Essays on Electronic Health Records (EHR) Process Framework and Design-Theoretic Model in a Multi-Stakeholder Context

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Karoly Bozan
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Introduction

Health information technology (HIT), and more specifically electronic health record (EHR) systems offer the capacity and promise to increase the quality of care, to improve efficiency and effectiveness in the healthcare delivery process, and to reduce care related costs. While the electronic health records is a patient-oriented, aggregated, longitudinal system that compiles patient medical records, the underlying software attributes define the EHR system characteristics. Similar to other data driven applications, the data itself is of limited value unless carefully designed intelligent software support the core processes and the ultimate decisions. In a healthcare environment, this software is expected to support the care process and clinical decision making in addition to capturing, storing and retrieving digital patient information in the required format to an authorized user.

Just like information systems (IS) in general (Henderson & Venkatraman, 1993), HER systems assume increasing strategic roles within healthcare organizations with the aim of quality patient care across the healthcare continuum. In order to support the organization-wide use of information, EHR systems need to span across multiple patient-care processes and departments aiding different stakeholder groups in their job functions. Consequently, these user groups will have varying objectives and expectations from the EHR system to support their information and decision making needs.

The success of an EHR system implementation is measured by the degree it is used (e.g. Devaraj and Kohli, 2003) because it meets the users’ expectations. It is an especially challenging object to meet in a multi-stakeholder environment and a common reason for IS implementation
failures is that organizations decide on a technological solution without fully understanding the underlying processes and stakeholder objectives (Sallas et al. 2007; McGowan et al. 2008).

Our research contributes to the literature through enhancing the theories, upon which we build our investigation. We also provide practical implications to vendors, project executives, and users.

**Summary of Essays**

Understanding the users’ perspectives and objectives prior to deciding on an IT investment is crucial for the success of the project (Bowen et al., 2007). Healthcare organizations adopt and implement EHR system solutions to improve organizational operations. However, due to legislator pressure, healthcare entities begin to deploy EHR systems in haste. This urgency often results in overlooked needs from the users and in poor EHR system choice that does not accommodate the objectives of its stakeholders. Furthermore, EHR software vendors may not have the time to properly understand the activities and processes the users perform and their often diverging needs within these activities and processes. In order to meet the organization’s needs, the existing business processes need to be evaluated on a granular level and all downstream EHR system users need to be considered during software development, in requests for proposals from EHR software vendors, and during implementation.

This dissertation research, in two separate empirical investigations using 168 participants, examines the design and implementation of electronic health record (EHR) systems across stakeholders groups involving practitioners, patients, administrators and auditors.

The first essay considers the fundamentals of the processes that surround what governs good health care objectives and addresses the need for research concerning the lack of
understanding of stakeholder objectives within activities and processes that makes up a healthcare organization’s operations. This deficiency has a significant impact on the choice of information system and its implementation success.

The literature provides three central reasons for why the health care industry differs from others and how it may influence EHR implementation (Boonstra and Govers, 2009):

1. Hospitals have multiple distinct objectives across departments.

2. Hospitals have substantially different and complex processes and structures from other industries.

3. Hospitals have different stakeholders in their workforce with their own objectives even within the same process.

Literature still lacks compelling evidence on the effect that different stakeholder groups have on EHR system selection and implementation. A prevalent explanation to information system implementation failure is the lack of system use by one or more user groups. This perspective holds when users’ job functions are not supported, they will work-around the system and partially or fully abandon its use. In the first essay of my dissertation research, I delve into the understanding of users’ expectation they have towards an EHR system to explain stakeholder expectations discrepancies and provide an empirical test on the stakeholder groups’ level. Essay 1 of this dissertation research answers the following research question: What are the factors and processes across stakeholders that can contribute to successful EHR implementation in outpatient healthcare?
We evaluate the main stakeholder groups’ objectives on a never before scrutinized granularity. Therefore, the emphasis in this dissertation research is not just at the system characteristics level, but also at a deeper, process and activity level. We propose an EHR Maturity Model (EMM), following Paulk et al’s (1993) Capability Maturity Model and empirically validate our findings of stakeholder misalignment, which may provide important guidance for not only healthcare organizations during vendor selection but the users and system designers alike.

We highlight and delineate four sequential processes of (1) scheduling patient visit, (2) reviewing patient medical records, (3) diagnosing and treating patients, (4) reporting and follow-up embodying 24 activities. In validating stakeholder differences, the study examines the gap between stakeholder perceptions of importance and perceptions of satisfaction. Findings from a detailed review suggest significant gaps in reporting and follow-up followed by diagnosing and treating patients, reviewing patient medical records, and scheduling patient visit. The gaps surface disconcerting evidence of misalignments between stakeholders, albeit required to use EHR systems for everyday operations. The gaps identified in this research is the first in this area of research to examine stakeholder needs and gaps at a granular levels of healthcare operation and practice, allowing researchers and practitioners to pinpoint process-level disparities and address mechanisms to mitigate and rectify them. Furthermore, due to the granularity of our proposed EMM, it may also provide guidance for business process redesign.

As mentioned above, the EHR system use across all downstream users drives the success of the implementation project. Research investigating the proper design of EHR systems in a multi-stakeholder context remains scarce in the system design literature. Following existing information system design theories and models, in essay 2, we propose a design theoretic model
(DTM) adopted from and expanded upon Walls et al.’s (1992) information system design theory and answer our research question: What are EHR design criteria and how do expectations of satisfaction with EHR design kernels impact stakeholders’ openness to use an EHR system?

The unique approach of our DTM is that we consider both the organizational and system level simultaneously while they are clearly distinguishable in our model. This allows for capturing organizational level requirements on an abstracted level, while it will be translated to the system or design level for the developers. Therefore, our DTM builds the bridge between organizational or stakeholder needs and the system characteristics and features that are designed to meet those specific needs. Following these methodological steps, which are governed by alignment kernel theory, ensures that the designed artifact meets the often diverging needs of stakeholders on a more granular level.

Following our DTM, we extract meta-kernels and kernels with three EHR system characteristics across eleven specific features. As a part of the kernel exposition element of the DTM, the research forwards a hypothesized framework highlighting the interlinkages and relationships between stakeholder expectations of satisfaction and stakeholders' openness to use a system. We follow the expectation-confirmation theory (Oliver 1980) as the theoretical base for our empirical testing. Findings surface a positive relationship between expectations of EHR system availability and portability and between portability and usability. The findings interestingly highlight negative relationships between portability, security/accountability and confidentiality on openness to use because of portability, confidentiality and usability. The findings suggest that higher expectations of EHR characteristics can often reduce stakeholder use-behavior. Furthermore, our discoveries highlight that aspects of portability, accountability
and confidentiality serve as a double edged sword and suggest a fine balance in crafting operational and regulatory policies for effective use of EHR systems across stakeholders.

The results strongly support our proposed kernel relationships in our framework and contribute to system design literature in a number of ways. First, we connect the often segregated, yet tightly associated organizational requirements and system level characteristics. We provide the methodological steps from broad problem identification to specific system features to remedy the problem. Second, we investigate and empirically confirm the kernel relationships on the stakeholder role level, which unravels an often overlooked difference in expectations and satisfaction within a kernel. We also used the expectation-confirmation theory that has not yet used to guide the kernel exposition element of any design theory or model. Finally, the practical implications for users, vendors, and project executives are evident as we provide the sequential steps required for a better understanding of multi-stakeholder driven EHR system requirements and the resultant design steps to conform to the expectations.

Overall, this dissertation research provides an overarching understanding of the diverse needs of a multi-stakeholder EHR system and highlights the importance of this often disregarded phenomenon. Furthermore, we provide theory driven guidance to better prepare both the designers and the users to accommodate the needs on a more granular level. We argue that as one of the main reason for EHR system implementation failure, following our proposed approach may result in higher user satisfaction, which translates into more successful EHR system implementations. This research is particularly relevant as a surge in EHR implementations may be expected in the next few years.
Essay 1

Process Framework of a Multi-Stakeholder EHR system

Chapter 1:

Introduction

1.1. Motivation

Despite astronomical national healthcare spending in the United States (Heffler et al. 2002), patients often lack consistent, quality and safe care (National Healthcare Quality Report, 2006; Marjoua & Bozic, 2012). In addition to the expensive and inconsistent care, healthcare is one of the few industries, which is about two decades behind in terms of innovative information systems to improve quality and patient safety (Hughes, 2008). Data is repeatedly delivered manually to users in the healthcare system and accumulates reams of paper that is virtually impossible to analyze. The healthcare industry in the United States is in dire needs for improvements in the way it functions.

Myriad of case studies and research suggest that health information technology (HIT), and more specifically the electronic health records (EHR) systems show the capability and promise to increase the quality of care and reduce health care related costs (Zdon and Middleton 1999, Keshavjee et al. 2001, Wang et al. 2003, Barlow et al. 2004, Chauddhry et al. 2006, Jha et al. 2008). In order to expedite the implementation of such major information system, President George W. Bush issued an executive order on April 27, 2004 to establish the Office of the
National Coordinator for Health Information Technology (ONCHIT) with the mission of implementing electronic health records (EHRs) nationwide, within the following decade (Executive Order 13335, 2004). In line with his predecessor’s long-term initiative, President Obama signed the Health Information Technology for Economic and Clinical Health (HITECH) Act under the American Recovery and Reinvestment Act (ARRA or “stimulus plan”) in February of 2009. $19 billion in funds is allocated to providers and hospitals to promote EHR adoption and Meaningful Use under the HITECH Act. In addition, $59 billion is allocated to incentivize EHR adoption healthcare incentives as part of the ARRA. The Executive Order’s strategic framework envisioned interconnected clinicians on the regional and national level through the EHR adoption.

The 10 years for nationwide EHR implementation that President Bush anticipated has passed and we see a lackluster implementation rate over time. Neither the national, regional and practice type implementation rate are above 58% in 2012 (DesRoches et al. 2013, Robert Wood Johnson Foundation, 2013). Even basic EHR implementation to hospitals lags at 44% while comprehensive EHR system implementation is at only 17% in 2012 (Abramson, 2012).

The role and advantages of EHR to achieve a more coordinated and higher quality care are indisputable. EHR is a complex, organization-wide information system with different user groups with varying interests and needs and, often times, conflicting levels of engagements and objectives (McGlynn 1997, Joss & Kogan 1995). In order to design and implement this highly interdisciplinary care concept, information needs to be available to the right person at the right time and place in the form expected from all stakeholders involved (Toussaint & Coiera, 2005).
1.2. Purpose of Research

Organizations implement information systems to increase productivity, efficiency and effectiveness, and consequently decrease cost and increase revenue and quality of service. Silver et al. (1995) found that information systems capabilities largely depend on the organization and user characteristics, the system development and implementation and the technology’s interaction with the organization and its environment. Organizations depend heavily on information systems, which are used by multiple different stakeholder groups with different levels of engagements and often conflicting expectations from the system. Karahanna and Straub (1999) found that stakeholder groups rarely have input in the choice of information systems (Hess et al., 2008; Suchman, 2002; Lyytinen et al, 2006), along with its specific characteristics and the system often only supports a functional set within the organization (Benbya and McKelvey, 2006). Therefore, the question arises: how a single-function based system can support the more demanding and complex inter-departmental work functions that involve multiple stakeholder groups? This contradiction highlights that the apparent benefits of IS are accompanied by drawbacks. To surface these drawbacks, we need to understand the level that an information system accommodates the organizational operations on the process level and on the organizational level. In this dissertation research we will answer the following research question: What are the factors and processes across stakeholders that can contribute to successful EHR implementation in outpatient healthcare?

In spite of successful IS implementations (Fitzgerald & Russo, 2005; Pan, Pan, & Flynn, 2004; Pan, Pan, Newman, & Flynn, 2006) research on the implementation failures abound (e.g. Kim & Pan, 2006; Lam & Chua, 2005; Lemon et al. 2002; Pan, 2005). Assessing and addressing stakeholders’ expectations during system design, as fulfilling their expectation are inevitable to
IS project success. Therefore, a clear understanding of stakeholders involved, their role and objectives in the organization and workflow is inevitable for ensuring IS implementation success and system use (Bowen et al. 2007).

Users expect information systems to represent the world as they perceive it (Wand and Weber, 2004). This expectation is particularly challenging to fulfill in the healthcare industry due to its complex domain as a result of the distributed decision making by different users with differing perspectives and objectives (Effken, 2002). Therefore, requirements of an information system have changed from static statements of desirable system characteristics to dynamic evolution of rationales that mediate the design complexity of multi-stakeholder users (Jarke et al. 2011). Unfitting design of information systems do not only hinder the productivity of the organization by failing to deliver the expected benefits (Murphy & Simon 2002), but also jeopardizes its service quality, which is especially important in the healthcare industry. Hence, this dissertation research aims to provide a comprehensive guide to understanding the varying needs and expectations of system users within and across patient flow processes of a healthcare organization.

