- Increased interest in clinical applications - Off-the-shelf systems became available through vendor community - Shared systems among smaller hospitals
1980s	- Medicare introduced prospective payment system for hospitals - Medicaid and other private insurers follow suit - Increased Need for financial and clinical information	- Unveiling of the PC - Advent of Local Area Network (LAN)	- Expansion of clinical information systems in hospitals - Affordable and powerful computers became available to smaller organizations - Distributed data processing - Increased integration of financial and clinical information systems
1990s	- Medicare changes in physician reimbursement - Health care reform efforts of Clinton administration - Growth of managed care and integrated delivery systems - Calls for adoption of computer-based patient records	- Unveiling of the Internet - Internet revolutionized how organizations communicate with each other, market services, conduct business - Cost of hardware drops	- Vendor community explodes - Wide range of HIT products and services available - Increased use of Internet by health care organizations - Growing interest in clinical applications - Still relatively small growth in adoption of EMR systems
2000 and beyond	- HHS calls for standards on EHR - Spiraling health care costs - Economic upheaval and growing number of uninsured - Federal stimulus money available for HIT - New administration	- Internet use reaches new level - Voice recognition rebounds - Bar coding and RFID - PDAs and mobile computing - Web 2.0 and Cloud Computing technologies	- Infusion of HIT funding - National call for EHR adoption - Regional health information organizations - Increased need for point of care clinical systems

Table 2 History and Evolution of HIT – summary based on (Wager, Lee, & Glaser, 2009)

Both information technology development and the changes in healthcare environment are critical in shaping the current and future state of HIT. One of the recent and most important IT development is cloud computing, which we have discussed in section 2.1. Next we will

review the recent most important legislation and regulations that shape the healthcare environment.

Important Recent Healthcare legislation and Regulations

1) HIPAA

In 1996, Congress passed the Health Insurance Portability and Accountability Act (HIPAA) in hope of improving the portability and continuity of health insurance; combat waste, fraud, and abuse in health insurance and health care delivery; promote medical savings accounts; improve access to long-term care services and coverage; and simplify the administration of health insurance; and for other purposes (NIST, Effect of the HIPAA Privacy Rule on Health Research). In 2003 the Title II of HIPAA was passed with additional regulations on the use and disclosure of Protected Health Information (PHI).

The HIPAA defines a set of rules to facilitate continuation of health insurance coverage among American workers who change employers. The HIPAA Security Rule specifically focuses on the safeguarding of Electronic Protected Health Information (EPHI). Under the HIPAA Security Rule, each covered entity[1] must:

- Ensure the confidentiality, integrity, and availability of EPHI that it creates, receives, maintains, or transmits;
- Protect against any reasonably anticipated threats and hazards to the security or integrity of EHPI;
- Protect against reasonably anticipated uses or disclosures of such information that are not permitted by the Privacy Rule.

2) FISMA

In addition to HIPAA, the Federal Information Security Management Act (FISMA) also affects the use of HIT. FISMA enacted into law in 2002 defines three security objectives for federal government information systems: (1) Confidentiality, (2) Integrity, and (3)

[1] Covered entities include covered healthcare providers, health plans, healthcare clearinghouses, and Medicare prescription drug card sponsors. Details on covered entities can be found in the NIST document.

Availability. The purpose of FISMA and HIPAA was to establish a uniform set of federal standards nationwide for how health plans and most health care providers should treat the identifiable health information that they receive from their patients.

FISMA applies to all federal agencies and all information types. Some federal agencies are subject to the HIPAA Security Rule based on their functions and use of EPHI. All HIPAA covered entities, which includes some federal agencies, must comply with the HIPAA Security Rule. The Security Rule specifically focuses on protecting the confidentiality, integrity, and availability of EPHI.

3) ARRA and HITECH Act

HIPAA is important from a policy standpoint, but most of the impetus for HIT adoption, primarily Electronic Health Records (EHR), comes from the American Recovery and Reinvestment Act (ARRA) stimulus bill in the form of incentive payments through Medicare & Medicaid.

The ARRA was signed into law by President Obama on February 17, 2009 to stimulate the U.S. economy and simultaneously promote certain policy objectives. It touches almost every aspect of the U.S. economy. It prevents dramatic state cuts in Medicaid, expands funding for preventive health care services and health care research, and helps the unemployed buy health insurance. Its most profound effect on doctors and patients will result from its unprecedented $19 billion program to promote the adoption and use of HIT and especially EHRs (Blumenthal, 2009). Among the $19 billion, $17 billion is in financial incentives for physicians and hospitals to adopt and use EHRs, and $2 billion for ONC to put support systems in place for technical help and improvements and to authorize a variety of tools for building the requisite infrastructure.

The Health Information Technology for Economic and Clinical Health (HITECH) Act was signed as a part of ARRA to promote the adoption of HIT by physicians and hospitals with a prescribed timeline. The HITECH authorizes incentive payments through Medicare and Medicaid on demonstrated meaningful use of certified EHRs.

What is "meaningful use of certified EHRs"? First of all, to qualify as certified EHR technology, a system must be tested and certified by the Office of the National Coordinator for Health Information Technology (ONC). The ONC keeps and releases a list of approved EHRs that have been determined to meet the requirements of "meaningful use". The list is called Certified Health IT Product List (CHPL)[2].

Secondly, the term "meaningful use" means: the use of a certified EHR in a meaningful manner, such that it complies with a set of objectives. In short, meaningful use will require that providers document that they are using certified EHR technology in ways that can be measured in quality and in quantity (Turner, 2011).

The Federal government provides a pool of HITECH funds to pay eligible professions up to $44,000 in reimbursements from Medicare and $65,000 from Medicaid for meaningful use of a certified EHR starting in 2011. It is no surprise that a swarm of technology vendors started to promote a vast array of technologies designed to fulfill the HITECH vision of integrating advanced technology into the delivery of healthcare services. In the rush to implement EHR solutions and receive financial incentives, many organizations overlook the importance of selecting an appropriate technology rather than a one-size-fits-all solution. However, it is very encouraging to see many of the solutions on the CHPL are cloud computing based solutions.

This type of government stimulation has played an essential role in advancing technology adoption in the health care industry. While we have to admit the apparent benefits for the quickened industry wide movement towards using newer technologies, we should also note that it causes a cyclic effect on certain types of technology development. This cyclic effect of government stimulation plans will be discussed later.

[2]The full list of approved venders of CHPL can be found here: http://onc-chpl.force.com/ehrcert

4) ACA

The Affordable Care Act (ACA) was enacted on March 23, 2010. It contains some tax provisions that became effective in 2010 or 2011, with more to be implemented in the next several years.

According to a 2011 survey, the reforms at the ACA in the U.S. could stimulate the reduction of the number of underinsured adults in the country by 70 percent upon the increase of the affordability of care for people (Cathy Schoen, 2011).

According to another survey (The Kaiser Family Foundation and Health Research Educational Trust, 2011) the two most popular provisions of the ACA reform law – allowing young adults to stay on their parents' insurance policies until age 26 and requiring health plans to offer some preventive service for free – together accounted for about 2% increase in insurance premiums. However, the average annual premium was 8% higher for individual coverage, or 9% higher for family coverage. The increase was only 3% in 2010.

At the same time, one study (The Commonwealth Fund, 2011) appeared in the journal Health Policy shows that the U.S. ranked last among high-income nations on preventable deaths.

Since the birth of the ACA, criticism that the ACA has caused a rise in health benefit premiums has never stopped. It is understandable. Many people believe that Americans are paying higher premiums with less quality in return. Adding more people to the insured pool seems to make things worse.

Issues of legislation and Regulations

The HIPAA, FISMA, HITECH, and ARA were formed at different times with different focuses. But they are also interrelated, e.g. the HITECH Act contains a number of important changes to HIPAA privacy and security requirements for physician practices (Shiner, 2010). They also share the common goal to promote the development of a nationwide healthcare information network and to create a helpful and holistic medical records system to address

a wide range of healthcare issues. As the population ages and healthcare costs soar, making the healthcare service more efficient and effective, as well as finding the means to reduce costs, are the top priorities for the healthcare industry.

However, we should also note that this legislation and regulations have side effects to the healthcare community. The first issue is the lack of enforcement, or inconsistency when there is enforcement. One goal of the regulations is to maintain an appropriate balance between protecting individual privacy and the ability to use the de-identified healthcare information for the common good. But sometimes those laws don't match up and cause confusion. The HHS delegated to the Administrator, Centers for Medicare and Medicaid Services (CMS), the authority to investigate complaints of noncompliance. The current "complaint-driven" enforcement process leaves many unturned stones. CMS has recognized the need for an enhanced enforcement process whereby CMS would proactively address compliance issues through a compliance audit process.[3] The new process is yet to be developed.

Another issue is the problems caused for the secondary uses of PHI. All individually identifiable health information held or transmitted by a covered entity is protected under the Privacy Rule. The regulations allow the use of non-identifiable or de-Identified information for secondary uses such as for scientific research, administrative use, comparative performance use, etc. The Privacy Rule does not supersede either FDA regulations on research or the Common Rule[4]. "De-identified" PHI is under no disclosure restrictions. It is more acceptable to use the data for common good (e.g. for research), but many businesses also use the data for commercial purpose such as service targeting and advertising. The current regulations are not always clear on the restriction of secondary uses of PHI.

A third issue is the variability in the interpretation of the HIPAA Privacy Rule. The Covered Entities are a limited set of entities. If the entity that is using the health care data is not

[3] https://www.cms.gov/Enforcement/, retrieved on Jan 27, 2012.

[4] The Common Rule is formally called "Federal Policy for the Protection of Human Subjects". More information on the Common Rule can be found on HHS.gov "http://www.hhs.gov/ohrp/humansubjects/commonrule/index.html"

covered by HIPAA, then they are only concerned when access to information is from a covered entity. It causes limitations on some important types of research, such as chart reviews, retrospective cohort studies, population-based case control studies, multi-center studies, and so on.

However, despite all the issues and concerns about the legislation and regulations, they sent strong positive signals to the healthcare industry to build a better and more organized healthcare information network using advanced technologies.

On a Pragmatic Level

Reducing health care costs while providing better health care services is the ultimate goal, and it are not easy to achieve. Health care is a far-reaching issue because it is a basic right of human beings and it affects everyone's daily life. At the national level, it became one of the most critical tasks and challenges for the administration and the legislation. Because of the importance of the issue, while the politicians and the media are focused on the high-profile debates, many medical providers, scientists and researchers are spending lots of their time and energy trying to tackle on the challenges at pragmatic level.

Developing and promoting cost effective HIT systems is one of the areas that can positively impact health care reform. The adoption of the EHR can increase efficiency and improve the quality of healthcare. A better connected information network could reduce losses due to fraud. Although HIT by itself cannot solve the problem of high healthcare cost, developing an interoperable healthcare information network can provide a platform to implement real-time controls. There is a study shows that such an infrastructure investment has the potential to produce significant national savings (Parante, Mandelbaum, Hanson, Cassidy, & Simborg, 2008).