1.3. Research Problem

Care delivery in the healthcare industry involves conflicting viewpoints of users and the support of collaborating inter-professional teams, practice administrators, patients and practice auditors. Consequently, designing a system that supports all stakeholders’ expectations has been a challenging task. After reviewing the use of clinical information systems and identifying their functions, Dorr et al. (2007) concluded that electronic health records systems lack the multi-stakeholder support.
More stakeholders require varied system features and characteristics (Ravichadran and Rai 2000, Hirscheim & Klein 1994) based on their respective and functional tasks they perform within the system. Due to the extended and involved value chain of the EHR system, multiple groups of stakeholders are involved. These diverse groups of users utilize a variety of system features and characteristics, which might overlap across the stakeholders and result in differing perceived value of the same feature.

Information system features need to accommodate a diverse group of stakeholders. Aligning the IS with users’ varying need, therefore, becomes more difficult (Corvera Charaf et al. 2013, Vaast and Levina 2006) and results in a more complex system deployment (Bergman et al. 2008). Therefore, the system features need to follow a rigorous system design methodology, which accounts for the varying need of the stakeholders and the benefit they seek. It is especially important in the context of EHR, where the same feature might be perceived differently based on user’s need and the function it supports.

In the present study, we address the need to identify the disparity that exists among the stakeholder groups using the EHR system. For this purpose, we propose the need for understanding the areas where the deployed EHR system does not acknowledge the varying needs of the different stakeholders or the extent it acknowledges them. Therefore, alignment between stakeholder objectives and the supporting system features is inevitable for successful EHR implementation. The success of an EHR system implementation is measured by the degree it is used (e.g. Devaraj and Kohli, 2003) because it meets the users’ expectations. Kirsch (1997) found that the alignment of the interests of multiple stakeholders during the implementation process helped to achieve the desired outcome. Furthermore, involving users in the system
First, we identify the stakeholders and the role of an EHR system in the healthcare industry. Then, we categorize each stakeholder group and the variations in their identities and interest in the EHR systems. This allows us to identify the conflicting interests different stakeholders have while working within the same patient encounter process. Ultimately, understanding the stakeholders’ system use helps us to identify the varying system feature use within the same process and propose the importance of alignment for system implementation success.

1.4. Role of an EHR System

An EHR system is becoming the major part of patient information source and users increasingly rely on it to provide clinical decisions support. More specifically, in replacement of the paper-based records and charts, EHR is expected to be the sole source of digitized information on patient’s medical history and current conditions. This comprehensive set of information often comprises different practices and providers in different physical locations and provider networks. The patient medical records must be compiled in a coherent and readable way understandable by the patients as well since they must have access to their medical records.

Electronic health records support patient flow across the care delivery process, hence the multi-stakeholder involvement across departments and job functions. In addition to the comprehensive patient medical records, EHR is used by its stakeholders to aid the logistical processes, the patient care protocol, and data entry. The logistical function of the care process includes the appointment settings, physicians order entries and lab result retrievals.
The patient protocol or care process is supported by a comprehensive EHR systems’ decision making tool and the Clinical Decision Support (CDS) application. It provides physicians, staff or patients with timely and relevant care specific information intelligently filtered to support efficiency, effectiveness, increase quality and reduce adverse effects. The information could be as simple as medication reminder to the patient or as complex as diagnostic support to physicians with condition-specific order sets and clinical guidelines.

Accurate data entry and retrieval is imperative for proper continuity of care, especially if it takes place at a different provider or specialist in a different network. Proper documentation templates and appropriately recorded clinical notes in an EHR system are central to the quality information and, in turn, to the quality of care.
Chapter 2:

Theoretical Underpinnings

EHR system, as an integrated clinical tool is viewed as the support of multiple stakeholders across multiple processes, each of which includes a number of different activities. The challenge of supporting these different users and the variety of tasks they perform through their job functions calls for the need for aligning the users and their perspectives. Furthermore, the understanding of current processes may lead to the identification of missing or redundant activities in patient care and serves as a precursor for reengineering the business processes (Carayon 2006, Karsh 2004). This will allow the EHR system to properly support all functions as their perspectives are recognized and aligned. After identifying the stakeholders and the processes with their activities, we will develop a reference model that pinpoints the disparities among stakeholder perspectives and helps to identify the process-level and organization-level maturity to aid a proper EHR system implementation (Aykol and Ince, 2008). Process level accommodation comprises the multi-stakeholder support within a process; while the organizational level accommodation encompasses the level a system supports multiple functions across departments and job functions within an organization. Furthermore, it is important for a healthcare organization to understand the underlying processes and their activities of the patient flow through all stakeholders’ perspectives from beginning to end to recognize the exact needs that a system needs to support.

This dissertation research, therefore, contributes to the literature across information systems, healthcare, and management domains. Understanding the stakeholders, their expectations from an information system and the underlying business processes is the precursor for the proper
information system choice and the opportunity for stakeholder-driven process reengineering in
the making. Furthermore, organizations do not only look for project level performance
enhancement, but also for a reference model that provides directions on how to alter processes to
enhance organizational level enhancements and institutionalize software development practices
(Slaughter and Kirsch, 2006). Therefore, this dissertation research extends the existing research
body on the following three concepts:

- Stakeholder Alignment Theory
- Business Process Reengineering
- Capability Maturity Model

2.1 Stakeholder Alignment Theory

Alignment is the shared understanding and degree of which goals, demands, needs, and
objectives of one component are consistent with the same of other component within an
organization (Nadler and Tushman 1980). The literature provides evidence of alignment being
one of the central tenets to improved organizational performance (Beer et al. 2005, Miller 1992,
Reich and Benbasat 1996) and researchers of the topic have placed emphasis on identifying the
aspects that promote and maintain alignment (Reich and Benbasat 2000, Chan et al. 2006).
Mukhopadhyay et al. (1997) believe that an effectively used IT system does not only improve the
“numerically” measurable results, but it also positively enhances the “soft” measures, such as
organization operates at the highest level of effectiveness.
Even though the literature consists of many synonyms of alignment, such as fit (Porter, 1996), integration (Weill and Broadbent, 1998), bridge (Ciborra, 1997), harmony (Luftman et al., 1996), fusion (Smaczny, 2001) and linkage (Venkatraman, 1989), all refer to the consistency among different components of the business, such as individuals or groups of stakeholders.

System development in a multi-stakeholder context requires accommodation of the varying needs and objectives of the different user groups that are involved in a process. Therefore, it has a major implication on the success of information systems implementation (Zhang et al., 2005). While this concept is familiar to researchers (Avison and Wood-Harper, 1990; Darke and Shanks, 1996; Jurison, 1994; Papazafeiropoulou et al., 2002; Pouloudi and Whitley, 1996, 1997), it has been neglected in practice (Jurison, 1994). In this research, therefore, we seek to develop the understanding about stakeholders’ diverging and converging objectives during the patient-PCP encounter and how these varying needs might influence the choice of EHR system, its service objective, and user commitment.

As the perception of and reaction to IS implementation varies among the stakeholders of the system, multi-stakeholder alignment is required when designing IS for any industry. Implementing IS to meet the diverse and inconsistent needs, goals, demands and support the functions of different work groups remains a challenge for CIOs (Luftman et al. 2006). It is especially true in the healthcare industry, where considerably different functional groups are involved during the care coordination. IT support for care coordination is recognized as one of the top strategic drivers of healthcare organizations’ IT efforts. IT teams are also responsible to meet stringent regulatory requirements that are unique to the healthcare industry.

- Numerous participants are involved in the care coordination process
- These participants are dependent on each other to carry out disparate activities
- Each participant needs sufficient knowledge of their and other participants’ roles, involvement and available resources, in order to carry out these activities
- Participants depend on exchange of information among them to properly manage patient care activities
- The integration of care activities has the common goal of delivering appropriate health care services

2.1.1 Use of Stakeholder Alignment in a Multi-Stakeholder EHR System

Care Coordination in this dissertation research is defined as a process that focuses on information-sharing across providers, patients, types and levels of service, sites and time frames (www.HHS.gov). The alignment in care coordination does not differ in the context of EHR as it involves multiple stakeholders, with varying interests, values and goals, and having some degree of alignment converging consensus based mechanism. Because EHR systems require the integration of confidential information that is filled in, read, and processed across multiple workflows; many different stakeholders are involved in the process.
The importance of multi-stakeholder alignment in care coordination is central, due to the nature of the information the stakeholders deal with and the output they deliver. In order to assess the varying needs and objectives of the different stakeholder groups, we developed a granular understanding of the activities that are comprised in the course of the entire patient-PCP interaction process. This will simplify the healthcare organization’s understanding of the processes involved across functions and the extent that the processes are aligned across the different stakeholders involved in the care processes.

Organizations are in need of a model that allows for assessing the maturity of a multi-stakeholder implementation. The EHR Maturity Model (EMM) we propose will provide an excellent foundation for this assessment and will highlight the area where the deployed information system does not accommodate the varying needs of the different stakeholders or the extent it accommodates them on the activity level.

2.2 Business Process Reengineering

Organizations in the service industry realize and emphasize that their business processes are becoming their critical corporate assets and properly managing these processes have the promise of increased customer satisfaction, market share and performance (Seethamraju, 2012). Business process reengineering has been a reoccurring item on the MIS Quarterly Key Issues for IS Executives yearly list since the 90’s in terms of properly identifying current processes and discovering process improvement opportunities (Brancheau et al. 1996; Luftman et al. 2005). A number of existing research has found IT investments as both enablers for and barriers to changing business processes (Bashein et al. 1994; Coulson-Thomas 1994; Stoddard and
Jarvenpaa 1993, Benjamin 1993; Broadbent and Butler 1995; Davenport 1993; Earl 1994; Earl and Kuan 1994), especially when the chosen IT infrastructure is inflexible or inappropriate (Brancheau et al. 1996; Wastell et al. 1994).

Business process reengineering (BPR) first emerged as a management paradigm some two decades ago with the works of researchers such as Davenport (1993), Davenport and Short (1990), Dixon et al. (1994), Hammer (1990, 1996), Hammer and Champy (1993), Harrington (1991), Johansson et al. (1993) and more. One of the most cited researchers of the topic, Hammer and Champy (1993), define BPR as “the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service, and speed” (1993, p. 32). While the word “radical” was misleading, Hauser and Paper (2007) proposed to change it to “meaningful” to further emphasize the appropriateness of the process change rather than the magnitude or rate (Melao and Pidd, 2008).

In spite of the number of reported organizational performance successes due to BPR (e.g. Martinez, 1995; Caron, 1994), the high rate of BPR project failures were attributed to lack of partnership between IT and business (Martinez, 1995) and not fully understanding the existing processes and related activities (Brynjolfsson and Hitt, 2000). Furthermore, Barua and Winston (1998) and Barua et al. (1996) contend that organizational IS is complementary to organizational processes and the IS implementations need to harmonize with the business processes.

It can be concluded that it is erroneously commonplace for organizations to come up with a technological solution without fully understanding the underlying process, activities and stakeholder objectives. This has been the center piece for IS implementation failures in
organizations and healthcare is especially prone due to the overarching processes across functions and the involvements of different stakeholder groups.

2.2.1 Use of Business Process Reengineering in a Multi-Stakeholder EHR System

This dissertation research considers the fundamentals of the processes that surround what governs good healthcare objectives. Therefore, the emphasis in this dissertation research is not just at the system characteristics level, but also at a deeper, process level. The model we developed support the mechanism for business process reengineering in the making in multiple ways:

1. We increase the granularity of the processes by including multiple stakeholder objectives and highlight the convergence or divergence among the user groups.
2. The model proposed allows an organization to understand both the process level (depth) and corporate level (breadth) maturity of an information system implementation.
3. The above two approaches together allow us to create a set that prefaces a streamed, organizationally and multiple stakeholder driven process reengineering in the making.

The objective of this dissertation research in terms of BPR is primarily to identify the processes and their underlying activities and offer a maturity model for business process reengineering purposes. Process reengineering is contextual by industry, therefore case mix variations need to be accounted for. For example, in service organizations process automation and replication is more difficult than in a production environment because of higher inherent variability between human involvements. Many variables need to be accounted for during BPR in a healthcare organization, such as the type of the organization, the type of health problems
treated, and the regulatory outcome with which the processes need to be aligned. Therefore, providing the process model among multiple stakeholders and across functions provides the representation healthcare organizations will need to use in order to evaluate and redesign their patient care processes.

2.3 Capability Maturity Model (CMM)

Providing high quality, low cost and quick time to market software development continues to be a challenge for software vendors. For decades, the software development industry has sought after some kind of methodology that improved quality and efficiency while reducing development time and cost (Harter et al. 2000). Organizations do not only look for project level performance enhancement, but also for a reference model that provides directions on how to alter processes to enhance organizational level enhancements and institutionalize software development practices (Slaughter and Kirsch, 2006).

Software project success is largely dependent on the people, process, and technology. Since process is the most easily neglected factor, process-oriented quality approach is necessary for a successful software development project. Clearly, higher level of process maturity will reduce unexpected results and uncertainty (Aykol and Ince, 2008).

Paulk et al. (1993) developed the Capability Maturity Model (CMM), which is a development model to guide the formality and proper optimization of development processes rather than spontaneous practices. The formally defined steps optimize the development process by providing managed result metrics and more aligned processes. The evolving sequence of maturity levels are defined in the CMM and provide guidance for process enhancements and a controlled software development process.
The primary purpose of CMM is to provide the tools necessary to support improvements for process used to develop and maintain systems and products. A formal appraisal of the current processes gives the organization a suggestion of the maturity of its processes. Positioning the current processes with the roadmap that CMM provides gives a clear vision of where the maturity is in terms of the clearly provided, increasingly organized and systematically developed and more mature processes.

2.3.1 Use of CMM in a Multi-Stakeholder EHR System

Our research offers a CMM variant by allowing healthcare organizations to assess their EHR system implementation maturity levels to serve multiple stakeholders within a process across different functions. As described in our EHR maturity model, we look at two dimensions of an implementation: the process level (depth) and the corporate level (breadth).

Health care is a heavily regulated and complex, inter-functional service industry. Each process activity involves different user groups, who most likely use the same information system to capture, store, retrieve, and process information. To serve the varying needs of these users, the information system implementation process needs to assess and understand the extent the user objectives converge or diverge. These steps ensure the process level understanding similarly to CMM, where software process maturity levels are categorized. The inter-functional assessment allows management to understand and position the corporate maturity of the implementation process.

Overall, our EHR maturity model allows healthcare organizations to understand all the processes and activities that are involved in patient care coordination. Our process framework
helps with the understanding of multi-stakeholder involvement and the extent an information system fulfills the varying needs of different job function during the entire patient care process.
Chapter 3:

Framework Development

The process framework introduced in this dissertation research consists of stakeholders and processes with their subsequent activities. We argue that perceptions about both the expectations and satisfaction of stakeholders within processes and activities will be different. We will highlight the gap on a granular, activity level across all stakeholders.

First, we identify the stakeholders, their expectations and the processes that they participate throughout the care delivery. Then, we follow healthcare process mapping (Dickson, 2008) to identify the level of convergence and divergence across stakeholders on the activity level.

Stakeholders

Stakeholder, as a term, is one of the more recent phrases in the information systems field. However, the reference to and the importance of stakeholders has been an essential part of the literature for much longer than the term itself. As early as the 70’s, researchers started to realize the importance of involving end users not only in information systems development but also in the implementation. One of the earliest references to credit multi-stakeholder involvement, and viewed as an important precursor for information systems implementation success, can be credited to Mumford and Weir (1979). End users and executives were increasingly involved in the system development and implementation process, both in theory and practice, in addition to the sole focus on the technical characteristics of a system (Markus 1983).
The first traces of stakeholders as a definition dates back to 1963 and Freeman (1984, p.31) summarizes this term as “those groups without whose support the organization would cease to exist”. More recently, Donaldson & Preston (1995) define stakeholders as “persons or groups with legitimate interests in procedural and/or substantive aspects of corporate activity”.

The literature offers a range of different definitions for stakeholders with a significantly differing groups identified as information systems stakeholders. Boddy and Buchanan’s (1986, pg. 12) definition includes “all those who have a practical concern for the effective application of new technologies, and who are in a position to take or to influence decisions about why and how they are used”. Other definition from Willcocks and Mason (1987, pg. 79) identify computer system stakeholders as “people who will be affected in a significant way by, or have material interests in the nature and running of the new computerized system”. The more recent general stakeholder definition of Ahn and Skudlark (1997, pg. 3) states that “the stakeholders are a group of people sharing a pool of values that define what the desirable features of an information system are and how they should be obtained”.

Ahn & Skudlark (1997) identify stakeholder interest conflicts in the case of information systems implementation. Their work, however, lacks specific stakeholder group identification and their varying perspectives. The main emphasis is placed on conflict resolution and management approach through decision analytics approach. Bento (1996) also points out different stakeholder perspectives, the computing specialists and users within information centers. The author concludes that the sustainable operation of these information centers highly depend on their ability to balance the contradictory needs and requirements of these stakeholder groups.
Pan (2005), in his stakeholder analytical framework, pointed out the importance of stakeholder identification as a prelude to considering a multi-stakeholder system (Schimdt et al. 2001). Furthermore, Pan (2005) concluded, that stakeholders’ expectations is another important factor to consider, especially if a widening gap exists between stakeholders’ expectations and an organization-wide project’s goals. Lastly, Pan (2005) pointed out the conflicting interests of stakeholder roles and relationship (Oz & Sosik, 2000) as a possible threat and cause of IS project failures.

Failures of information systems, especially in the healthcare setting (Pirnejad et al, 2008) are often times due to the lack of attention to how the designed artifact will perform and impact the organization and being impacted by the organization. Since organizations are social structures, they involve different stakeholders with varying interests and involvements based on their roles and responsibilities. EHR, an organization-wide information system, by default, involves multiple groups of users with different functional operations. Greenhalgh et al. (2010) conducted a four year (2007-2010) longitudinal research on summary care records, a structured summary held on a national database and accessible to authorized stakeholders, implementation success factors in England. They found that the implementation success greatly depended on the interaction between the different stakeholder groups “with different values, priorities, and ways of working” and their ability to simultaneous use the system.

According to Garets and Davis (2006), stakeholders in EHR: “represents the ability to easily share medical information among stakeholders and to have a patient's information follow him or her through the various modalities of care engaged by that individual. Stakeholders are composed of patients/consumers, healthcare providers, employers and/or payers/insurers, including the government”.

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The above description of information sharing among different stakeholders raises the point on varying perspective on use of the same EHR system. In an EHR environment, the multi-stakeholder approach is important in order to maximize the benefit of the EHR system. These different groups of stakeholders have varying objectives when using the Electronic Health Records as opposed to using the paper-based information. Following the literature on healthcare stakeholders (Ovretveit 1992, McGlynn 1997, Joss & Kogan 1995, Walker et al. 2008), in this research, we identify the following stakeholders groups across the patient flow processes:

- Patients
- Primary Healthcare Providers (PHP)
- Practice Administrators
- Auditors

### 3.1 Stakeholder Expectations of an EHR System

As stakeholders’ expectations from a healthcare information system (such as EHR) may vary, designing an EHR system with multi-stakeholders involves the detailed understanding of stakeholders’ involvement in the care delivery processes. Furthermore, understanding all stakeholders and their objectives throughout the patient flow process and on a more granular level, the activities within each processes is inevitable for designing and successfully implementing any information system (Beynon-Davies, 2004).
3.1.1 EHR System Expectations by Primary Care Providers (PCP’s)

Providers refer patients with need for advanced care to hospitals or specialists with which they are affiliated. In the past, these physicians’ admitting privileges were limited to few clinics or hospitals. Those providers who were not part of a physician-hospital affiliation felt little pressure to implement technology that aids the information sharing with hospitals (Anderson et al. 2007). However, with increased EHR adoption in larger healthcare organizations, such as hospitals, care delivery practices realize the possible benefits of interfacing and sharing information with them across multiple information system. Evidently, these shared systems need to operate across a distributed system rather than a monolithic system with centralized control (Buck et al. 2009). Primary care providers realize the need for and value of up-to-date patient health information for confident clinical decision making. Operations across multiple systems need to provide patients’ personal health history from multiple sources (Christiensen & Grimsmo 2008).

Primary care providers capture and input data into EHR systems using different mediums, for example, system provided templates (Buck et al. 2009), digitized paper records as attachments (Scott, 2007) and medical transcription (Whiting-O’Keefe 1988, Wachter 2006). It is essential to primary care providers to have a system that captures, stores, processes and displays the required information regardless of the input sources and types.

3.1.2 EHR System Expectations by Patients

Patients are the largest “potential” user groups of EHR systems, especially with aging population (Cheek et al. 2005). Empowering patients through “self-management” to meet their health needs is suggested to be a possible method to meet the increasing demand for health care (Newman and Vidler 2006, Pharow et al. 2008, Falcao-Reis 2008). It is noted that better access
to technology helps patients to engage more in their health-care (Cimino 2002, Earnest et al. 2004). Autonomous patient population demand access to personal health information (Pagliari et al. 2007), but also shows significant interest to access their information in the EHR systems (Tang & Lee 2009, Mandl et al. 2007), hence “patient-engagement” is an important initiative especially with the capabilities EHR systems offer.

Computers and Internet access offer remarkable opportunities for patients to be in control and make informed decisions about their own care (Richards, 1999; Brennan, 1999; Ramsaroop & Ball, 2000). Patients have interest in their own care (self-management) and show the potential to become experts of their own care with proper access to educational material and their own health information (patient engagement) (Ball & Lillis, 2001; Lindenmeyer et al., 2010; Jordan et al., 2008; Protheroe, 2008). Patients underutilize their health information and they do not only desire to access their electronic health records, but also want to have input in what their records include (Kim and Johnson 2004). For example, patients may submit daily weight or blood pressure or blood sugar readings (Lindenmeyer et al., 2010) data through a portal, to which data their doctor is granted access. Also, patient portal, which is part of a comprehensive EHR system, is capable of allowing patients to input side effects of their medication or symptoms of their health issues, but few mechanisms are in place to allow patients to contribute information to their health records (Ball & Lillis 2001). Fleur et al. (2012) found that a web-based survey of patients reported outcomes, such as quality of life, could be made immediately available in the EHR system and used for treatment or research purposes. Previously, this information was captured during a physician’s office visit and the information was entered in the form of codes or abbreviations, which were difficult or impossible to understand by the patients.
While patients are engaged through various modalities of care, their main expectation is to receive satisfying and effective treatment based on the latest health information they have available regardless of the source of information. Having question such as “when did you receive your last tetanus shot” at a check-up decreases patient’s confidence in the provider and the information they have available.

Another benefit that patients realize through a patient portal is the convenience of scheduling appointments and requesting prescription refills (Goldman et al. 2010). These features reportedly increase their satisfaction with the service they receive from their provider (Goldman et al. 2010).

3.1.3 EHR System Expectations by Healthcare Administrators

In addition to coordinating the medical practice employees on multiple locations and handling financial matters, healthcare administrators are also key to strategic planning. It encompasses the preparation of return on investments (and pro formas) for new services, locations and physicians. Healthcare administrators, among other duties, are required to stay current in healthcare and its technology. They always look for technology that makes the practice more productive or efficient. Healthcare administrators develop impact report on capital investments, such as EMR/EHR. They are also responsible for compliance for local, state and federal laws, such as OHSA, HIPAA, EOE, ADA … etc. and ensuring the security, privacy and proper storage and release of medical records. Therefore, the proper use of electronic health records can greatly support the multifaceted daily work of a medical practice administrator. It enables the practice to run smoothly and EHR provides access to information (reports) needed to manage the organization.
Healthcare administrators’ objectives include efficient practice operations. For example, they may use EHR functionalities to track personnel task completion status and the time it takes to complete. On the patients’ satisfactions side, healthcare administrators are able to track patient wait times and identify bottlenecks to improve practice workflow efficiency.

Compliance with privacy and security regulations are some of the healthcare administrators’ main concerns (Groban & Silie, 2013). The privacy notices and consent forms may be electronically attached to the patient health records and readily available for audit purposes. Furthermore, audit trails can be automatically stored and this information gives insight to patient records access and edits history by person who performed the action and machine used for the access. Healthcare administrators may update and maintain staff access to patient information. For example, certain roles, such as clerks, may only see the registration and billing information but would not have access to clinical information of the same patient. Access report can be generated for audit and overview, however, system design need to account for these specific tasks only administrators perform.

3.1.4 EHR System Expectations by Auditors

Close to 100,000 deaths and $30 billion are the estimated yearly effect of medical errors in the United States (Kohn et al. 2000). Properly designed and regulated electronic health records systems are viewed as a system with potential to dramatically reduce these numbers and save lives through enhanced medication monitoring, timely access to critical medical information, tracking and managing infectious disease, and other “meaningful use” stipulations (Tjia et al. 2011, Alvarez, 2004). However, the serious adverse effects of system failures demand regulatory oversight. In order to realize the benefits of EHR systems, the development, maintenance, information sharing and medical informatics need to be closely monitored and controlled by
regulatory interventions. The need for regulations is inevitable; however, it is also challenging and a sensitive undertaking. The goals of the regulations may hinder the adoption and widespread use of the systems.

Healthcare is one of the most heavily regulated industries in the United States. In addition to federal, state and local regulations, private organizations have their own regulatory standards. Of course, most of these are related to the physicians and staff professional certifications and institutional operations but a number of the regulations are in regards to software, such as EHR.