As discussed above, users of PHI can range from patients, service providers, insurance companies, to researchers and government agencies. There is a tremendous amount of data accumulated or being accumulated over time. Different users need data mining and analysis for both research and interventional usages. One example is the Scalable Nationwide Network for Effectiveness Research (SCANNER) study, funded by the Agency for

Healthcare Research and Quality (AHRQ) and led by Principal Investigators at UCSD & MIT, which evaluates effectiveness of clinical interventions in real populations. The SCANNER project will develop a scalable, secure network for comparative effectiveness research that allows for flexibility in disclosure policy and data sharing among participant sites. This kind of study relies on the data collected in the process of care across different time, location, format, and very often on different network systems.

Cloud computing is considered a suitable solution for these requirements by many experts in the field. It is scalable, easier to implement, and easier to share. However, most healthcare or clinical organizations are relatively new to cloud computing comparing to government agencies and large providers. The challenge is how to overcome the concerns these healthcare organizations have on: 1) How security, safety, and reliability of data storage in the cloud are being ensured; and 2) How to work with the existing healthcare networks and standards, such as Nationwide Health Information Network (NwHIN) and Health Information Exchange (HIE) vendors[5].

NwHIN seeks to provide a nationwide interoperable health information infrastructure (network of networks) for secure data exchange over the Internet. NwHIH is almost always deployed as the CONNECT Gateway. CONNECT is open source software with three components: 1) Gateway, which implements NwHIN specifications; 2) Enterprise Service Platform, which enables connections to the Gateway; and 3) Universal Client Framework, which provides a development platform for end-user applications.

This landscape is changing as HHS is now pushing NwHIN Direct. NwHIN Direct describes a set of standards, services and policies to guide the development of secure health data exchange over the Internet. It is a much simpler and less capable solution downsized from NwHIN since NwHIN has proved to be too complicated. "While CONNECT was developed to meet the needs and requirements of government agencies and large organizations, NwHIN Direct focuses on smaller entities, such as physician-to-physician connectivity. It builds off CONNECT to offer an additional set of standards and specifications to support point-to-

[5] E.g. InterSystems, Axolotl, Medicity, DBMotion, etc.

point interactions for meaningful use of HIT, " says Doug Fridsma, M.D. and acting director of the office of standards and interoperability in the Office of the National Coordinator for HIT (Goedert, 2010).

Many of these issues represent both technical and business challenges. Evaluation of these issues can be very difficult when they face a new project. It is critical for decision-makers to choose the optimal approach early on in the project to ensure its final success.

3. System Analysis

3.1 The Healthcare Information Technology (HIT) Ecosystem

As the name suggested, HIT is in the domain of IT, but it is a subset domain of IT. Many generic IT developments can be directly applied to HIT systems. There are also healthcare domain specific characteristics that differentiate HIT systems from other types of IT systems. Within HIT, there are also numerous sub-systems that make up the entire core functionalities supporting healthcare information systems' needs, e.g. EHR is one of them. For the purpose of refining the discussion in this thesis, the scope of IT, HIT, and EHR is illustrated in Figure 2.

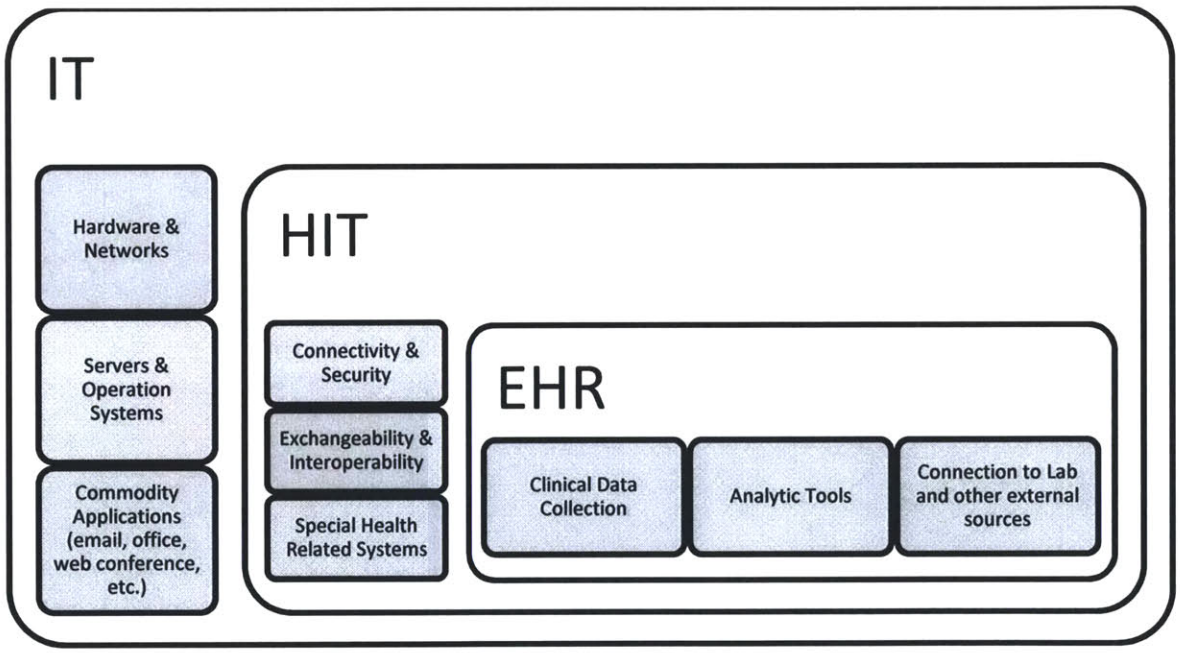


Figure 2 System Scope (Original)

HIT as a system has all elements to be an Ultra-Large-Scale (ULS) system by the measures of: the number of people employing the system for different purposes; the amount of data stored, accessed, manipulated, and refined; the number of connections and interdependencies among subsystems; and the number of software and hardware elements (Northrop & AL, 2006). The large HIT system affects virtually all players in the healthcare community. It is such a broad technology that complementary investment in a broad set of areas is required to maximize the value of HIT. A study done by RAND Corporation (Bower,

2005) compared the diffusion of HIT to IT diffusion in other industries and indicated that HIT is definitely not a stand-alone or plug-and-play type of benefit, it is much more effective when combined with vigorous competition and deregulation, and when used appropriately it can deliver dramatic changes in the overall delivery of care.

Healthcare Entities

Compared to other types of information technologies, HIT has its own characteristics. First of all, it is important to understand the complexity of the healthcare network. As illustrated in Figure 3, HIT systems interact with a broad span of healthcare entities. These entities play diversified roles and they must cooperate with each other in order for proper healthcare information to be created, maintained, transmitted, and utilized. These entities are the owners of the HIT systems, at the same time they are also the customers.

Figure 3 Healthcare Entities (Original)

Another important characteristic is the uneven use of information technology in different healthcare entities. While some hospitals are using advanced computing and information systems to provide modern services, some other health care facilities may still rely on paper based manual processes to collect data. To build a reliable HIT infrastructure, the development and advancement of HIT cannot be locally focused. Because the healthcare entities are interconnected to each other, healthcare information and other data has to be communicated and shared.

Market Structure

Market structure is defined by the number and size of the firms in the market; the ease with which firms may enter and exit the market; the degree to which firms' products are differentiated; and the information available to both buyers and sellers regarding prices and product characteristics. Market structure characteristics determine competition, which ranges from perfect competition where there are many small sellers and many buyers, a homogenous product and everyone is a price-taker, to a pure monopoly where there is only one supplier or a monopsony, a market with only one buyer. Between these extremes there are other structures such as monopolistic competition (many buyers and many sellers with a differentiated product) and oligopoly with a few sellers varying in size and power in the market. The ideal economic structure is perfect competition which has the following characteristic: many sellers and many buyers and each one individually too small to affect price levels so they are all price-taker not price-sellers (Mwachofi & Al-Assaf, 2011).

The HIT market structure is complicated. As we have discussed, HIT is an ultra large system with a large amount of players. Each of the healthcare entity segments (as shown in Figure 3) is big enough to form its own market. For example, the health care receivers have a consumer-oriented market with products range from home care devices to on-line health condition self-assessment, etc.

The healthcare provider market can be segmented into large hospital (>200 beds), midsized hospitals (100~200 beds), small hospitals (<100 beds), and physician practices. Within these segments, the large and midsized hospitals often behave more like standard enterprise

customers in the macro IT space, while small hospitals and physician practices are demonstrably more adverse to significant capital expenditures (Harding, 2009). The HIT vendors have become associated with specific market segments. For example, large companies like Allscripts, Cerner, and Epic are the main vendors for the large hospital market. McKesson is the dominant player in the midsize hospital market, and smaller hospitals are predominantly served by companies such as Computer Programs and Systems. Allscripts is the best known name in the physician practice market, which is the most numerous and fragmented market segment.

The RAND study (Bower, 2005) also concluded that there were neither empirical nor theoretical reasons to worry about too many or too few buyers or sellers in the HIT market. There are a substantial number of HIT suppliers providing various HIT products. The entrance barrier is low as it is relatively easy for new players to find niche markets in HIT to start their ventures.

The EHR market has become a more condensed market however. In 2002, 7 suppliers had 74% of the EHR market and the remaining 26% were composed of smaller players and home-grown systems (Bower, 2005). Today, the top four EHR vendors made up 80% of the EHR market, with hundreds of smaller players in the remaining 20%. We see mergers and acquisitions are still happening among the EHR venders, e.g. Allscripts merged with Eclipsys in 2011.

We should also notice the presence of Health Center Controlled Network (HCCN) organizations. According to the Health Resources and Services Administration (HRSA, HHS), a HCCN is "a group of safety net providers with a minimum of three collaborators or members collaborating horizontally or vertically to improve access to care, enhance quality of care, and achieve cost efficiencies through the redesign of practices to integrate services, optimize patient outcomes, or negotiate managed care contracts on behalf of the participating members." These HCCN organizations assume responsibility for research, development, negotiations and vendor management on behalf of multiple healthcare facilities in terms of developing and/or adopting new HIT systems. By centralizing these

responsibilities, they can achieve economy of scale in terms of IT spending and outsourcing. This is an important characteristic that will be further discussed in later sections.

Business Model

There has been a lot of talk of transitioning toward a subscription model for HIT to better align the cash outflows associated with purchasing a system with the Medicare and Medicaid incentive payments. In the physician practice or ambulatory market, we have already seen the software-as-a-service take hold (The Wall Street Transcript, Aug 10, 2009). The emergence of the cloud computing model of product delivery is compelling for small hospitals and physician practices, because it allows them to match their expenditures with their revenue stream while avoiding big upfront HIT investment.

The increased prevalence of cloud computing also pushes HIT vendors to explore and expand more types of cloud computing offerings. However, for large enterprise-sized healthcare providers, in-house perpetual license products continue to be considered preferred option because of their existing investments and sizable IT department.

Understanding the HIT ecosystem and integrating the relevant information together will enable new information technology adoption to be better synchronized with the real-time needs of the healthcare network in an economically feasible context. Although we will emphasize the cloud computing aspects in our future discussion, we should also note that the same philosophy is applicable to any types of new technology adoptions.

3.2 System Architecture

Cloud computing services are offered most commonly in the following ways:

- Infrastructure-as-a-Service (IaaS): storage and computing resources as a service. The main advantages are lower costs, increased flexibility, and the ability to rapidly start up and shut down services. This type of service also helps moderate capital expenditures by reducing the need for on-site data center infrastructure and computing systems.

- Platform-as-a-Service (Paas): tools and environments to build and operate cloud applications and services. This is newer in the marketplace, but adoption is expected to increase significantly over the next few years.
- Software-as-a-Service (SaaS): on-demand use of software over the Internet. This type of services has been on the market for several years, and has the greatest uptake so far.
- IT-as-a-Service (ITaaS): or sometimes is called Business Process as a Service (BPaaS). This service type combines the application elements of cloud computing with a human aspect. The main difference from traditional IT outsourcing is the fact that the human resources providing the ITaaS service are pooled as well between different clients.

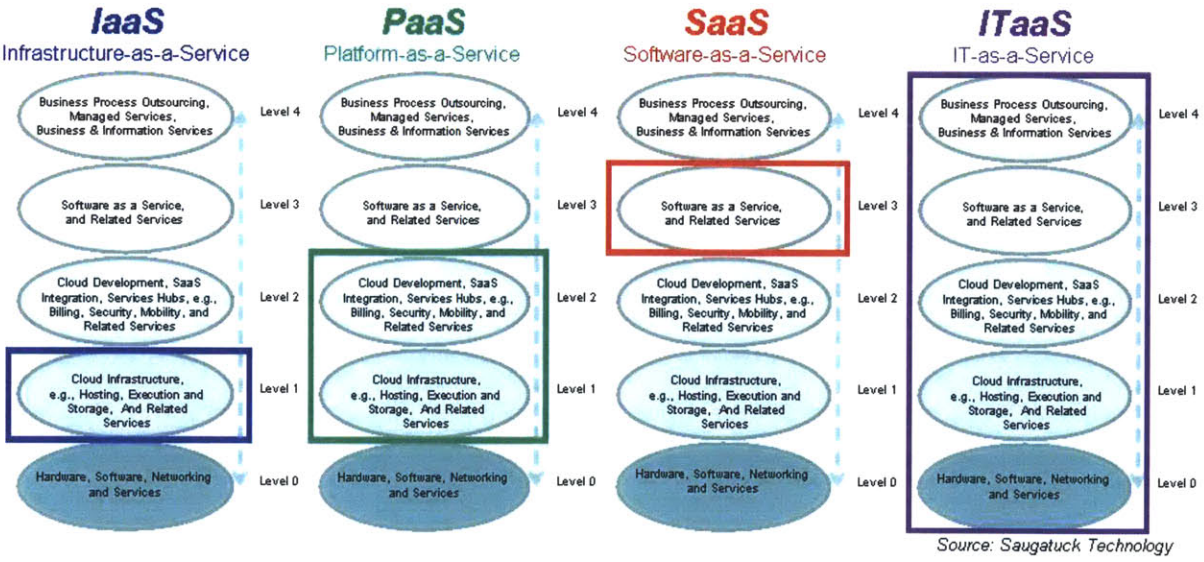


Figure 4 System Architecture (Bittman, 2009)

Each cloud computing service model has a different level of awareness and business acceptance. At the moment, software-as-a-service is confirmed as the most popular service model (Deloitte, 2011). This is supported by the uptake of CRM, Collaboration and other applications in the cloud by businesses. Platform-as-a-service and infrastructure-as-a-service are making significant inroads as business usage of cloud computing solutions becomes more sophisticated.

There are also several distinct deployment models for business use of cloud computing, including:

- Public cloud: Public cloud computing uses the public internet and shared computing resources to deliver services and capacity on demand. This model uses one or more data centers that are shared among multiple customers, with varying degrees of data privacy and control. From the customer's perspective, using public cloud is similar to outsourcing, except the scalability is greater and the billing model resembles a utility.
- Private cloud: Private cloud computing architectures are modeled after public clouds, but they're built, managed, and used internally by an organization. This model uses a shared services model with variable usage of a common pool of virtualized computing resources. Data is controlled within the organization.
- Hybrid cloud: This is a mix of public cloud services, private cloud computing architectures, and classic IT infrastructure, forming a hybrid model to meeting specific needs. Static hybrid cloud computing does not share data and services between the public and private components. Dynamic hybrid cloud computing is architected in a way that data and services are interchangeable as if they are located in the same virtual operating system. Supplier relationship management is a good example of an application that fits well with a hybrid model.

These system architectures and models are applicable to cloud computing in all types of IT environment, including HIT.

3.3 Business Dynamics

In previous sections, we mentioned the cyclic effect of government stimulating acts on HIT development. To be more specific, when the Federal or State government passes laws or stimulating plans to promote advanced technology adoption in healthcare by providing incentives to individuals or institutions, it will inevitably create a rush to implement the technology being promoted. These laws and acts can make enormous strides in advancing

technology adoptions, but the strides sometime can be so large that the whole body may lose balance when the legs move too fast.

Take the HITECH Act as an example. Many organizations have adopted certified EHR quickly in order to qualify for the incentives. However, hospitals or healthcare facilities have unique workflows, clinical concerns, and limitations of existing infrastructures. During the quick adoption wave, the drivers that should motivate the organization to implement health information technology shift from improving clinical care and practice to achieving the HITECH incentives. As a result, understanding of the organizations' specific needs and requirements, incorporating of physicians' and user groups' inputs, and integrating with existing IT infrastructures and systems, will become secondary priorities.

No EHRs are designed to operate in isolation. If the above concerns were not addressed at the beginning of the adoption, sooner or later, they will become such a big obstacle that the players in the field have to stop and take a step back to revaluate them. That will be the time we see a drawback of the rapid growth in new technologies.

Figure 5 shows the effect of government stimulation act on technology adoption curve.

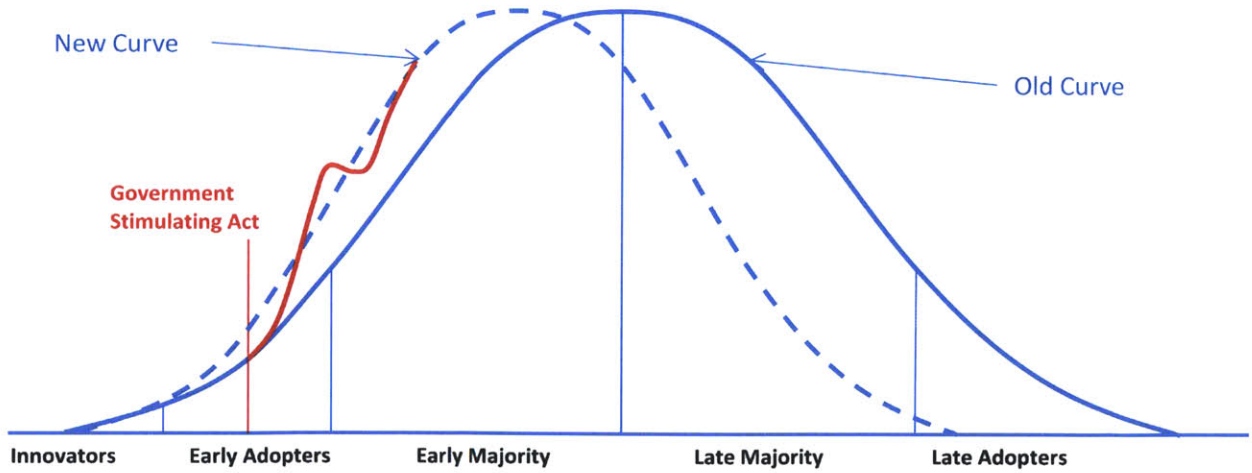


Figure 5 Government Stimulation Act Effect on Adoption Curve

Figure 5 Government Stimulation Act Effect on Adoption Curve

4. Findings - The framework

As we stated in the proposal of this thesis, the purpose of this research work is to research and define a framework for cloud computing adoption in healthcare information systems when moving forward from traditional computing approaches. Users of this framework can be the cloud providers and developers (the Vendors), or the network computing service seekers (the Clients).

To make the framework a complete approach, we looked at:

- The adoption curve of technologies across the board
- the system architecture and ecosystems of the cloud computing;
- the stages of each of the layers and players in the transition process;
- the roles of each player during the transition, and their business models;
- the comparison method in both technical and business areas;
- and the comparison of risks and unknowns.

The transition is a dynamic process that changes over time. Instead of building one instance of the framework that only fits today's market situation, we tried to build one that can be used over time with updated information, as various players move from their current stage to the next on the technology adoption curve.

The proposed framework also considers the specific marketplace conditions and regulations in related to Healthcare, as they play a critical role in the development of HIT systems and the adoption of cloud computing.

As shown in Figure 6, the proposed framework consists of five major categories: Strategy, Regulations & Policies, Technology, Implementation, and Evaluation. This framework is developed based on organizational decision making process and provides matching tools to address decision maker's concerns. The framework can be used to reason about and investigate cloud adoption decisions.