Any institution using EHRs must comply with a number of regulatory and accreditation requirements, and these regulations serve the purpose of patient and data protection, interoperability with standardized oversight, and the regulatory bodies are to enforce these laws and regulations in regards to electronic health records. As healthcare providers adopt technologies, such as EHR, in addition to heightened capabilities, the practices’ system complexity increases, which puts security and compliance at risk (Mandl et al. 2004). Internal auditing ensures that operating processes and the set of actions are in compliance with the regulations.

Internal auditors expect the system to be auditable to ensure data integrity and confidentiality. Ene-Idordache et al. (2009) suggest the following system features to comply with the statutory and regulatory requirements in the clinical information technology setting: user authorizations, audit trail, attributability, data validation, and system integrity.
Chapter 4:

Processes

4.1 Physician-Patient Encounter Process Mapping

As patient’s care may stretch across providers, departments, and facilities, it involves a number of different teams, such as radiology, laboratory, anesthetics and such. Furthermore, patient’s care is supported by administration and audits to ensure compliance. Healthcare process mapping (Dickson, 2008) is an excellent tool for capturing divergence and convergence among the stakeholders’ expectations from the supporting healthcare information system across the patient’s care processes.

Healthcare process mapping is a form of clinical audit that follows the patient through the care processes, which allows identifying setbacks or inefficiencies (Kollberg et al. 2007, Bevan and Lendon 2006). Process mapping provides information on the experience of stakeholders involved (Kim et al. 2006) by breaking down the entire process into sequential steps or activities. Layton et al. (1998) identify these sequential steps or activities between two points (admission to discharge) as process of care or patient pathway. Healthcare systems involving multidisciplinary teams and specialties benefit from process mapping through identifying redundancy or potentially missed stage or unsafe workarounds stakeholders might do in the patient care (Taylor & Randall 2007, Ben-Tovim et al. 2008, Bodenheimer & Grumbach 2003).

Process mapping in a service organization is challenging, as opposed to in a manufacturing setting, especially specific to healthcare setting, where case mix variation implies that not every patient and complaint is treated the same way. Furthermore, constraints of the
physical and technological environment and alterations resulting from human and personal preferences results in customized processes. However, the processes during a general patient encounter in an office visit setting has been identified as the most commonly occurring set of sequential activities and their understanding is critical to form the base of patient care (Hausman, 2004). Activities within a particular process are perceived to be more uniform across healthcare settings, though they still vary across stakeholder groups.

The development of the patient health care encounter process mapping involved a series of steps: (1) reviewed and drew conclusion from existing patient flow and process mapping literature; (2) researchers reviewed personal experience and observations of patient health care encounter and discussed with a number of representatives from each stakeholder groups identified in this research; (3) conducted a series of interviews with subject matter experts to discover and categorize the activities within the processes. As Macal (2005) suggests, the completed patient flow has been checked against the actual process for accuracy.

The patient health care encounter process is a sequence of four major processes, which we identified as follows: (1) schedule / administer patient visit; (2) collect & review patient medical information; (3) diagnose & treat patient; (4) report & administer follow-up visit.

The above processes are nested in activities, which need to be completed in order for the patient to move forward in the patient health care encounter process. Due to the nature of health care, multiple stakeholder groups are involved in each of the above processes with their own goals, interests and objectives, which may or may not converge. We put all activities under scrutiny through the lenses of the four stakeholder groups identified earlier. As the stakeholder objectives vary within activities, EHR systems need to accommodate their diverse needs. These
disparate and, often times, conflicting needs may or may not converge with the system support capabilities for the particular activity.

In the next section, we scrutinize each health care encounter process, the activities in which the processes are nested and the objectives of each stakeholder groups within the particular activity. The process/activities and stakeholder objectives are graphically represented in Figure 1.
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<tr>
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<td>Review / enter information</td>
<td>Provides input</td>
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<tr>
<td>Review / Update Medical History</td>
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<td></td>
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<tr>
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<td>Provides input</td>
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<tr>
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<td>Documents evaluation / Identifies problem areas</td>
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<td>Generate hypothesis from available information</td>
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<tr>
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<td>Run Diagnostics Check (compare symptoms and history with expected symptoms)</td>
<td>Provides input</td>
</tr>
<tr>
<td>Treatment Plan</td>
<td>Assign Treatment based on best fit hypothesis and patient’s history</td>
<td>Chosen treatment is explained and input is solicited</td>
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<td>Remote exam Secure Network Connection</td>
<td>Remote Exam Secure Network Connections</td>
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Figure 1.: Stakeholder Objectives across Patient Flow Processes and Activities
4.1.1 Process Sequence Block #1: Schedule / Administer Patient Visit

Activity 1: Appointment Scheduling –

A central issue is scheduling PCP’s for the right patient. From the PCP’s perspective, a misscheduling could lead to lost revenue and patient dissatisfaction. It is important for the patient to choose the preferred physician at a mutually convenient time. Simultaneously, health care administrators need to ensure that scheduling reflects the expected length for office visit to avoid schedule slide. Auditors ensure patient information safeguard measures.

- Primary Care Provider (PCP): Availability of PCP’s need to be maintained up-to-date in the scheduling system.
- Patient: Patient states PCP and date of appointment preferences.
- Administrators: Ensure that appointment lengths are adjusted to meet patient visit complexity. PCP utilization rate is checked and maximized.
- Auditors: Ensure privacy of patient information while capturing details over the phone (not written on paper then entered in system)

Activity 2: Administering Patient for Office Visit –

This activity involves confidential medical history retrieval and recording. The information is either retrieved from internal or external (other PCP’s) record system. Patients expect only the required information accessed and retrieved by only the PCP who is involved in the patient’s care. It is critical to comply with information safeguard regulations and provide safeguard measures in a meaningful way upon audit.
• **Primary Care Provider (PCP):** This process is ideally administered in the EHR system, where PCP availability is managed at multiple locations. This requires that the EHR system works with all physical locations’ internal systems.

• **Patient:** The patient expects that their records are securely accessed and updated with visit details.

• **Administrators:** Administrators expect that only the necessary patient health history is accessed by the person scheduling the appointment.

• **Auditors:** Medical history is entered and stored in an EHR system and retrieved upon authorized access. Auditors ensure the integrity of the data and audit access log.

*Activity 3: Administering Patient for Office Visit – Exam Room Assignment*

The confidential patient medical information needs to be accessed by the PCP from multiple locations: (1) prior to meeting with the patient to understand medical history and (2) in the exam room where updates to the medical records will take place upon meeting with the patient. PCP’s want straightforward access to these information while other stakeholders want secure access and security measures and activity log in place upon each access.

• **Primary Care Provider (PCP):** Reviews patients’ medical history in a secure environment and secures information before leaving for the exam room. Update exam room status upon completing care in them. Ensure that no personal information of patients is left for unauthorized access.

• **Patient:** Expects PCP to have accessed and reviewed existing medical history prior to entering the exam room.

• **Administrators:** View exam room availability to coordinate maximum occupancy.
• Auditors: Ensure that proper security measures are taken for patient medical information access from any access point.

4.1.2 Process Sequence Block #2: Collect and Review Patient’s Health Information

(Rogers & Shuman, 2000)

Activity 1: Review of Vital Signs–

Reviewing medical history vital signs with the patient (if possible) is central to proper documentation and elimination of possible misunderstandings and typing errors. Medical assistant or nurses take vital signs and review self-administered readings with patients, enter in the system for the PCP to reviews with patient. A central audit concern is the access to and update of patient records. It is essential to create and provide access to such logs for auditing.

• Primary Care Provider (PCP): Update medical records with current vital signs, medical assistant reviews medication. PCP reviews chronological lab work, evidence-based treatment guidelines, clinical notes from last visits
• Patient: provides self-measured values if daily self-administered readings was requested
• Administrators: Ensure whether the self-administered readings are flagged in case of mis-readings. Entry-log access in case of vital signs value entry corrections or device malfunctions
• Auditors: Entry log access for ensuring patient privacy

Activity 2: Review/Update Medical History–

Reviewing medical history with the patient (if possible) is central to proper documentation and elimination of possible misunderstandings and typing errors. Audits ensure
proper sequential steps are taken during review and the appropriate measures are taken when urgency is determined.

- Primary Care Provider (PCP): Reviews and updates specific medical history information based on patient’s feedback, complaints and characterized symptoms
- Patient: Provides accurate description of symptoms
- Administrators: Control for proper documentation of symptoms
- Auditors: Audit for proper documentation and response on perceived urgency

Activity 3: Admission Note Review –

The availability and accessibility of admission notes are crucial for proper treatment plan. Accompanying patients’ history and demographics ensure the supporting documentation needed for treatment plan. If such information is available from other providers, exporting (EHR, fax, electronic transmittal… etc.) prior to appointment needs to be coordinated by administrators. Data confidentiality is crucial during this exporting process.

- Primary Care Provider (PCP): Inpatient care requires admission notes, which provide reason for admission and baseline for patient’s status. The review of admission notes takes place prior to meeting with the patient and PCP accesses the notes for the reason of patient visit. The availability of history of present illness and medical history are vital for the proper evaluation of admission reason.
- Patient: Patient is required to properly and responsibly fill out medical history prior to office visit and indicate current medication, allergies, family and social history… etc. along with symptoms of current complaint.
• Administrators: To ensure the availability of health history for the PCP, administrators need to enable timely feed and export of data from the practice management software to EHR. It is especially important when cross-provider referral was sent electronically to a third party interface.

• Auditors: Information security is essential during cross-system data communication. Data confidentiality regulations are enforced and audited by Auditors, internal or external.

4.1.3 Process Sequence Block #3: Diagnose and Treat Patient

Activity 1: Physical Exam –

Based on the available and updated health information PCP’s and patients align and agree on treatment goals. Confidentiality is maintained and audited by administrators and auditors to ensure that sensitive information is not accessible by medical assistants, only by the treating PCP’s (such as HIV test results… etc.).

• Primary Care Provider (PCP): Assesses patients’ condition based on updated medical history with the understanding of patient’s complaints and reason for visit and urgency and tests/lab results.

• Patient: Updated on exam approach and provides input.

• Administrators: Information availability in a secure environment.

• Auditors: Audit for compliance of patient medical information confidentiality.

Activity 2: Diagnosis – Analyze and Assess Symptoms and Test Results –
PCP’s assess and analyze the available information and identify the area of concern, while other areas are checked and identified as not affected by patient symptoms. All findings and reasoning are properly documented for auditing purposes.

- Primary Care Provider (PCP): Identifies problem areas based on initial examination. Records findings in medical records.
- Patient: Assists (if able) in condition assessment
- Administrators: Ensure proper and detailed recording of findings.
- Auditors: Audit for reasonably supported problem areas based on supporting facts and findings, auditing decision making aid system if available.

Activity 3: Diagnosis –Generate Diagnosis Hypotheses–

Diagnosis must include the identification of possible problems and elimination of those that do not fit the symptoms. PCP’s generate hypotheses from their own knowledge. PCP’s identify other sources needed to generate all possible hypotheses and properly document chain of reasoning. Administrator ensures proper resources are available and maintained to assist with hypothesis generation and support regulatory compliance.

- Primary Care Provider (PCP): Generates diagnostic hypotheses based on the available information and initial assessment. Checks medical evidence on hypothesized patient problem and updates patient medical records.
- Patient: Assists (if able) in hypotheses generation and understands possible problems.
- Administrators: Ensure updated medical evidence sources to assist and improve hypotheses generation.
Activity 4: Diagnosis - Evaluate and Dismiss Unfit Hypotheses – (Summerton, 2004)

Diagnosis must include the identification of possible problems and elimination of those that do not fit the symptoms. PCP’s identify additional sources to support correct hypothesis and dismiss unfit hypotheses. It is inevitable to have up-to-date medical history from inter and intra-organizational sources. The data integrity must be ensured in the process.

- Primary Care Provider (PCP): Comparing symptoms with medical history and their expected symptoms helps PCP’s to dismiss unfit hypotheses. It is imperative to have up-to-date and available data in the EHR system in an accountable manner.
- Patient: Assists (if able) in hypotheses evaluation and understands possible problems. Explained and understood best fit hypothesis.
- Administrators: To ensure the availability of health history for the PCP, administrators need to enable timely feed and export of data from the practice management software to EHR.
- Auditors: Up-to-date medical history is audited for its availability and integrity.

Activity 5: Treatment Plan–

Choosing the best fit treatment to a condition requires considering the patient’s health history or possible reactions to the chosen treatment. Assigned treatment must be properly documented as it might go under internal and external audit. Patient is involved in the decision making and the chosen method is explained.
• Primary Care Provider (PCP): Assigns treatment after checking with contraindications, drug interactions, and inconsistencies with prior conditions and treatments. Confirms and approves best fit hypothesis records in patient’s medical records.

• Patient: Explained and understood treatment plan

• Administrators: Approve assigned treatment (if treatment is Medicaid eligibility dependent, administrator needs approval)

• Auditors: Audit for properly chosen treatment plan based on available information

Activity 6: Establish Follow-Up Plan—

After treatment is identified and assigned, it is imperative to determine proper follow-up care. Patient needs to understand and commit to self-administration of care. Follow-up visit needs to be scheduled and remind patient as the date of the follow-up visit approaches.

• Primary Care Provider (PCP): Enter follow up care based on treatment chosen

• Patient: Understands follow up care and shared goals

• Administrators: Update schedule in line with occupancy rate goals

• Auditors: Audit for proper follow-up plan based on treatment chosen

Activity 7: Patient Education—

Educating the patients on their condition is imperative for proper care, especially if it mainly depends on the patient through self-administered care. Offices using EHR are required to provide patient education material for a percentage of patients as part of the Meaningful Use (Stage 1) Requirements (§170.302(m)). The proper patient education material is printed at the end of treatment and administrators ensure the availability of proper patient education material.
• Primary Care Provider (PCP): Print treatment-relevant education material
• Patient: Understands treatment-relevant education material
• Administrators: Ensure proper indexing of treatment education material. If EHR used, ensure that target patient body receives treatment-relevant education material to fulfill Meaningful Use guidelines.
• Auditors: Audit for treatment-relevant education material content and patient-specific medical information printed on the material

Activity 8: Prescription Order—

Prescription is an important part of most treatments. PCP’s usually provide the prescriptions to patients at the end of the office visit or for meeting Stage 1 Meaningful Use Requirements (eRx §170.304(b)), PCP will send prescription electronically to the patient-designated pharmacy. PCP explains the proper prescription administration; however, pharmacist will reiterate it. If secure patient portal is available, the medical dosage is also displayed there for the patient.

• Primary Care Provider (PCP): Writes paper prescription or electronically sends it to the designated pharmacy.
• Patient: Views prescription and dosage on the patient portal, and orders prescription refill, if applicable.
• Administrators: View prescription quota report.
• Auditors: Audit for prescription quotas.

Activity 9: Paper Records Access—
PCP may create or retrieve paper based medical reports or patient health information. Offices having electronic medical records in place may opt to digitize earlier paper records for quicker and more secure access. Patients or other providers may request access to earlier medical history. Safeguarding and providing access control is more efficient for digitized copies.

- Primary Care Provider (PCP): Paper based practices require locating patient records in the repository. Electronic records can house scanned images and properly captured details from earlier, paper-based records.
- Patient: Has the right to request a copy of their medical records, paper based or electronic.
- Administrators: Ensure safeguarding measures to access paper records.
- Auditors: Audit for proper security measures and access control.

Activity 10: Hand written Notes–

Similar to paper records based medical records, handwritten notes are captured on paper, available for digitization. Patients or other providers may request access to handwritten notes as part of their medical history. Safeguarding and providing access control is more efficient for digitized copies.

- Primary Care Provider (PCP): Paper based practices require locating hand written notes in patient records in the repository. Electronic records can house scanned images of the notes and properly captured details from earlier, paper-based hand-written records.
- Patient: May request copy of the notes.
- Administrators: Ensure safeguarding measures to access hand-written records.
• Auditors: Audit for proper security measures and access control.

Activity 11: Voice Recorded Notes–

Similar to paper records based medical records, voice recorded notes are captured outside of the electronic medical records system; however, the audio files are available for transcription. Patients or other providers may request access to voice recorded notes (or their transcripts) as part of their medical history. Safeguarding and providing access control is more efficient for digitized copies.

• Primary Care Provider (PCP): Voice recorded files are transformed to text in the patient’s medical records. In EHR systems, the voice file may be attached as well.

• Patient: May request a copy of their medical records.

• Administrators: Ensure the use of qualified transcription services, usually outsourced.

• Auditors: Audits for authorized and qualified transcription service provider and the proper handling of patient medical information.

Activity 12: Remote Examination (Phone vs. Video Capability)– (Perednia and Allen, 1995)

Telemedicine and remote medical examinations gain popularity through efficiency (Kon et al. 2009, Marcin et al. 2004) and financial benefits (Marcin et al. 2004b) in rural or underserved geographic areas. PCP’s are scheduled remote diagnosis and connected through secure high-speed data connection, which are accessible by patients at a remote location. Ensuring secure connection and compliance with such regulations is essential for remote examination.
• Primary Care Provider (PCP): Diagnose over video and audio supported connection through the Internet, if applicable.
• Patient: Schedules and prepares for remote exam with proper infrastructure.
• Administrators: Ensure the secure communication channel availability for remote examination.
• Auditors: Audit for secure connections and safeguard measures implemented.

4.1.4 Process Sequence Block #4: Report

Activity 1: Superbill creation (charges for exam, procedures, supplies etc.) –

PCP’s are required to properly document and sign off on every check they performed and treatment administered with supplies used. PCP reports on complexity of medical decision and time spent counseling, and provide it to coders to prepare invoice for patient. This invoice may be accessible through the secure patient portal where payment may be processed as well.

• Primary Care Provider (PCP): Provides complexity of medical decision and time spent counseling.
• Patient: Access to the superbill through the patient portal, if applicable.
• Administrators: The superbill is transparent for administrators in order to check for accuracy.
• Auditors: Auditors review superbills for accuracy and treatment appropriateness

Activity 2: Insurance Claim Submission–

Health insurance is offered to offset medical expenses for patients. Before insurance claim is submitted, the medical coding department assigns the proper ICD code to report the
procedures performed and the information necessary for the medical biller to process a claim for reimbursement by the appropriate medical insurance agency. The insurance claim may be accessed by the patient while the administrators and auditors review the claim history report for compliance or approval purposes.

- Primary Care Provider (PCP): Properly created superbill. Provides further clarification if coder has questions.
- Patient: Access to the insurance claim through the patient portal, if applicable.
- Administrators: Submit reviewed and approved insurance claim.
- Auditors: Access to claim history report.

Activity 3: Generating Statement and Billing Patient/Insurance—

Billing for the services and supplies is vital to demand payment from patients. Upon all processes and services properly documented, coded and submitted to the billing department, patient is sent the medical bill, which may also be accessed through the secure patient portal, if applicable. Administrators and auditors review and audit billing to ensure that coding and charges reflect the care administered.

- Primary Care Provider (PCP): Respond to requests on services/supplies used for treatment.
- Patient: Access to the bill through the patient portal, if applicable.
- Administrators: Ensure proper billing
- Auditors: Audit billing in line of services/supplies provided for care.

Activity 4: Enable and Use Patient Portal—
Larger health care organizations widely provide secure, on-line patient portals to give immediate access to past and current patient medical information. Some portals even allow email exchanges between providers and patients, allow patients to request prescription refills, update contact information, download forms… etc. Ensuring authorized, secure access and data storage is critical for online patient portals.

- Primary Care Provider (PCP): N/A
- Patient: Enable patients to view appointments, lab results, medications, and in some cases, input certain measures.
- Administrators: View account status reports (sign-ups, usage… etc.). Ensure secure communication channel.
- Auditors: View attestation report and ensure information exchange safeguards.

**REPORTS: Audit Trail (monitoring authorized access)**

Sets of security-relevant chronological records are generated as documentary evidence of activities (access, deletion, alteration… etc.) that have affected patient medical records. Administrators maintain proper access rights and view audit trail reports to ensure authorized access.

- Primary Care Provider (PCP): N/A
- Patient: N/A
- Administrators: Approve personnel access. View access report.
- Auditors: Audit access report.

**REPORTS– Meaningful Use (functional measures of core and menu objectives)**
Practices that use EHR need to provide evidence of meaningful use of the system to qualify for payment from the federal government under the Medicare or Medicaid Incentive Program. Specific list of core and menu objectives are provided within the guidelines and administrators ensure the proper use in order to meet the criteria.

- Primary Care Provider (PCP): N/A
- Patient: N/A
- Administrators: View functional measures of core and menu objectives usage report.
- Auditors: Audit for functional measures of core and menu objectives to determine MU eligibility.

REPORTS – QI (reduction of inconsistencies) Research, Outreach (list of patients by specific conditions) for practices with implemented EHR system.

In order to reduce healthcare inconsistencies, EHR shows a promise to increase communication and information flow between providers and patients. PCP’s generate lists of patients by specific conditions to use for quality improvement, reduction of disparities, research or outreach. This report provides one of the conditions for Meaningful Use Incentives.

- Primary Care Provider (PCP): Generate report on listing patients of a specific condition.
- Patient: N/A
- Administrators: View reports generated by PCP
- Auditors: View reports generated by PCP to determine MU eligibility.

Feedback – Targeted or anonymous questionnaires
Feedback provides valuable information to service providers. It is especially true in the health care setting, where patients not only go through a series of customer service encounters (registration, waiting room… etc.), but their treatment effectiveness largely depends on the provider’s attention to their symptoms and concerns. Patients generally have a number of choices among providers, therefore customer service needs to be evaluated through surveys and weak areas identified and corrected.

- Primary Care Provider (PCP): N/A
- Patient: Receive questionnaire after the office visit or through mail, e-mail or patient portal.
- Administrators: Survey reminders and analyze survey data. Put process in place for corrective measures.
- Auditors: N/A

**Healthcare Products Recommendation for Certain Health Conditions** (marketing, advertisement)-

Products that supplement and may aid treatment are widely available “over-the-counter”. PCP’s may recommend such available products, which are not part of the treatment but deemed beneficial for the success of the treatment. These recommendations may be given during office visit or made available on the secure online patient portal. Administrators approve and overview these recommendations, especially when samples are provided, which are heavily regulated.

- Primary Care Provider (PCP): Suggests treatment relevant healthcare products.
- Patient: Receives treatment relevant healthcare products suggestions during visit or through mail, e-mail or patient portal.
• Administrators: Enable relevant healthcare products list and index properly to treatment
to provide suggestions.

• Auditors: Audit for conflict of interest and enforce sample distribution guidelines.

Follow-up Care –

Based on patient condition and treatment assigned, follow-up treatment is scheduled
usually at the time of treatment received. This follow-up is essential for PCP controlled patient
care and reminder needs to be administered and monitored.

• Primary Care Provider (PCP): Medical history and details from previous visit(s) need to
be available for PCP’s with access log in case of amendments.

• Patient: Effective EHR systems send follow up reminder to patient.

• Administrators: Reminder is sent to patient and follow-up fulfillment report is generated
through EHR systems.

• Auditors: Follow up fulfillment

4.2 Business Process Reengineering in EHR Patient Flow Processes

Bynjolfsson and Hitt (2000) found that lack of understanding the business processes and
their related activities within an organization results in decreased performance and organizational
inefficiencies. Similarly, supporting an organization through an information system requires full
understanding of the existing processes. However, it also provides an opportunity to find
inefficiencies or missed activities that further define a process. Business process reengineering
provides the ground for understanding the stakeholder perspectives and the current processes to either design a properly supporting information system or choose the best fit system from vendors.

The nature of healthcare organizations with the overarching processes through patient care is especially prone to misalignment across stakeholder perspectives and calls for scrutiny of business processes. The identified processes and their related activities allow us to identify the stakeholder perspectives within each activity and provide tools to assess an organization’s maturity within a particular process and across the processes. Project executives may use this tool to understand whether or not a particular EHR system is a good fit for their organization. Consequently, our proposed assessment of process level and organization level maturity provides a great starting point to evaluate the processes as we provide a more granular level of understanding the patient flow.
Chapter 5:

EHR Implementation Model

We identified the processes and activities through patient care and the objectives of different stakeholder groups. In order to support these sometimes varying objectives the healthcare information system, such as EHR, will need to be able to support stakeholder expectations within a particular process or across multiple functions. Tying together these various perspectives, health care organizations often find themselves at a loss understanding the extent their information system are developed and mature enough to manage and sustainably support the multiple stakeholder groups that are aimed to concurrently form the best type of care coordination. An EHR system’s processes and characteristics, which are particularly relevant to a physician may or may not be relevant to other stakeholders, such as the patients, administrators or auditors, although all stakeholders together form an integral part of delivering quality care and patient satisfaction within an accountable care organization.

As every stakeholder group has an expectation from the system while performing an activity in the patient health care encounter process, the EHR system may or may not provide for these expectations for one group versus the other. In order to find whether expectations across stakeholder groups converge or diverge, we use a granular understanding of processes that highlight a maturity model. This model helps to simplify a health care organization’s ability to understand and codify its processes and to ensure that its processes are mature enough to support or align themselves across multiple stakeholders. It is important for an organization to have a model that will assess the process maturity in terms of a system implementation that is serving multiple stakeholders.
In addition to patient health care outcome, we simultaneously consider the organization level outcomes in terms of information system support. Patient care takes place in a distributed care delivery system that overarches multiple departments and job functions. A proper EHR system does not only need to support all stakeholders within a particular patient care process, but also it needs to support multiple functions on a corporate (organizational) level.