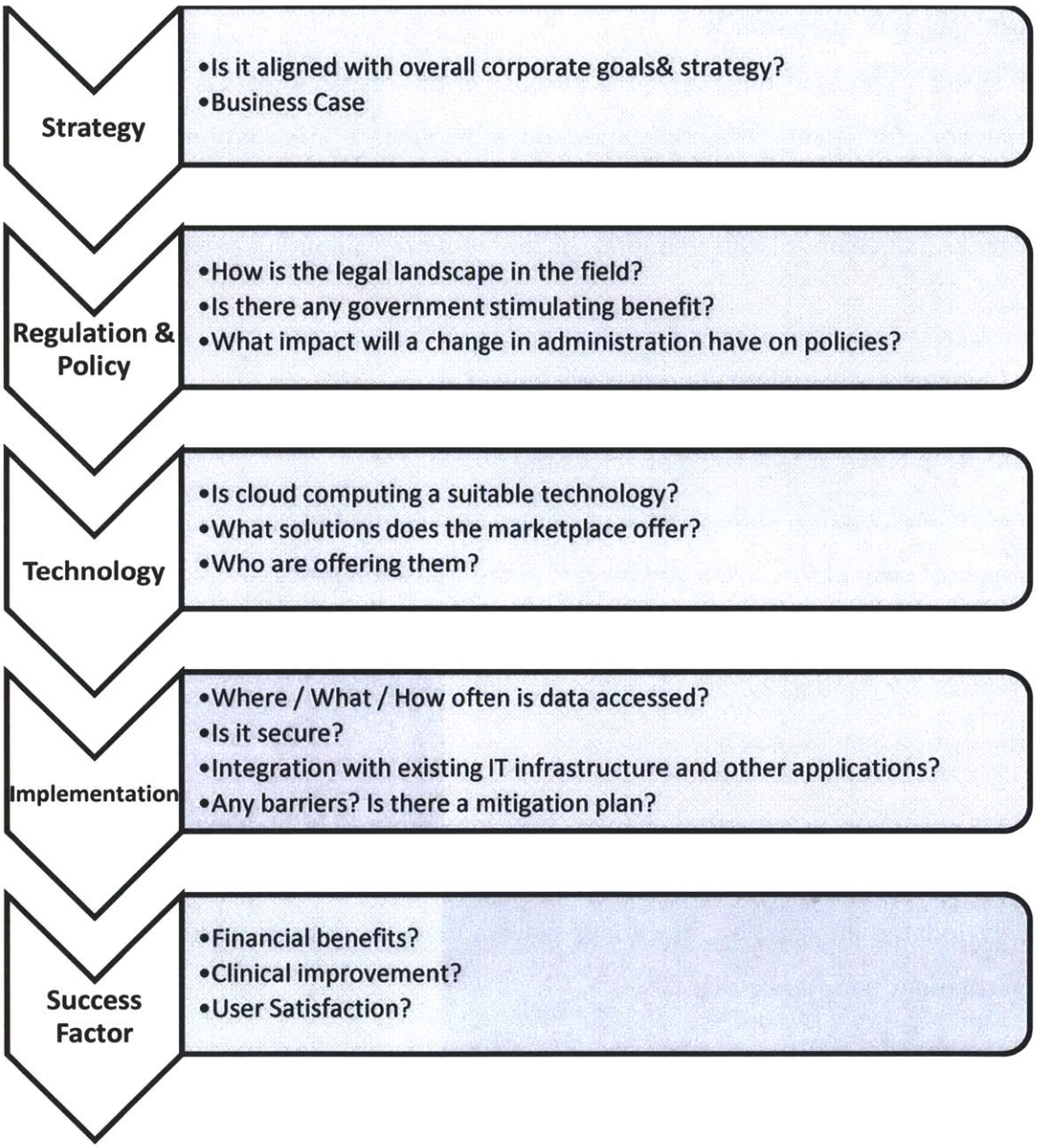


Figure 6 the Framework (Original)

Although the five categories of the framework can be applied independently or sequentially, we recommend that the users use the following evaluation process to get a thorough understanding and better alignment for their project.

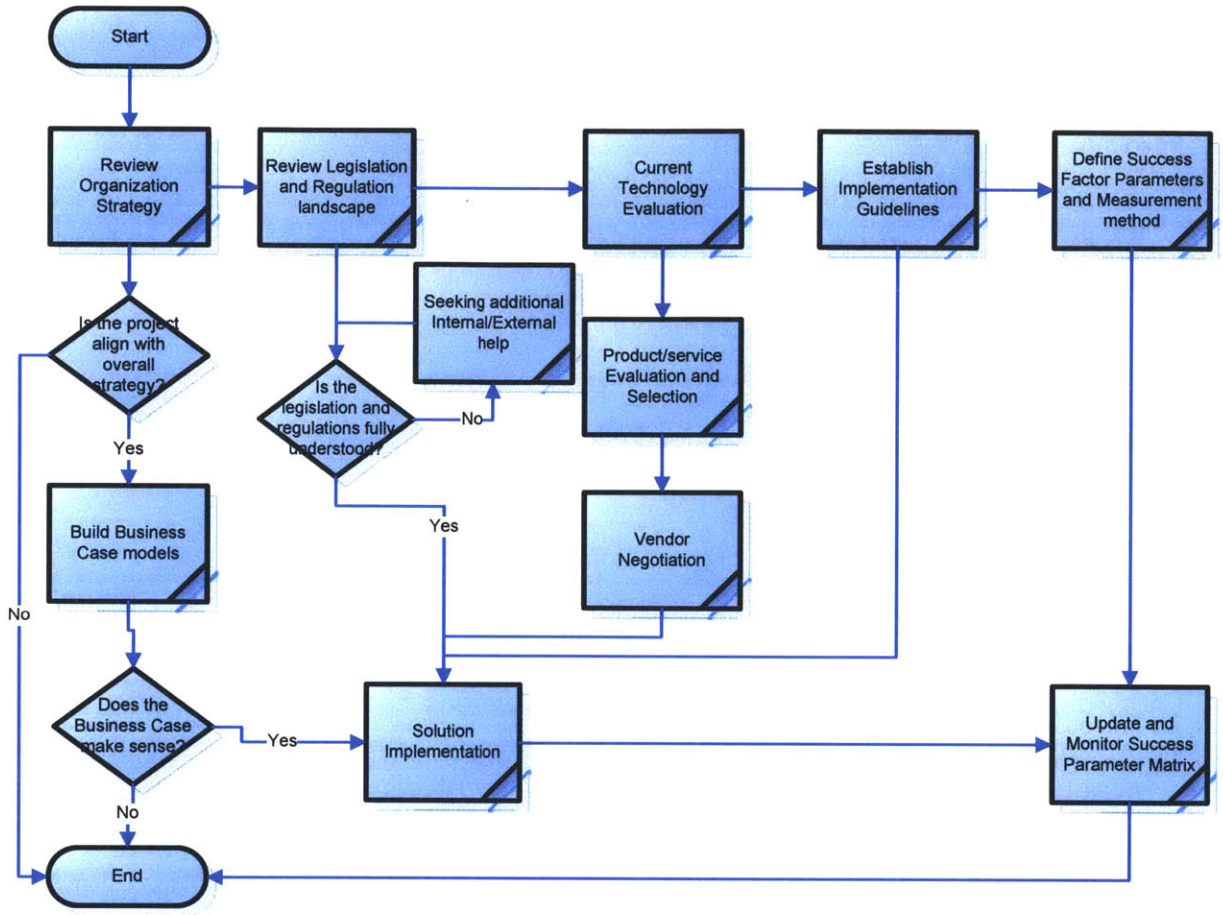


Figure 7 Cloud based HIT system adoption process

4.1 Strategy

The adoption of cloud computing is an organizational challenge that should not be isolated from other organizational goals and strategies. Establishing clear organizational goals and strategies for the use of cloud computing is the first critical step in cloud adoption. More than half organizations who has successfully adopted cloud computing defined a five-year technology roadmap for their organization (CDW LLC, 2011). Because adopting cloud computing in enterprise environment is non-trivial, carrying out long-term planning is necessary and can be done only when the benefits of cloud computing match the goals of the organization.

Cloud computing allows organizations to realize their strategic objectives by shifting the focus from dedicating time and resources on commodity services and processes to their

core value-generating process, especially using public cloud services. Organizations will be able to shift responsibility and the management of non-core IT capabilities to cloud providers.

In healthcare organizations, the top goals generally fall between the following lines:

- Improved healthcare services
- Standardized and simplified healthcare information
- "Anywhere access" to data, documents, and applications
- Consolidated IT infrastructure
- Compliance with regulations and policies
- Reduced IT capital requirements and operating expenses

According to a study by Deloitte, the organizations that successfully adopted cloud computing did so mainly because of the clear business case and the quick realization of the business goals (Deloitte, 2011). The challenge that needs to be addressed is to provide accurate information on costs and risks to ensure that decision makers can compare trade-offs and make informed decisions (Khajeh-Hosseini, Greenwood, Smith, & Sommerville, 2010).

The business case for investing in cloud based HIT can be built from several perspectives. It must consider both monetized and non-monetized aspect.

- From a business perspective, cloud computing offers the potential to bring more flexibility in business processes. The potential to scale the cloud platform rapidly while paying only for the actual usage provides the organization with the possibility of rapid and flexible scaling or capacity for critical business processes.
- From a financial perspective, any HIT investment has immediate purchase costs, adaptation to the local organization, and staff training. Because profits = revenue – costs, all organizations benefit from becoming more efficient and reducing the costs per patient (PG, SC, & EB, 2006). Cloud based HIT requires less upfront investment by using a utility billing model instead of hardware acquisition. It benefits the

organization from a cash flow point of view. The business case for cloud based HIT depends on the downstream financial benefits exceeding the initial investment plus the on-going fees. An assessment on the costs associated with the use of cloud computing should be done in comparison with what is then the current IT cost to support accurate estimation and informed decision making. Because the cost and benefits are both long term, an NPV calculation should be used for return on investment.

- From an IT perspective, cloud computing enables a transformation on how information technology is managed and used. By using a combination of cloud computing with traditional IT systems, organizations can achieve new levels of agility and flexibility allowing to deal with the rapid changes that the current economy requires and to better support the business. The disruptive effect cloud computing has on how business interact with IT, confirms that the business needs to ensure they clearly position IT towards the business, have a good understanding of the business needs and above all, become true business partners to implement and execute business strategies.
- From an employee perspective, cloud computing and related technologies have a significant impact on the way work is performed. Through the use of public and hybrid clouds, data and application access becomes ubiquitous as long as an internet connection is available. This allows employees to work from remote locations without much trouble getting access to their data and applications.
- From an organizational perspective, the adoption of cloud computing in IT, Sales, and HR is apparent in healthcare, but for the core business applications (e.g. EHR, etc.), there is still a lot of room to grow. With cloud computing, responsibilities of each department may change or shift with the proposed system. New groups may be added and old groups may be dissolved. Operational feasibility should be studied to clarify responsibilities and strategic dependencies among organizations and departments with the cloud adoption. Even if the change is small, it helps the decision making.

4.2 Regulation & Policy

Health care is a highly regulated industry, so is health information technology. In order to successfully adopt cloud computing, one must make sure the solution complies and provide means to comply with all related regulations, policies and standards. "What does the regulation and policy landscape look like?" becomes an imminent question for every healthcare entity. Without clear understanding of the landscape, one may end up with unrealistic estimation on the complexity of the solution. With full understanding of the regulation and policy landscape, it set a good starting point for selecting the right set of cloud candidates.

Government stimulation plans also play very important roles in promoting modern computing system adoptions in health care. Many organizations are passive rather than proactive in terms of taking on new rules and adapting to new requirements. But when there is a stimulation plan enacted most organizations change their behaviors. A clear and correct interpretation of these plans are sometimes difficult to achieve, but is critical to have.

Furthermore, regulations and policies develop and evolve over time, especially when there is a change in administration of the government. It also makes sense to take a moment and think about what impact it might have on your cloud adoption plan.

In section 2.2 we reviewed the history of the development of HIT and the related regulations. The recent enactment of laws and regulations is reshaping the healthcare system. HHS has the authority to promulgate regulations and guidance to support the development of a nationwide HIT infrastructure. The HHS website has a list of current regulations and guidance[6]. The Centers for Medicare & Medicaid Services (CMS) also

[6] HHS website:
http://healthit.hhs.gov/portal/server.pt/community/healthit_hhs_gov__regulations_and_guidance/1496,
Retrieved on Jan 11, 2012.

provides a comprehensive list of regulations, guidance and standards[7]. Table 3 shows a combined list of these regulations, guidance and standards that are related to EHRs.

Regulations & Guidance	Description
PCAST Report on HIT[8]	"Realizing the Full Potential of Health Information Technology to Improve Healthcare for Americans: The Path Forward" provides recommendations for using HIT to facilitate the real-time exchange of patient information.
Standards and Certification Criteria for EHR	Issued by ONC that identifies the standards and certification criteria for the certification of EHR technology, so eligible professionals and hospitals may be assured that the systems they adopt are capable of performing the required functions.
Certification Programs	A defined process to ensure that EHR technologies meet the adopted standards, certification criteria, and other technical requirements to achieve meaningful use of those records in systems.
Meaningful Use of EHR Final Rule	Guidelines to health professionals and hospitals on how to adopt and use electronic health record technology in a meaningful way to help improve the quality, safety, and efficiency of patient care.
Medicare and Medicaid EHR Incentive Programs	Incentive payments to "meaningful users" who use health information technology to improve value and efficiency of care delivered to patients.
CLIA Program and HIPAA Privacy Rule: Patients' Access to Test Reports	The proposed rule would modify the CLIA of 1988 regulations and the HIPAA Privacy Rule in order to give patients the right to get a copy of their health information, including test results, directly from a clinical lab.
HITECH Breach Notification Interim Final Rule	Guidelines to specify encryption and destruction as the technologies and methodologies that render protected health information unusable, unreadable, or indecipherable to unauthorized individuals.
Section 1561 Recommendations	These recommendations include initial standards and protocols that encourage adoption of modern electronic systems and processes that allow a consumer to seamlessly obtain and maintain the full range of available health coverage and other human services benefits.
Freedom of Information Act	The FOIA provides a crucial mechanism for making government more open by allowing the public to request information which the government is then statutorily obligated to provide.
Paperwork Reduction Act of 1995	The PRA significantly changes many aspects of Information Collection by the Federal government, which requires agencies to plan for the development of new collections of information and the extension of ongoing collections well in advance of sending proposals.
Economic Recovery Act of 2009 (ARRA)	The ARRA includes measures to modernize our nation's infrastructure, enhance energy independence, expand educational opportunities, preserve and improve affordable health care, provide tax relief, and protect those in

[7] CMS website: https://www.cms.gov/home/regsguidance.asp, Retrieved on Jan 11, 2012.

[8] The PCAST report is a set of recommendations that many in the healthcare community are aligned with. It is not a regulation or law, but is important for the HIT adoption.

	greatest need. As a part of ARRA, the Medicare and Medicaid EHR Incentive Programs will provide incentive payments to eligible professional, eligible hospitals and critical access hospitals as they adopt, implement, upgrade or demonstrate meaningful use of certified EHR technology.

Table 3 HIT Regulations, Guidance and Standards

Regardless of the size of the organization, they are expected to run according to accepted business practices and in compliance with applicable laws in an ethical manner, and to avoid costly litigation. The HIPAA and HITECH laws spell out the minimum necessary standards of protection on privacy and security and set forth the expectation that the organization continually evaluate the adequacy and effectiveness of their information protection controls. An organization that fails to comply with HIPAA can face fines up to $50,000 per violation. The breach notification requirement of the HITECH Act explicitly state the legislative intention to create an incentive on all covered entities to secure and protect PHI or suffer financially. These impose big information security risks on healthcare providers and HIT vendors. While the healthcare organizations and physicians can get incentive payments for rapid HIT adoption, they also bear the burden of complying with the intensive regulatory requirements, which in some cases outweigh the monetary benefits of the incentive programs.

4.3 Technology

As discussed in previous sections, cloud computing is a new evolving technology. New developments, new solutions, and new offerings are being added quickly and quietly. Even just in the health care industry, more and more vendors and developers join the marketplace every day. As an integral part of the framework, the purpose of the technology study is to understand the characteristics of cloud computing development in healthcare and seek the suitability of the candidate solution.

For example, Amazon recently announced its HIPAA compliant cloud providing services, and claimed that "healthcare businesses subject to HIPAA can utilize the secure, scalable, low-cost, IT infrastructure provided by Amazon Web Services (AWS) as part of building HIPAA-compliant applications." Amazon does it through data encryption and a set of security policies and processes controls. However, according to many experts in the field, the

Amazon AWS is not exactly HIPAA compliant, e.g. there is no customer accessible AWS API call audit log; there is no way to restrict the source IP address from which the AWS API key can be used; each AWS account is limited to a single key, which evokes unauthorized disclosure of the key and results in total breakdown of security, etc. (Lieberman, 2011) (Balding, 2009).

In the evaluation of cloud computing key technologies development stages. We will use a factor of 1 to 10 to indicate the advancement of these areas:

Key Technology Development	Factor	Development
Data Center (Storage & Management)	7	Large IT companies (e.g. Amazon, Microsoft, etc.) have offered data storage and management services that specifically designed for healthcare applications. A 7 is used to indicate the fast development, but less maturity.
Virtualization	10	Virtualization technology is generic for all types of cloud computing. HIT can leverage the well developed virtualization technologies for other IT offerings. We rate it at 10 since there is no known barrier for transferring to cloud computing for HIT.
Safety & Security	5	Safety and security is still the main concern for cloud based HIT. The recently enacted laws and regulations have set more requirements in this regards, which imposed significant challenges on healthcare providers and HIT vendors. We give it a 5 as the safety and security aspect of the cloud based HIT offerings is yet to be demonstrated.

Table 4 Key Cloud Computing Technology Development in HIT

It is important to know the advancement in these areas because they are the fundamental enablers of the cloud computing architecture. Any break-through in these areas may cause radical change to cloud computing architecture.

In addition, we will evaluate the market maturity levels (number 1~5 for least mature to most) for cloud computing at different layers by looking at the market adoption rate and size.

Service Model	Least Mature (1)	Less Mature (2)	Early Mature (3)	Advanced Mature (4)	Fully Mature (5)
Infrastructure as a Service	X				

Platform as a Service			X A few PaaS vendors started to offer PaaS services		
Software as a Service				X More and more SaaS services are being offer in both clinical and administrative HIT market.	
IT as a Service		X Small physician offices and health centers have started to use ITaaS. Large hospitals and healthcare organizations have not very much engaged.			

Table 5 Cloud based HIT Market Maturity

Through the matrix of these factors we hope to provide a clear and accurate depiction of the cloud computing technology development under the current market conditions. The layers represent the spectrum of cloud computing architecture from the lowest to the highest. As we exploding the architecture into more details, the number of layers may increase accordingly.

Each industry has a market maturity map different from other industries. The causes of the differences might be the different roles IT plays, different regulations and policies imposed on them, or the different stickiness of the conventional computing habits. Government stimulus bill (like ARRA) may also have an effective impact on the speed of the market adoption rate.

After study and comparison of technologies available on the market, using the factor matrix, we can make a confident selection on the most suitable technology that meets the organization's needs.

4.4 Implementation

After the strategic alignment, the study of regulations and policies, and the selection of the technology, we can then proceed to the next step and focus on implementation. It is always a good idea to think of the flow of information and come up with an implementation plan that met the organizational needs.

For any cloud computing adoption project, the first challenge is to seamlessly integrate the cloud deployment with the organization's existing IT infrastructure. One of the important roles of IT is ensuring proper data integration between applications and systems and preventing incompatible solutions to be acquired and implemented. When an organization fails to implement proper data integration between clouds and other legacy solutions, there is the risk of creating "departmental data silos". Transferring data from one cloud service to another is not an easy process and it leads to sharing deficiencies.

We should consider what role the IT department needs to play during the implementation. As it becomes ever easier to implement applications using cloud computing, IT might be excluded from implementing IT solutions in the organization (Chorafas, 2010). It is especially valid in organizations where there is limited IT resource. Especially Software-as-a-Service solutions allow for easy and straightforward implementation, as in most cases these solutions need no specific IT assistance with regards to installation, configuration and deployment. On the other side, when IT is involved, this involvement is in the first place to ensure the chosen cloud solution gets properly integrated with other applications and systems or that IT provides proper application support.

We should also consider what type of cloud to implement. Private clouds are popular in large enterprises because they give business the most direct control and the greatest confidence in data security and information assurance. Public clouds are easy to get on or off. Sometimes, hybrid might the best solution. As organizations become more comfortable with cloud computing, they will increasingly seek to capitalize on the different advantages of each cloud type and related architectural models.

Decisions	Questions
Type of Cloud	- Which one best suits your needs? Public, Private, or Hybrid?
Data	- Where is the data collected and stored? - What is the data format? - Who owns the data? - What level of privacy and confidentiality is needed?
Communications	- What does the data flow look like? - How much bandwidth is needed from the cloud? - How much computing power do you need? - What is your usage pattern? - What level of availability and accessibility is needed?
Application	- What functions and features do you require? - Does the cloud vendor provide off-the-shelf solution? - Do you need customization? - How much additional development is needed?
Security	- What are your security requirements? - Does the cloud provider meet your requirements?
Regulatory Requirement	- Does the cloud comply with required regulations?

Table 6 Implementation Checklist (Original)

Last but not least, we should identify roadblocks and develop a mitigation plan to ensure a smooth implementation. For many hospitals with large legacy systems, from mainframes to databases and local network, they usually have very large programming libraries with extensions and patches, that were typically written ten, twenty, or more years ago. Many of these programs are mission critical and cannot be easily adjusted to provide interfaces to cloud applications. But in many cases, the new cloud base solution has to replace or work together with the old legacy systems. In this situation, a system re-engineering effort is needed, which includes data mapping, process mapping, and workflow re-design, and so on, in order to provide a fully functional cloud solution. As you can see, this is not a short easy task. The project leader has to acquire adequate resources, time and budget to accomplish it.

4.5 Evaluate the "Success Factor"

Establishing clear and measurable success criteria is the first step. This will generate support from end customers and decision makers within the enterprise. Success criteria should be

broader than just IT metrics. Although IT metrics are important, functional key performance indicators, executing and supporting organizational goals (e.g. average length of patient visit, customer satisfaction rate) will elevate the benefits of the adoption.

Using measurable and quantifiable dimensions of parameters can make meaningful and reliable comparison among projects, or different solutions for the projects. The quantifiable parameters for hospitals and physicians can be developed from the following areas: Quality, Process Improvement, Financial, and Customer Satisfaction, to show the business performance comparison before and after the project implementation. Many organizations have defined their own key performance indicators (KPIs) to measure the business health of the organization and ensure that all employees at all levels are in sync with the organizational goals and strategies. These KPIs should be considered as a source for the success factors to measure the project output as well. As discussed at the beginning of the framework, the key for a successful cloud computing adoption is to align with the organization's goal and overall strategy. The definition of the success factors needs to show that in a quantified way.