In order to understand how mature a health care organization’s patient care processes are and how mature the organization is in relation to its EHR system, we identify two dimensions: process level maturity and corporate level maturity. These two dimensions cover the varying and often conflicting expectations from an organization-wide information system. Our approach considers a standalone independent practice and a healthcare organization with multiple providers and sites with all levels of care. Process and organization level maturity is applicable to any size of practice or specialty with minor customization based on process or activity differences.

5.1 Process Level Maturity

An information system must cover the pertinent set of processes to be deemed supportive for achieving the general goal. In order to provide advanced health care to patients, the care processes must simultaneously involve multiple stakeholder groups within a health care organization. The level that an EHR system supports all relevant stakeholder groups within a particular patient care process may be measured by the process level maturity. For example, within the review / update medical records all stakeholder groups’ expectations converge as their expectations are to have completed up-to-date medical records in the system. Contrary to this example, we found that each stakeholder groups have divergent expectations during the appointment scheduling process. While PCP’s expect to have their availability captured, patients
expect to visit their preferred PCP. Administrators’ goal is to have all PCP’s fully utilized, while Auditors expect the patient medical information handled in a secure and confidential manner. This example draws attention to the different objectives and expectations each stakeholder might have within the same process. The supporting information system, however, might only support one stakeholder group expectations, leaving others dissatisfied with the system.

The extent that EHR supports the varying objectives of stakeholders within a particular process during the patient-PCP encounter indicates the process level maturity of the HER system. When a system only supports the need of one stakeholder group, it may lead to the doubt of the usefulness and the rejection of the system and may result in the use of “workarounds” by other stakeholders as they perceive the system as inadequate for their needs. This may also lead to ineffective processes as information needs to be shared across multiple systems and possibly puts confidential patient information at risk.

5.2 Corporate Level Maturity

Information systems support either one functional set or a larger set of processes within a corporate establishment. EHR systems need to support inter-departmental information sharing in the course of the patient care across multiple operational functions. The extent or breadth on which the EHR system is being implemented across the health care organization, defines the corporate level maturity of the system. The system that only supports a functional set, regardless of the depth that function is being served, will need to be able to share information with the supporting system of other functional sets, which may have increased information security risk.
5.3 Implementation Maturity Model

In order to understand the impact an information system has on an organization, it is important to evaluate and identify both the depth and the breadth the system accommodates the organizational functions. As Slaughter and Kirsh (2006) noted in their field study on software process improvement that organizations seek for a reference model that enable them to institutionalize software development practices. We use Capability Maturity Model (CMM) (Paulk et al. 1993) to formally apprise current processes and provide the reference model to organizations to assess their process level and organizational level maturity for information system implementation.

After we established the general processes of the entire patient-PCP interaction sequential processes, it allows us to originate the EHR maturity model (See Figure 2 below). This model identifies both the process level accommodation across multiple stakeholders (depth) and corporate level accommodation across multiple functions or processes (breadth) within the health care organization. Our proposed EHR Maturity Model highlights the level of convergence or divergence of objectives and, in turn, expectations from a supporting EHR system that exists among stakeholders.
### EHR Maturity Model

<table>
<thead>
<tr>
<th>Process Sequence Blocks</th>
<th>Activity Sequence</th>
<th>Level of Convergence</th>
<th>Primary Care Provider (PCP) (including nurses)</th>
<th>Patient</th>
<th>Administrator</th>
<th>Auditor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Schedule / Administer Patient Visit</strong></td>
<td>Appointment Scheduling</td>
<td>25%</td>
<td>Stakeholder Expectation Convergence / Divergence</td>
<td>Converge</td>
<td>Diverge</td>
<td>Converge</td>
</tr>
<tr>
<td>Administering Patient for Office Visit</td>
<td>Converge</td>
<td>100%</td>
<td>Converge</td>
<td>Diverge</td>
<td>Converge</td>
<td>Diverge</td>
</tr>
<tr>
<td>Exam Room Assignment</td>
<td>75%</td>
<td>Converge</td>
<td>Converge</td>
<td>Diverge</td>
<td>Converge</td>
<td>Diverge</td>
</tr>
<tr>
<td><strong>Collect &amp; Review Patient Information</strong></td>
<td>Review of Vital Signs</td>
<td>50%</td>
<td>Diverge</td>
<td>Provides input</td>
<td>Diverge</td>
<td>Entry validation</td>
</tr>
<tr>
<td>Review / Update Medical History</td>
<td>Diverge</td>
<td>50%</td>
<td>Diverge</td>
<td>Provides input</td>
<td>Proper documentation</td>
<td>Validation</td>
</tr>
<tr>
<td>Review of Admission Notes</td>
<td>5%</td>
<td>Diverge</td>
<td>Diverge</td>
<td>Update demographics and medical history</td>
<td>Diverge</td>
<td>Report Admission Notes</td>
</tr>
<tr>
<td>Physical Exam</td>
<td>50%</td>
<td>Examine patient</td>
<td>Converge</td>
<td>Provides input</td>
<td>Controlled access</td>
<td>Diverge</td>
</tr>
<tr>
<td><strong>Diagnosis - Analyze and Assess Symptoms and Test Results</strong></td>
<td>Diagnosis - Generate Diagnostic Hypotheses</td>
<td>25%</td>
<td>Diverge</td>
<td>Provides input</td>
<td>Documentation Audit</td>
<td>Diverge</td>
</tr>
<tr>
<td>Diagnosis - Evaluate and Dismiss Unfit Hypotheses</td>
<td>0%</td>
<td>Diverge</td>
<td>Diverge</td>
<td>Medical evidence sources</td>
<td>Diverge</td>
<td>Audits for compliance</td>
</tr>
<tr>
<td>Treatment Plan</td>
<td>50%</td>
<td>Assign treatment based on best fit hypothesis and patient's history</td>
<td>Converge</td>
<td>Chosen treatment is explained and input is solicited</td>
<td>Approved Assigned Treatment</td>
<td>Diagnosed and condition is managed</td>
</tr>
<tr>
<td>Prescription order</td>
<td>75%</td>
<td>Create Prescription</td>
<td>Diverge</td>
<td>View Prescription Request and Refill</td>
<td>View Prescription Quota Report</td>
<td>Converge</td>
</tr>
<tr>
<td>Paper records accessibility</td>
<td>25%</td>
<td>View / request Digitized Records</td>
<td>Diverge</td>
<td>Digitized Records Completeness Report / Ensures confidentiality</td>
<td>Diverge</td>
<td>Audits for proper security measures</td>
</tr>
<tr>
<td>Voice recorded notes</td>
<td>25%</td>
<td>View / request transcribed notes</td>
<td>Diverge</td>
<td>Transcribed notes Completeness Report / Ensures confidentiality</td>
<td>Diverge</td>
<td>Audits for proper security measures</td>
</tr>
<tr>
<td>Remote examination (Phone vs. video capability)</td>
<td>75%</td>
<td>Diverge</td>
<td>Schedule Remote Exam</td>
<td>Converge</td>
<td>Remote Exam Secure Network Connection</td>
<td>Converge</td>
</tr>
<tr>
<td>Process Sequence Blocks</td>
<td>Activity Sequence</td>
<td>Level of Convergence</td>
<td>Primary Care Provider (PCP) (including nurses)</td>
<td>Stakeholders' Activity Level Convergence / Divergence</td>
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<td>Stakeholder Expectation</td>
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<td></td>
<td></td>
<td></td>
<td>Views / pays invoice through mail or secure patient portal</td>
<td>Review Superbill</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Review Medical Records</td>
<td>Converge</td>
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<td></td>
<td></td>
<td></td>
<td>Review Medical Records</td>
<td>Audits Superbill</td>
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<td>Diverge</td>
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<td>Diverge</td>
<td>Diverge</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Report &amp; Follow Up</td>
<td>Superbill creation (charges for exam, procedures, supplies etc.)</td>
<td>50%</td>
<td>Provides details for services, supplies</td>
<td>Converge</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Insurance claim submission</td>
<td>0%</td>
<td>Provides clarifications to coders as needed</td>
<td>Diverge</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Generating Statement and Billing</td>
<td>0%</td>
<td>Provides clarifications to coders as needed</td>
<td>Diverge</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Enable and use Patient Portal</td>
<td>0%</td>
<td>View appointment</td>
<td>Diverge</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>REPORTS - Audit Trail monitoring (authorized access)</td>
<td>100%</td>
<td>View appointment</td>
<td>Diverge</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>REPORTS - Meaningful Use (functional measures of core and menu objectives)</td>
<td>100%</td>
<td>View appointment</td>
<td>Diverge</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>REPORTS - GI (reduction of disparities, research, outreach (list of patients by specific conditions)</td>
<td>50%</td>
<td>View appointment</td>
<td>Diverge</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Feedback - Targeted or anonymous questionnaires</td>
<td>0%</td>
<td>Use for quality improvement, reduction of disparities, research or</td>
<td>Diverge</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Healthcare Products recommendations for certain health conditions (marketing advertisement)</td>
<td>75%</td>
<td>N/A</td>
<td>Converge</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Follow-up care</td>
<td>50%</td>
<td>N/A</td>
<td>Converge</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Figure 2: EHR Maturity Model*
The EHR maturity model categorizes the major process sequence blocks: (1) schedule / administer patient visit; (2) collect & review patient medical information; (3) diagnose & treat patient; (4) report & administer follow-up visit. Within each sequence block, we identified the major activities and the stakeholder objectives within each activity. These objectives may or may not converge among stakeholder groups since they serve different functions within an activity.

The extent that EHR supports the varying objectives of stakeholders within a particular process during the patient-PCP encounter indicates the *process level maturity*. We inspect four major stakeholder groups and define the convergence rate of an activity as follows:

- **0% convergence rate** - if all stakeholder groups have different objectives within an activity of the patient flow process. Example: appointment scheduling activity, where PCP’s expect to have their availability captured, and patients expect to visit their preferred PCP. Administrators’ goal is to have all PCP’s fully utilized, while auditors expect the patient medical information handled in a secure and confidential manner.

- **50% convergence rate** – if two stakeholder groups have the same objectives within an activity of the patient flow process. Example: during diagnosis PCP’s and patients align goals and treatment approach. On the other hand, administrators need to ensure that only PCP’s involved in the treatment will have access to the patient’s medical records. Auditors’ objective is the audit for controlled access and to ensure compliance in terms of access to only patient medical records that are essential for the diagnosis.

- **75% convergence rate** – if three stakeholder groups have the same objectives within an activity of the patient flow process. Example: during exam room assignment PCP’s need relatively simple access to the patient’s medical records in preparation for meeting the
patient; however, patients’, administrators’ and auditors’ objectives are the guarantee for medical records confidentiality.

- 100% convergence rate – if all stakeholder groups have the same objectives within an activity of the patient flow process. Example: the treatment plan chosen is based on available information and the input from patient. Similarly, administrators and auditors review the chosen treatment with regards to available information.

These steps within the model may help expose the degree of convergence necessary to have properly designed EHR system for multi-stakeholder use. We find that a satisfactorily usable information system must meet half of the user groups’ objectives. Furthermore, the model allows for understanding the stakeholders’ objectives within the current processes in the entire patient flow during the patient-PCP encounter. The understanding of the processes and the stakeholders’ objectives within each activity may be an effective starting point for assessing and re-evaluating the objectives to improve the convergence rate.

The identified processes cover the entire patient-PCP encounter that overarches multiple departments and job function, therefore it allows for the understanding of corporate level maturity. An EHR system, which has the capability to support all activities, is considered to have a high degree of corporate level maturity. Conversely, when an EHR system only partially supports the activities identified for the entire patient-PCP encounter that system is considered to have a low degree of corporate level maturity.

A properly designed EHR system will have a high degree of maturity for both dimensions: process level maturity and corporate level maturity. Having only one of the dimension fulfilled will require the information passed across other information systems that are
used to cover the needs for either the processes across multiple stakeholders or the breadth across the functions. Therefore, the EHR maturity model will help to determine (1) the extent the patient-PCP encounter is supported by the EHR system across multiple stakeholders; (2) the extent the EHR system supports the patient-PCP encounter across multiple functions; (3) the identification of current processes in its entirety and the opportunity to make modifications for a more efficient care coordination.

Chapter 6:

Empirical Validation of the Implementation Maturity Model Schema

6.1 Research Design and Method

A review of the literature suggests that existing studies limit their attention to conflicting stakeholder interests (Ahn & Skudlark, 1997; Oz & Sosik, 2000; Pan, 2005) but these studies either lack empirical evidence or they focus on one particular process or stakeholder group (e.g. Greenhalgh et al. 2010). Our Maturity Model Schema encompasses the PCP-Patient encounter processes and their activities from the time of appointment scheduling until the follow-up care across all four major stakeholder groups. This approach provides a more realistic dissection of the health care industry reflecting its multi-layered and sequential processes and the levels stakeholders are involved in each of the activities. Thus, professionals representing all four previously identified stakeholder groups across six different healthcare institutions (Shi & Singh, 2008) were presented an online questionnaire. Please refer to Appendix B for the full questionnaire.
Our aim is to empirically validate the differences between stakeholder perceptions and use of healthcare information systems through an online questionnaire.