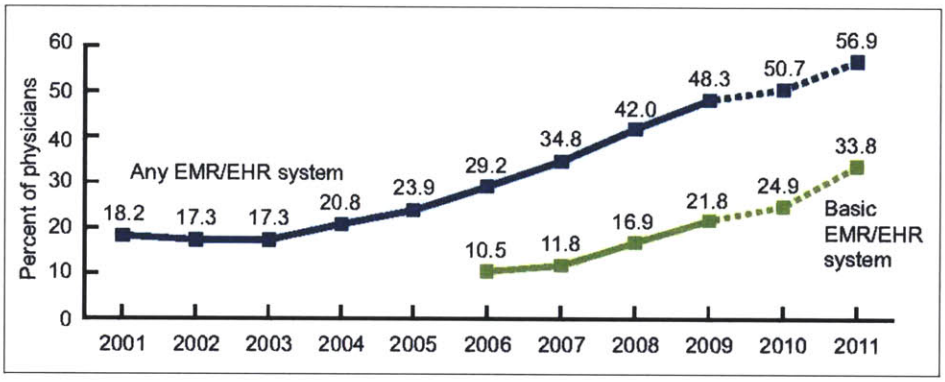
5. EHR - A Case Study

After the ARRA simulation plan, many IT vendors started to develop, test, and implement systems that provide meaningful use of EHRs. Cloud computing is also one of the solutions. A case study on cloud computing for EHR is used to evaluate the framework and show that the readiness of cloud adoption in EHR systems.

To set the stage, we will use PTSO of Washington (PTSO) as the subject of the study. In essence, PTSO is a Health Center Controlled Network (HCCN) providing centralized healthcare information systems to multiple Community Health Centers (CHCs). PTSO provisions software development, application management, technological infrastructure, project management, and ongoing support services for clinical care delivery and patient management systems. They have centralized database storage that hosts the data warehouse for all healthcare centers under their membership. They also provide some data center management services such as disk racks,

real-time replica systems, disaster recovery systems, etc. PTSO is incorporated in 2004 in Seattle, WA and has eight (8) CHC members and over 55 clinic sites. In 2011, there were approximately 335 providers, 140,000 patients using PTSO network which had over 550,000 annual encounters.

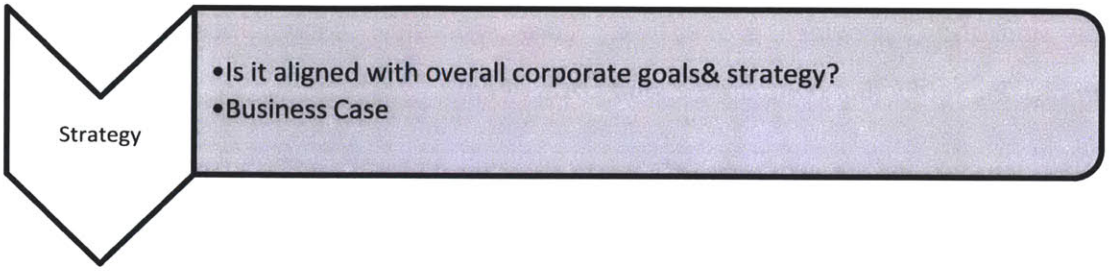
The previous President of the United States, G.W. Bush, set the goal for most Americans to have EHR by 2014 (White House Executive Order, 2004). According to the National Ambulatory Medical Care Survey (NAMCS) done by the National Center for Health Statistics (NCHS) in 2011 on patient visits to office-based physicians that collects information on use of EHR/EMR systems has shown that the adoption of EMR/EHR systems has increased (Figure 8).



NOTES: EMR/EHR is electronic medical record/electronic health record. "Any EMR/EHR system" is a medical or health record system that is all or partially electronic (excluding systems solely for billing). Data for 2001–2007 are from the in-person National Ambulatory Medical Care Survey (NAMCS). Data for 2008–2009 are from combined files (in-person NAMCS and mail survey). Data for 2010–2011 are preliminary estimates (dashed lines) based on the mail survey only. Estimates through 2009 include additional physicians sampled from community health centers. Estimates of basic systems prior to 2006 could not be computed because some items were not collected in the survey. Data include nonfederal, office-based physicians and exclude radiologists, anesthesiologists, and pathologists.
SOURCE: CDC/NCHS, National Ambulatory Medical Care Survey.

Figure 8 Percentage of office-based physician with EMR/EHR systems: United States, 2001-2009, and preliminary 2010-2011

The number suggested that the pace of adoption of EHR is quickening. If PTSO is going to adapt to a new EHR system, how should they start their evaluation? Is cloud computing a suitable technology? If so, how and what does it cost to implement a successful solution? Using the framework developed above, we hope to help PTSO to make a clear and confident decision.



When PTSO considers the adoption of a new EHR system, the first step is to evaluate the overall alignment of strategy and corporate goals (as shown in Figure 7). As stated on PTSO's website, PTSO's vision is to become "the technology services partner of choice to enhance community health center business processes and improve community health." The mission of PTSO is: "To work in partnership with CHCs to improve patient care through shared, cost effective technology and services."[9] Adopting cost effective technology to improve patient care is one of PTSO's organizational strategies. Cloud based EHR as one of the fast developing technologies has received much attention from the IT and HIT industries. So the question to be answered is, "does the adoption of a cloud based EHR system align with PTSO's goals and strategy?

A systematic review on the impact of HIT on quality, efficiency, and costs of medical care (Wu, et al., 2006) concluded that the benchmark institutions have demonstrated the efficacy of HIT in improving quality and efficiency. An updated review as a continuum of the above study (Goldzweig, Towfigh, Maglione, & Shekelle, 2009) confirmed the previous conclusion, and also indicated the paucity of quantitative cost-benefit data and calculation of actual HIT implementation.

Southern California Evidence-based Practice Center (EPC) has provided an evidence-based practice report on the costs and benefits of HIT systems, along with an accompanying interactive database that catalogs and assesses the existing evidence (PG, SC, & EB, 2006). This report systematically reviews the literature on the implementation of HIT systems in all care settings and assesses the evidence in specific circumstances, such as the costs and benefits of HIT for pediatric care, the costs and cost-effectiveness of implementing EHR, and so on. The result of this study showed that, *EHRs were associated with improvements in service and other*

[9] PTSO homepage: http://www.ptsowa.org/about-us.html. Retrieved on December 27, 2011.

resource utilization, provider productivity, care efficiency, documentation quality, clinical decision-making, guideline compliance, and costs of care.

Apparently, the studies confirm that, in general, implementing an EHR system aligns with PTSO's organizational goal of improving patient care. However, the literature also indicated that building a business case using quantitative cost-benefit models is still in early development stages. There is a lack of meaningful data to calculate and show numerical financial benefits and gains.

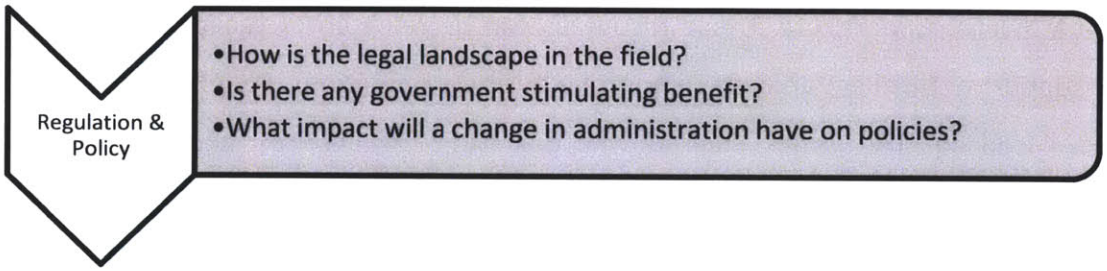
In this case we will discuss the business case of cost-benefit of adopting a cloud based EHR system at PTSO in qualitative senses:

- From a business perspective: as a membership organization, one of PTSO's tasks is to help its members to be more efficient and effective at their business processes through training, education, and new technology adoption. Information and knowledge sharing on business processes across members of PTSO can be achieved by using cloud based EHR systems. When there are other HCCN or similar organizations using the same cloud, sharing data or function across multiple organizations is also possible. Cloud based EHRs are generally developed to scale and to serve a greater base of clients, therefore they provide a powerful platform for the clients to share best practices on their business processes.
- From a financial perspective, implementation of an EHR system requires substantial capital investments, especially at the beginning of the learning curve for training and loss of productivity. However comparing to conventional EHRs, the cloud based solutions not only improve workflow and reduce paperwork, but also reduce the cost of infrastructure and space usage, as well as the need of hiring more employees to manage and maintain on-premise systems (Kundra, 2010). Software upgrades and ongoing support can be outsourced to the cloud vendors. All of these provide necessary cost savings for PTSO to stay flexible and cost competitive in financial needs.
- From an IT perspective, migrating to cloud-based EHRs will free up the IT resources devoted to functions such as network administration, system maintenance, and

hardware support, etc. Those resources can be released or reallocated to user-facing support or business analysis to improve business operations. For example, they can stay focused on EHR usages, such as who are using EHR services, which departments are most frequently users, and other usage patterns. By doing so, the IT group will get a better understanding of the business, and improve its services accordingly as an integral part of the business, and then ultimately becomes a stronger force in driving the business using appropriate information technology (Thompson, Osberoff, Classen, & Sitting, 2009).

- From an employee perspective, an easy-to-use cloud based EHR system not only makes their jobs easier, but also makes their skills transferable when they move from one organization to another. As discussed in section 2.1, cloud computing becomes more and more popular in most industries or areas. The skills developed in cloud EHR adoption by PTSO employees are applicable to other types of cloud adoptions. Either another type of cloud, or the same cloud in another organization, directly or indirectly adopting a cloud based EHR improves the competencies and competitiveness of PTSO's employees in the job market.
- From an organizational perspective, implementation of an EHR system typically requires significant organizational change, as new procedures and business practices have to be adopted in order to meet the EHR collecting and storing rules and regulations. A cloud based EHR system unifies these procedures and business practices among members of PTSO, at the same time also connects PTSO with others who use the same cloud. Although the same organizational change is required for both cloud based EHR and conventional EHR, a cloud-based solution provides more opportunities for benchmarking with similar organizations.

In summary, EHR systems are essential for improving efficiency and quality of health care, and cloud computing makes it easier and less expensive, both of which align with PTSO's overall goals and strategies. A qualitative analysis on the business case of adopting a cloud base EHR also shows multiple benefits in all perspectives. Thus, we conclude the adoption of cloud based EHR is strategically sound and beneficial to PTSO in the long run.



Next, we need to look at the regulations and policies.

HIT is heavily regulated due to the sensitivity and privacy rules of health information. EHR as a major component of HIT not only has to obey the laws enacted to overall HIT systems, but also has to follow the specific regulations and standards regarding EHR.