6.2 Questionnaire Administration and Elements

The online questionnaire was hosted by a well-known and reputable online survey software that allowed the questionnaire to be designed, published and distributed from its secure servers. The questionnaire consisted of six pages, not including the attestation page (Refer to Appendix I).

The first page asked for demographics information: (1) State, in which the respondent encountered a health care information system, on which the consequent answers were based on; (2) Healthcare Role, which the respondent represents and on which they based their answers; (3) Healthcare Institution, with which the respondent is most familiar.

The second to fifth pages included questions in regards to health care information system features. Each of the four pages focused on a separate system characteristic with its two or three system features. We previously identified the misalignment across stakeholders within organizational level processes in our Maturity Model Schema. We use system attributes on which the alignments or misalignments can be measured through stakeholder self-reported scales of perceived system feature importance and the actual satisfaction with such existing system feature (See Figure 3.). The difference between the two self-reported scores provides a measure of gap existence. We use ANOVA (v.22 for Windows) to assess the existence of misalignment across stakeholders by perception of existing healthcare system characteristics.
Every system characteristic and feature used in the questionnaire has been clearly defined using common language so that people with no information system knowledge would understand the definition. Respondents were asked to identify the importance of and satisfaction with each system feature across the four main PCP-Patient encounter processes that we identified in our Maturity Model Schema. A five point Likert scale was used to capture the importance, where 1 indicated not important at all and 5 indicated extremely important. Similarly, the satisfaction with system features was captured through a five point Likert scale. 1 represented not satisfied at all and 5 represented extremely satisfied. Respondents were given a link at every question, which provided further details on what activities were included in the processes.

The final page asked the respondents to rate their openness to frequently using a healthcare information system because it meets their expectations of a particular system feature, which were previously scrutinized for importance and satisfaction.
6.3 Sample Population

Respondents comprised of health care professionals who possessed some level of experience with some type of information system that supports the health care organization’s operations across one or multiple processes PCP-Patient encounter. The patient stakeholder group consisted of respondents, who had familiarity with patient portals and other self-managed healthcare technology for online appointment booking, refilling prescriptions, accessing medical information, etc.

The respondents were contacted through email or asked in person to participate in the survey. While the initial contacts were all personal acquaintances of the researcher, everyone was asked to forward the questionnaire to their colleagues who represent the same stakeholder group. The personal contacts and personal references to a colleague expected the respondents to engage in the survey more than if a similar survey is requested from an unknown person. A large group of healthcare administrators were contacted from a publicly available Regional Healthcare Partnership (RHP) list as well.

A somewhat short deadline was given to complete the online questionnaire (2 weeks) and a reminder email sent after one week. We did not provide random drawing for prize among those that completed the questionnaire. It reduced the possibility of unengaged responders, who complete the survey simply for the purpose of being included in the prize drawing.

The online survey software provider tracked the number of times the questionnaire was opened and the incomplete/complete questionnaires. There have been 35 incomplete questionnaires, which were eliminated due to inadequate information they included. Most
abandonment happened soon after the demographics, therefore not providing valuable information about the system features; thus these incomplete responses were eliminated.

We received 168 completed questionnaires of which 43 came from the patient stakeholder group, 41 came from the Primary Care Provider stakeholder group, 51 came from the Healthcare Administrator stakeholder group, and 33 came from the Healthcare Auditor stakeholder group.

6.4 Data Reduction & Validity Check

6.4.1 Dependent variables

Respondents were asked to identify their openness to more frequently using a healthcare information system because it meets their expectations of a particular system feature. All eleven system characteristics were asked separately and we used factor analysis in SPSS version 22 for Windows to identify the “intercorrelated” observed indicators, which load under a common factor (Field, 2000: 424). We employed principal component (PCA) method to extract the factors, and followed it with a varimax (orthogonal) rotation (Gorsuch, 1983: 205). Descriptive statistics of the indicator variables are presented in Table 1.
Table 1: Dependent Variable Descriptive Statistics

Testing for multicollinearity, we employed the Bartlett’s test of sphericity ($\chi^2 (55) = 881.13, p<0.001$), indicated that PCA was adequate for the data, the correlation matrix, in fact, is not an identity matrix. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is a high value of 0.858. This indicates that the data will factor well as the items will be able to be grouped into a smaller set of underlying factors.

We selected 11 factors to extract due to the fact that we have 11 system features that the indicator variables were measuring. Factors with factor scores of >0.6 were retained in accordance with Hair et al. 2010. The reliability statistics (Cronbach’s alpha) is 0.714, which indicates a level of internal consistency for our scale and exceeds the recommended 0.7 value (DeVellis, 2003; Kline, 2005). Construct validity evidence of self-reporting scales is supported as items loaded together measuring the same constructs. As Nunnally (1978) phrased: “… factor analysis is intimately involved with questions of validity … Factor analysis is at the heart of the measurement of psychological constructs”.

<table>
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<th>-598</th>
<th>0.373</th>
<th>Mean</th>
<th>SD</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>Correlations</th>
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</table>

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
Due to the single item loading of an indicator, we will not include it as a factor, and we will proceed with three factors, labeled as confidentiality, usability, portability (Table 2.).

<table>
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<th>Usability</th>
<th>Portability</th>
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<td>OTU_S_I</td>
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<td>OTU_U_Et</td>
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<td>Portability</td>
<td>OTU_P_Lo</td>
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</table>

Table 2: Factor Loading for the Dependent Variables

6.4.2 Independent Variables

In our questionnaire, we identified 11 system features, each of which had 8 questions to assess its perceived importance and the satisfaction with that particular feature across 4 processes in a healthcare information system. These 8 observed items per system feature result in 88 items.

Testing for multicollinearity, we employed the Bartlett’s test of sphericity ($\chi^2 (351) = 3021.94, p<0.001$), indicated that PCA was adequate for the data, the correlation matrix, in fact, is not an identity matrix. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is a high value of 0.859. This indicates that the data will factor well as the items will be able to be grouped into a smaller set of underlying factors. 48 indicators loaded into 11 constructs and supported the construct validity as they loaded into their respective factors representing system
features collectively. The reliability statistics (Cronbach’s alpha) is 0.823, which indicates a very high level of internal consistency for our scale.

6.4.2.1 Importance

While the initial 88 items included the importance of and the satisfaction with a particular feature, we retained 48 observed items across 11 factors. However, we repeated the factor analysis with a principal component extraction for only the observed items that asked for the importance of a feature and for items that asked for the satisfaction with a feature separately.

The importance of system features loaded into 7 factors with supported KMO of 0.846 and Bartlett’s test of sphericity (\(\chi^2\) (946) = 5488.89, p<0.001). 32 out of the 44 items loaded across the 7 factors. The validity is supported as items measuring the same constructs loaded together. The reliability statistics (Cronbach’s alpha) is 0.892, which indicates a very high level of internal consistency for our scale.

6.4.2.2 Satisfaction

Similarly, we performed the PCA for items measuring the satisfaction with system features. The importance of system features loaded into 9 factors with supported KMO of 0.730 and Bartlett’s test of sphericity (\(\chi^2\) (946) = 3336.65, p<0.001). 26 out of the 44 items loaded across the 9 factors. The validity is supported as items measuring the same constructs loaded together. The reliability statistics (Cronbach’s alpha) is 0.866, which indicates a high level of internal consistency for our scale.
6.4.2.3 Gap - Divergence

Finally, we calculated the gap between importance of and satisfaction with a system feature raw scores. The gap scores emphasize the level of divergence we have identified in the Maturity Model Schema across the four processes.

High level of importance and low level of satisfaction resulted in a positive gap score. Low level importance and high level satisfaction resulted in a negative gap score. In order to eliminate the negative scores and to maintain the importance of increasing values indicating higher level of gap, we shifted the scores so that no negative gap will be present. We added 5 to all gaps, therefore we eliminated all negative gaps as -4 was the lowest possible negative gap (importance = 1 – satisfaction = 5). Descriptive statistics of the indicator variables are presented in Table 3.
Table 3: Descriptive Statistics for the Independent Variables

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Security Confidentiality</td>
<td>5.602</td>
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<td>-0.667</td>
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<tr>
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</tr>
<tr>
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</tr>
<tr>
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<td>6. Security Integrity</td>
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<td>8. Security Integrity</td>
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<td>0.526</td>
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</tbody>
</table>

*Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).
The gaps between importance and satisfaction scores loaded into seven factors with supported KMO of 0.730 and Bartlett’s test of sphericity ($\chi^2 (946) = 3336.65, p<0.001$). 27 out of the 44 items loaded across the seven factors. The validity is supported as items measuring the same constructs loaded together. The reliability statistics (Cronbach’s alpha) is 0.866, which indicates a high level of internal consistency for our scale.

We chose to retain the gap scores and performed further PCA extraction to reduce the 27 indicator variables across seven 1\textsuperscript{st} order constructs (system features) into the final four 2\textsuperscript{nd} order constructs (system characteristics) (see Figure 4.), namely: security/accountability, usability, portability.

![Figure 4: 1\textsuperscript{st} and 2\textsuperscript{nd} Order Constructs of the Indicator Variables](image)

The 27 indicator variables loaded into the expected four factors, which we labeled system characteristics) with supported KMO of 0.859 and Bartlett’s test of sphericity ($\chi^2 (351) = 3021.94, p<0.001$). The validity is supported as items measuring the same constructs loaded together. The reliability statistics (Cronbach’s alpha) is 0.835, which indicates a high level of internal consistency for our scale. The 2\textsuperscript{nd} order construct loading are displayed in Table 4.
<table>
<thead>
<tr>
<th>Features (1st order constructs)</th>
<th>Factors - Characteristics (2nd order constructs)</th>
<th>Security/Accountability</th>
<th>Portability</th>
<th>Transparency</th>
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<td>Effectiveness</td>
<td>U_EL_3</td>
<td></td>
<td></td>
<td></td>
<td>.633</td>
</tr>
</tbody>
</table>

Table 4: Second Order Constructs of the Indicator Variables
6.5 Empirical Gap Validation

The previously presented four factors (1) Security/Accountability, (2) Portability, (3) Transparency, and (4) Usability span across all four PCP-Patient encounter processes. We used a Pivot table to display the gaps within system features across PCP-Patient encounter process by roles, which is displayed by Figure 5.

The graphs reveal the perceived gaps across stakeholders and PCP-Patient encounter processes along with the system characteristics. We used principal component extraction method to factor the indicator variables in their common groups, which we labeled with system characteristics, based on what items loaded together. The graphs clearly reveal the communalities of perceived gaps and positive perceptions (where gaps are negative). For the purposes of this graphical representation we used the original Likert scale rates, therefore negative values indicate higher satisfaction than importance. 100% gap would indicate extremely important (Likert scale 5) feature and not at all satisfied (Likert scale 1) with it. We subtracted the satisfaction score from the importance score and divided the result by 4, which is the maximum gap indicator, therefore represents 100% gap. Then we averaged these gaps across processes, indicator variables and stakeholders.

The graphs represent the empirical data to support our Maturity Model Schema:

- Security/Accountability system characteristic indicators loaded for all four processes and indicates higher gap across administrators and auditors. This supports our Maturity Model Schema, where Auditors and Administrators seem to converge across most processes except Diagnose & Treat Patient, where we see different magnitude of gaps. Primary Care Providers indicate higher satisfaction than importance, while patients
indicate mild gap between importance and satisfaction during Review Medical Information and Treatment processes. This supports our Maturity Model Schema where the PCP’s diverged across all activities except Diagnose & Treat Patient process.

- Usability system characteristic indicators were only factored in to Review Patient Medical Information and Diagnose & Treat Patient processes. PCP’s exhibited the highest gap during these two processes, while the other stakeholders indicated mild gaps.

- Transparency system characteristic indicators loaded to all factors beside the Scheduling Patient Visit process. While only PCP’s indicated high dissatisfaction across all three processes, the other stakeholders indicated their dissatisfaction mostly during the Report & Follow Up process, which is in line with our Maturity Model Schema, where the most activities with 0% convergences can be found.