From the Table 3 we can see that in order to be qualified as an acceptable EHR, it has to meet many specific rules and requirements. The legal landscape is very complicated. The government stimulation plan is provided, but requires substantial work to demonstrate "meaningful use" of certified EHR technology. Incentive payments are conditioned on the ability of providers to demonstrate "meaningful use" of EHRs, defined by the statute as (1) use of certified EHR technology in a demonstrably meaningful manner, including e-prescribing; (2) use of certified EHR technology that allows for the electronic exchange of health information to improve the quality of healthcare, such as promoting care coordination; and (3) reporting on clinical quality measures and other measures selected by the Secretary using certified EHR technology (ARRA, 2010).

HITECH employs both "carrots" and "sticks" to encourage the adoption and use of EHRs. It provides monetary incentives to eligible healthcare providers under Medicare and Medicaid, and also threatens financial penalties in the form of reduced Medicare payments for non-adopters. Table 7 and Table 8 show the details and schedule of the incentive payments from Medicare and Medicaid (Goldstein, 2010). Starting from 2011, physicians and hospitals who can demonstrate meaningful use of a certified EHR system can receive bonus Medicare payments for up to five years. Starting in 2015, physicians and hospitals that are not meaningfully using EHRs will be penalized in the form of reduced Medicare fees.

Adoption Year	First Payment Year Amount and Subsequent Payment Amounts in Following Years (in thousands of dollars)	Reduction in Fee Schedule for Nonadoption/Nonuse
2011	**$18, $12, $8, $4, $2**	$0
2012	**$18, $12, $8, $4, $2**	$0
2013	**$15, $12, $8, $4**	$0
2014	**$12, $8, $4**	$0
2015	**$0**	−1% of Medicare fee schedule
2016	**$0**	−2% of Medicare fee schedule
2017 and following	**$0**	−3% of Medicare fee schedule

Table 7 Medicare Incentive Payments for Meaningful Use of Certified EHRs by Eligible Professionals (in thousands of dollars)

HITECH also gives an explicit boost to state funding efforts for HIT under Medicaid by providing a 100% federal contribution to enable EHR adoption by Medicaid providers who serve a high volume of Medicaid patients. In order to qualify for the Medicaid incentive payment, a provider's patient load must be at least 30% Medicaid. While the HHS is obligated to implement HITECH's Medicare HIT incentives, Medicaid implementation is an optional state undertaking.

	Payment Year											
Adoption Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total Payment
2011	21.25	8.5	8.5	8.5	8.5	8.5	**0**	**0**	**0**	**0**	**0**	63.75
2012		21.25	8.5	8.5	8.5	8.5	**8.5**	**0**	**0**	**0**	**0**	63.75
2013			21.25	8.5	8.5	8.5	**8.5**	**8.5**	**0**	**0**	**0**	63.75
2014				21.25	8.5	8.5	**8.5**	**8.5**	**8.5**	**0**	**0**	63.75
2015					21.25	8.5	**8.5**	**8.5**	**8.5**	**8.5**	**0**	63.75
2016						21.25	**8.5**	**8.5**	**8.5**	**8.5**	**8.5**	63.75

Table 8 Medicaid Incentive Payments for Meaningful Use of Certified EHRs by Eligible Professionals (in thousands of dollars)

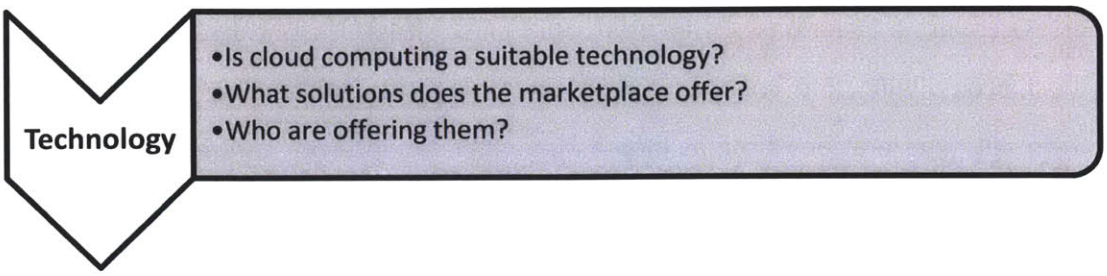
In addition to the incentive programs, HITECH also significantly revised the HIPAA law and established the national data security breach notification law for the first time by requiring covered entities to notify individuals whose unsecured PHI has been disclosed as a result of a privacy or security breach. This law is not limited to breaches of the security of online information or restricted to financially sensitive information, such as Social Security numbers. The statue applies similar breach notification requirements to vendors of PHRs (Personal Health Records), businesses that offer products or services through the Web site of a PHR vendor or a

covered entity that offers PHRs and entities that access information in or send information to a PHR (ARRA, 2010).

ARRA's HITECH provisions reflect a shared conviction among the presidential administration, Congress, and many healthcare experts that electronic information exchange is essential to improving health and healthcare. However, HIT as a means of improving the quality of healthcare and the efficiency of healthcare systems, still faces a number of implementation challenges. First of all, to support the new set of complex statutory and regulatory requirements for the incentive programs, technical and financial assistance for providers and federal and state agencies are required. Furthermore, these requirements will require changes in workflow processes and systems that will take resources and time to implement and upgrade.

When there is an administration change (e.g. 2012 selection), there generally will be some directional change in the regulatory rules. It usually takes a great amount of time for this type of directional change to become fully understood and enforced. Since most of these rules are long term (count in years), while the decision for an EHR adoption project is short term (count in months), the direct impact of administration change on a specific project would not be dramatic. Nonetheless, the implementation of EHR adoption projects may take years, including customization, workflow redesign, and sometimes changing vendors several times. The organization should monitor the situation and adjust long-term organization strategies accordingly.

We have discussed the effect of government stimulation on the technology adoption curve in section 3.3. During the technology evaluation and implementation, all of these rules and requirements have to be carefully considered and evaluated. They should be treated as a part of the requirement analysis before the design and development starts.



Organizations need to be savvy on technology selection. There are a lot of potential systems offered by various vendors. A recent search on ONC-ATCB certified EHRs returned 1132 ambulatory and 549 Impatient EHR products.

Generally all EHRs fall into three categories: 1) Client/Server model, 2) ASP based web model, and 3) Cloud Computing based. Table 9 shows pros and cons of each of these categories.

EHR Model	Pros	Cons
Client/Server	More control	Requires special SW installation; more investment in computer hardware and technical support;
ASP based	Browser ready; Medium accessibility;	Medium investment in HW and SW;
Cloud based	Browser ready; Superior accessibility; Scalability; Collaboration;	Least investment in HW and SW;

Table 9 EHR Technology Comparison

For PTSO, a cloud based EHR is a suitable technology because of the following reasons:

- There are a number of cloud based ONC-ATCB certified EHR solutions available, which indicates that cloud computing technology has passed the initial hurdle of developing commercial EHR clouds that are HIPAA and "Meaningful-use" compliant.
- PTSO as an HCCN organization puts a lot value on scalability of the system. Both scale up and scale down are needed as new member joins PTSO or existing member leaves PTSO. A cloud based EHR offers PTSO the maximum flexibility with minimum cost among the three models. For example, they can add or remove storage with Amazon or Google cloud at any time and only pay for the usage incurred. But with a conventional implementation, they have to buy extra storage space upfront, and it is nearly impossible to get rid of excess storage without financial penalty.

- PTSO covers a large base of locations (55 clinic sites). A cloud based EHR provides the best accessibility and collaboration as users are able to securely log in to the system from anywhere at any time as long as they have an internet connection. To be certified by ONC-ATCB, the cloud based EHRs need to demonstrate adequate assurance on privacy and security in a widely open environment (the Internet) to meet the HIPAA and HITECH Privacy Rules. This locational transparency where data can be requested and produced without regard to data location and without worrying about privacy and access control is very important to PTSO. The increasing trend of cloud computing adoption in other industries has been clearly evidenced in many surveys and studies (CDW LLC, 2011) (Deloitte, 2011). Even though health care industry has lagged behind, the same trend is also shown in the referenced surveys. Adopting a cloud based EHR solution fits into the overall industry trend and will prepare PTSO well for future development.
- Among the 1132 ONC-ATCB certified ambulatory and 549 impatient EHR systems, approximately 10% of them are cloud-based solutions. PTSO has the opportunity to choose from an abundant resource and find the solution meets PTSO's requirements.
- While safety and security of clouds still remain as a primary concern for many health care professionals, we should trust that the ONC-ATCB certified cloud based EHRs meet the security and privacy rules set forth by HIPAA and HITECH. The Computer Security Division of NIST has provided "guidelines on security and privacy in public cloud computing" (NIST, 2011) . Following the guidelines carefully will further eliminate those concerns that PTSO may have.

Table 10 shows a partial list of ONC-ATCB certified cloud based EHR solutions[10] and the companies who offer them. Since PTSO is a central network providing IT solutions to all its members, it has better information technology resources and expertise than a general health center. PTSO also has the capability of developing its own IT applications and solutions. Therefore, PaaS seems to be a better choice as it provides customer application development capability. However, in the EHR case, as we can see from the following table, most of these

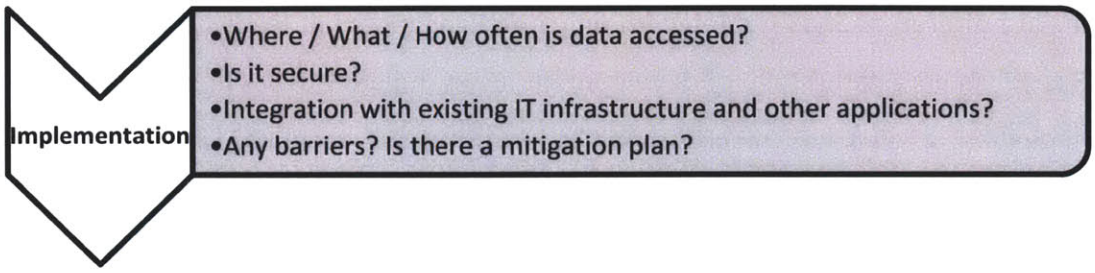
[10] http://www.cchit.org/products/onc-atcb; Retrieved on Jan 30, 2012.

solutions are offered as SaaS model, with only one PaaS model. It leads us to believe that PaaS for EHR is still in very early stage of development. Even though PTSO is pioneer in adopting new IT technologies, it also has responsibility in ensuring the reliability and robustness of its solutions. Using the factor matrix developed in section 4.3, we believe the best suitable technology for PTSO at this time is a SaaS cloud model, since it is so far the most mature model in the HIT cloud computing market (Table 5) and in the cloud-based EHR offerings.

Company Name	Product Name	Architecture Layer	Cloud Model	References
Athenahealth	AthenaClinicals	SaaS	Public	http://www.athenahealth.com/our-company/about-us.php
HePoEx: Microsoft	Connect EHR	SaaS	Public (Microsoft cloud)	http://www.hepoex.com/microsoftcloudpower.htm
Unifi Technologies	Unifi-Med	SaaS	Public	http://www.emritc.com/Unifi-Med.html
Sevocity	Secure Web EHR	SaaS	Private	http://www.sevocity.com/secure-cloud-ehr
CareCloud	CareCloud	PaaS	Public	http://www.carecloud.com/

Table 10 Cloud Based EHR Solutions

Please note, it will take additional detailed evaluation and vendor negotiation on terms and price before a final decision can be made on which specific product to select. This is beyond the scope of this thesis, so we won't get into it here.



Implementing an EHR solution can be a tedious task for an organization that has other similar systems or processes in place. Many research organizations and consulting firms have done a lot of prep work to ease and guide the transition. For example, the Healthcare Information and Management Systems Society (HIMSS) developed and published an exhaustive checklist focusing on the workflow, operations, and communications factors in an EHR implementation process. The full report is attached (Appendix I) and can serve as a great reference for anyone who is seeking to transition to EHR.

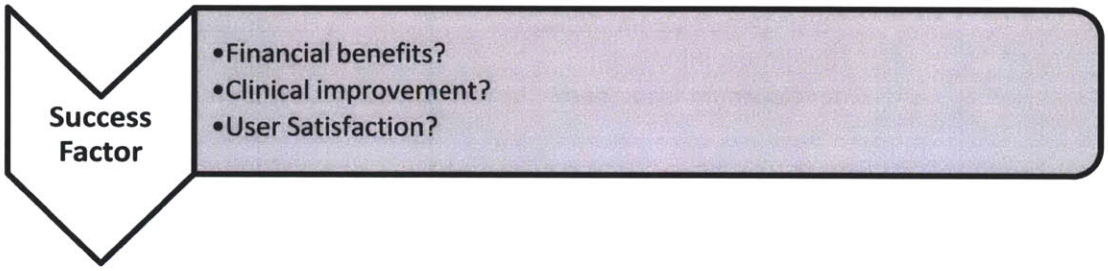
In order to make the checklist suitable for a cloud EHR implementation, we just need to further advance the HIMSS checklist for cloud adoption purpose. The HIMSS checklist is a 40-page long document. Most of the checklist items are applicable to any type of EHR system adoptions, including clouds. With just a few more add-ons specific for a cloud computing solution, the checklist will be ready to go.

Decisions	Questions	Answers
Type of Cloud	- Which one best suits your needs? Public, Private, or Hybrid? - Integration with existing IT infrastructure and other applications?	- In addition to EHR systems, PTSO also provides other IT services, such as operations and hosting services, report services, EDI services, etc. PTSO's existing EHR system is a self-hosted client/server system. In order to integrate the new EHR cloud into the existing infrastructure, a hybrid cloud seems to be the best option. Both public cloud and private cloud are also viable options.
Application	- Does the cloud vendor provide off-the-shelf solution?	- The cloud vendors provide off-the-shelf solutions as well as

	- Do you need customization? - How much additional development is needed?	customization capabilities. - The amount of additional development is dependent on the type and amount of customization. But it shall be a lot less than developing an EHR from scratch.
Regulatory Requirement	- Does the cloud comply with required regulations?	- ONC-ATCB certified EHR solutions must comply with required regulations such as HIPAA and HITECH.

Table 11 PTSO Cloud EHR Implementation Checklist

While the actual implementation is not a focus of this thesis, one should know that the implementation of the selected system takes more than just check the checkbox. A HITECH survey on EHR implementation shows that collaboration and information gathering from peers is critical to the implementation process, and workflow training and change in management are the two greatest challenges for EHR adoption (Carol, 2010). Here we attempt to provide a guideline built upon the lessons learned from other organizations so the same mistakes can be avoided for PTSO.



As stated by HSRA, HCCNs as business entities are also formed to exchange information and establish collaborative mechanisms to meet administrative, IT and clinical quality objectives. PTSO as one of the HCCNs must carry the same set of objectives. The adoption of EHR cloud should also support PTSO in achieving these objectives. Therefore, the success factors of the adoption shall include measureable performance parameters in various areas, such as quality improvement, process (operation) improvement, financial benefits, customer satisfaction, and so on, to support the organization objectives.

As the final step of the framework, we should investigate what criteria to use as indications of the successfulness of the EHR cloud adoption. Table 12 shows the chosen parameter for PTSO and the desired trend of after the EHR cloud adoption.

Success Factors	Before EHR Cloud Adoption	After EHR Cloud Adoption
Quality Improvement		
Number of CHC members	Base	Increase
Number of clinical sites	Base	Increase
Number of treatment(encounters)	Base	Increase
Encounter/employee Ratio	Base	Increase
System Downtime	Base	Decrease
Process Improvement		
EHR mistake instances	Base	Decrease
Average waiting time	Base	Decrease
Financial Benefits		
Software Annual Maintenance Cost	Base	Decrease
Hardware Annual Maintenance Cost	Base	Decrease
Customer Satisfaction		
Customer Overall Favorability	Base	Increase
Number of complaints	Base	Decrease

Table 12 Success Factors

It is important to establish the measurement method of these parameters at early stage to ensure necessary processes and data points are being defined and collected. (National Committee for Quality Health Care, 2006), (The Society of Hospital Medicine's Benchmarks Committee, 2006), and (Shih & Schoenbaum, 2007), have provided details and guidelines on the metrics and quantification methods to measure the hospital performance. We will not discuss the data collection and calculation of these parameters here, but referring to the above documents is highly recommended when implementing the metrics.

6. Conclusions

Health care organizations are rapidly developing their HIT systems, but they are still at the start of a transition period and face many challenges with respect to cloud computing adoption. There are currently no mature techniques or frameworks available to address the identified challenges. This thesis is an attempt to provide a framework to support decision-making during the cloud adoption for health care organizations.

The value of the framework is demonstrated using a case study that focused on adoption of cloud based EHR systems in an HCCN organization. The study showed that the framework is effective in identifying the outstanding issues and providing guidelines in solving these issues specific to the case. Based on the results of the analysis using the framework, it was recommended that adopting EHR cloud at PTSO fits its overall strategy and is supported by the business case; there are multiple choices of ONC-ATCB certified cloud based EHRs meeting the regulations and standards set forth by the government; cloud based EHR is a suitable technology for PTSO; and by following the implementation recommendations using the comprehensive checklist, the success of the adoption can be reflected in the measurements of the key performance parameters of the HCCN organization.

7. Acknowledgements

During this study I received tremendous help from my advisor David Hartzband. Thank him for his guidance and patience. I also thank Michael Lardiere, Doug Smith, Roy La Croix, Daniella Meeker, Natasha Balac, Dallas Thornton, Aziz Boxwala, Mike Gualtieri, and Ken Accardi, who have generously offered their time and shared with me their views and real life experiences in the field.

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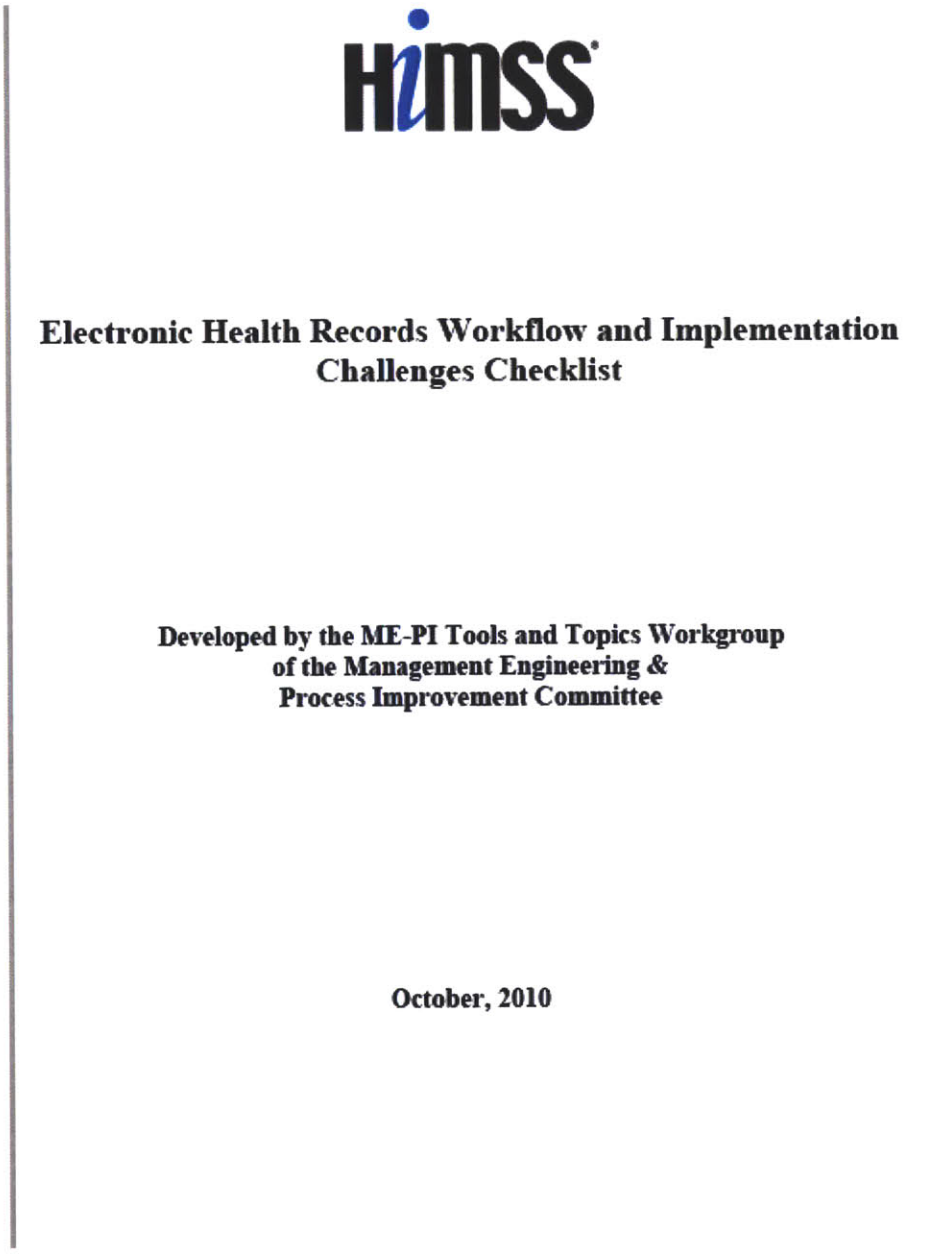
Appendix I EHR Workflow and Implementation Checklist (by HIMSS)

<<Double click on the image below to active the appendix document>>



HIMSS

Electronic Health Records Workflow and Implementation Challenges Checklist

Developed by the ME-PI Tools and Topics Workgroup of the Management Engineering & Process Improvement Committee

October, 2010

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