- Portability system characteristics indicators loaded across all four processes, in all of which Patients indicated high level of dissatisfaction. PCP’s indicated high gap during Review Patient Medical Information and Diagnose & Treat Patient processes, while administrators found the system perform far below their expectations during the Diagnose & Treat Patient and the Report & Follow Up processes. Auditors seemed to expect more from their current system during the Report & Follow-Up process.
Figure 5: The average perceived gap across system features and PCP-Patient encounter processes by stakeholder groups.
6.6 Statistical Analysis for Misalignment Across Stakeholders

We performed statistical analyses on the dependent and independent variables by stakeholder groups to support the existence of misalignments across stakeholders by perceptions of existing healthcare information systems. We used the previously established gap between the perceived importance of a certain feature Likert score and subtracted the perceived satisfaction with the same feature. Larger score indicates greater perceived gap in stakeholder satisfaction compared to the importance of the system feature. To eliminate possible offsetting effect of negative value (low importance – high satisfaction), we used the previously established method of adding 5 to each scores.

We already provided the descriptive statistics earlier for all 27 independent variables and three dependent variables in Table 3. We tested for the use of one-way ANOVA to support the existence of misalignment across stakeholders by perception of existing healthcare system characteristics. To fulfill an important assumption of the one-way ANOVA statistical test, we performed homogeneity of variances test, which satisfies the assumption that the population variances of the DV are equal for all groups of the IV’s. Unequal variances may increase the Type I error rate. We performed the Levene’s Test of Equality of Variances (homogeneity of variances test). Levene’s Test indicated four groups that had significant (P<0.05) Levene’s statistics, which signaled unequal variances between the DV and those four groups of IV’s, which violated the homogeneity of variances assumption and the ANOVA F-statistics cannot be reliable, even though they were statistically significant.

Even though only few IV’s indicated statistically significant Levene’s Test, we decided to proceed with a more robust ANOVA, the Welch test (Lix et al., 1996). The Welch statistic is based on the usual ANOVA F test. However, the means are weighted by the reciprocal of the
group mean variances (Welch 1951; Brown and Forsythe 1974b; Asiribo, Osebekwin, and Gurland 1990). The result of the Welch test is reported as the ANOVA. We found that all groups had significant p-values (<0.05), which allows us to conclude that not all group means are equal in the population. To be exact, it allows us to conclude that at least one group mean is different from that of other group means.

In order to find which stakeholder group’s responses signal statistical difference from others across all IV’s and DV’s, we performed the Games-Howell post-hoc test (Games & Howell, 1976). Most of the mean differences were statistically significant (P<0.005). The non-statistical differences occurred mostly between patients and PCP’s, which has been signaled on Figure 3., where the gaps were visually represented. Similarly, some non-statistical differences were spotted between auditors and administrators, which is also predictable as their expectations of a system is similar and the graphs visually indicated similar gaps for these two stakeholder groups as well. Please refer to Appendix A for details on our Levene’s Test, Welch Statistics, and the Games-Howell post-hoc test.
Chapter 7:

Discussion

The emergence and growth of electronic health records has generated political debate and significant interest in the business and academic research communities. Our study complements the insights drawn from former works on user and EHR system interaction by providing the first comprehensive multi-stakeholder approach of EHR system implementations.

Much of the research in EHR processes to date had been technological (e.g. Ammenwerth et al., 2001; Bates et al., 2003; Herbst et al., 1999; Rotman et al., 1999), behavioral (e.g. Littlejohns et al., 2003; Rotich et al., 2003) or investigated EHR implementation barriers (e.g. Kuhn & Giuse, 2001; LaDuke. 2001; Leung, 2003), with a relatively small number of papers considering the stakeholders’ perspective besides focused groups of physicians (e.g. Miller & Sim, 2004; Audet et al., 2005) and the impact of misalignment among these stakeholder groups. Our dissertation research scrutinized and broke down the patient flow of an office visit into general processes and the stakeholder groups’ objectives within each process. Then we identified whether one stakeholder group’s objectives is aligned with that of another. If it did, we identified the stakeholder groups’ objectives as converging. Conversely, if the objectives were found not to be aligned among stakeholder groups, we identified the stakeholder groups’ objectives and needs as diverging.

Our study integrates theories from the information systems and management literature, which discovers the divergences and convergences across processes in patient’s care. The objective of this dissertation research is to find both alignments and misalignments in EHR
processes used by multiple stakeholders, which offers significant implications for both the theory and practice of health care information systems and management.

We empirically validated our Maturity Model Schema based on data collected through an online questionnaire from stakeholders involved in the patient care process. The results were analyzed with factor analysis data reduction and validation technique. We used the gap between perceived importance of and satisfaction with certain healthcare information system features across four PCP-Patient encounter processes. The factor analysis revealed first and second order constructs which allowed us to group our indicator variables into four major groups based on system characteristics. The dependent variables were factored into three groups based on openness of frequently using a system if it satisfies user needs with common system features.

The results allowed us to validate our Maturity Model Schema, where we identified gaps across stakeholder perceptions across process activities. Welch Test statistical analytic technique supported the existence of misalignment across stakeholders by perceptions of existing healthcare system characteristics and Games-Howell post-hoc test supported our Maturity Model Schema by identifying the statistically different mean differences across stakeholder groups.

7.1 Practical Implications

Grounded in the stakeholder alignment theory, business process reengineering (BPR), and the capability maturity model (CMM), this study has developed a framework that supports companies with tremendous practical implications. Companies are able to gauge their EHR implementation maturity using our EHR maturity model. With the help of the model, companies are able to identify high (more than 75%), medium (50-75%) or low (less than 50%) convergence levels. In turn, they are able to identify processes that have the least amount of
convergence among the involved stakeholder groups’ objectives and develop system features that have flexibility to manage the diverse needs of the stakeholders.

We look at the implications for executives, users and developers in particular in the following sub-sections.

7.1.1 Implications for executives, project leaders and decision makers

Information system development and implementation project executives decide on the system characteristics to support user needs and the vendor they choose to deliver an information system. Choosing the product that fits the organization’s and users’ needs is a complex decision making process.

Making a decision on a product before fully understanding the often diverging goals and objectives of all stakeholders result in a system which will only serve part of the user group. It may give rise to unsatisfied users who will find the system unsupportive to their needs and work and may abandon or only partially use the system. Decision makers in an EHR system implementation must be familiar with their stakeholder needs, goals and objectives of the system. Our model helps to surface the diverging needs of the users among the different stakeholder groups, so that executives, project leaders and decision makers can plan with varying needs and find a vendor who can fulfill these needs or incorporate the different needs while designing the system.

Our EHR maturity model also may decrease the implementation time as incremental implementation has been viewed as the process required stabilizing and aligning different users of the system (McNulty and Ferlie, 2002). As the EMM we developed already includes the level of divergence and converges across stakeholders within an activity, project executives may better
plan for the system and features in need, therefore, decrease the implementation time and the cost associated with it.

Other implication that our EHR maturity model offers for project executives is providing guidance to alleviate unforeseen events with unintended consequences (Harrison et al. 2007). Since an information system integration and implementation project is complex in nature, project executives explore the implications of the projects in greater details than if it was a single system implementation. Our EMM provides a solid starting point to identify the possible sources of events that might have been unidentified until issues arose. For example, the varying needs of certain stakeholder groups might be overlooked until one group finds the new system unable to perform every aspect of their work functions. Having a pre-defined process model with all stakeholder groups’ tasks identified may provide a significant advantage when planning an information system implementation and integration in a multi-stakeholder environment.

7.1.2 Implication for designers and vendors

The development of software applications went through a shift in the past decade, where designers and software vendors realized that users’ perception of the system and the actual usage should be the main concern while designing software. As users’ productivity greatly depends on the actual use of the system (Davis et al, 1989), organizations have demanded usable and understandable systems that justify their financial investments (Brynjolfsson, 1993).

In the Process Disparity section of this dissertation research, we drew attention to the often diverging needs and heterogeneous goals of stakeholders within a particular step of the patient-PHP interaction process. Diverging goals and objectives needs to be accommodated with a carefully designed information system. Designing and building an information system within
the health care industry is increasingly challenging as more stakeholders are involved within the patient care coordination with different functions within a process. Furthermore, implementing a system with existing applications increases the complexity of system design, integration and implementation.

EHR system adoption is a multi-step decision process from planning to system selection phase (Columbus 2006; Lorenzi et al., 2009). Our model may be beneficial during the needs assessment and workflow analysis phases to surface the differing user needs and objectives. This is especially important for system designers and vendors as their product will not be adopted if the integration of their product requires (1) significant alterations to existing information systems or (2) significant change in the existing business processes and stakeholder activities. Therefore, designers’ and vendors’ goals should be to understand the current operational processes within and across a function, which is captured and revealed in detail in our EHR maturity model. Existing products may be compared with the model to identify gaps or flaws and generate ideas for product improvements based on the suggestions of the level of disparities within or across functions.

### 7.1.3 Implication for users

One of the major challenges of the development and effective use of the EHR system stems from the fact that there are a number of different job functions that are simultaneously involved during patient’s care. This results in varying objectives from different user groups that are using the same system during a particular process of patient’s care (Anderson et al. 1994). Any system-development and implementation project greatly depends on the user requirements and specifications that provide directions to software engineers. It is a well-established fact that
users and developers perceive the information system differently (e.g., Jiang et al., 2002; Landauer 1995).

Our model helps with the understanding of the diverse user needs and accommodates these differing needs with the proper system that supports the distinct requirements. It is especially important in the sense that software designers are often segregated from users and their exact need for the system is only captured in a generic design specification or functional requirement document. These specifications often ignore the varying needs for the same job function and the fact that what might be essential for one user could be unnecessary for the other. When the user and designer interaction is viewed as a dynamic and ongoing process, a user-centered approach, a customized system development is more likely to succeed and results in better acceptance rate (Mackay et al., 2000). Mapping out the different roles within a job function may have tremendous advantages not only for the designers, but also for users as they better understand the possible gaps in their operational processes and it could offer improvement opportunity. For example, when a user enters detailed information in the progress note, the same information might be asked elsewhere, which results in either cross-referencing the already inputted information (e.g., “Please refer to [name of input field] for further details) or rephrasing the already stated input. Understanding the use of this particular field will help database designers properly plan for capturing and retrieving the information as intended.

Furthermore, the EMM may enable users to identify workarounds they perform, but not noticed, unless the detailed operational process is reviewed. For example, using another system or technology to compensate for the shortcomings of the integrated system, this may result in lost or missing information. For example, some users are more comfortable using Microsoft Word to type up notes due to its advanced formatting or spell check functionalities, which may be missing
from an integrated system. Therefore, the notes may be stored separately, which increases the risk of loss of confidentiality or the permanent separation of information.

These workarounds might not be visible unless the business processes are clearly identified and the steps taken by each stakeholder captured. Our model may be beneficial to review the processes and identify current activities that deviate from the generally deployed steps.
Chapter 8:

Limitations and future directions

Just like any other studies, our research is limited in scope and therefore not exempt from caveats. However, these limitations prepare the ground for future research directions that extends on our study. First, we chose the level of granularity to be broad enough to fit into the Implementation Maturity Model Schema, which is a framework designed to be used by health care organizations. However, this level of detail does not cover the exclusive regulatory and procedural requirements specific to a particular type of health care organization or a particular department with specialized care delivery within the organization. Increased granularity may offer tangible advices and directions on the gaps identified during the “as-is” process classification.

Second, business process reengineering (BPR) is used in this dissertation research as the means to surfacing common processes employed within a health care organization and offers a starting point for enhancements. The service industry is highly volatile in terms of detailed process steps, therefore a framework is provided as a filter to identify and act upon the process and corporate level maturity. As process reengineering is not only contextual by industry, but also by departments and procedures within an organization, our EMM needs further relative details specific to the particular process.

Third, this research is limited to the operation of a standalone organization not linked to other, supportive third parties. It is essential to recognize that customer satisfaction greatly depends on the flawless integration of inter-organizational systems, especially in a complex
organizational setting such as the health care industry. This dissertation research does not provide the formal process linkage and connection with insurance industry in terms of claim submission and processing, and reimbursements. This missing linkage may have serious negative implications on the level of quality of care and in particular on patient satisfaction. Future research may find it valuable to investigate and examine the level of integration put in place with the insurance providers and extend the process mapping to understand external process linkages. This may aid with the evaluation of the level of integration and implementation necessary for seamless operation and adequate level of patient satisfaction.
Chapter 9:

Conclusion

In this dissertation research, we identified the need for a multi-functional information system within the health care industry. In spite of the obvious benefits of the information systems, EHR in particular, the drawbacks are prompting for a more detailed view. We found that EHR systems must accommodate the organizational operations on the process level and on the organizational level. Process level accommodation comprises the multi-stakeholder support within a process; while the organizational level accommodation encompasses the level a system supports multiple functions.

We identified the patient flow processes with all stakeholder groups, which served as an opportunity for business process reengineering in the making. Then we suggested an EHR maturity model to identify the level of divergence and convergence across stakeholders. The proposed EMM lets us examine the current state of care-coordination processes in place, their multi-stakeholder level support and the extent the current technology supports the patient-PCP encounter across multiple functions. This multi-dimensional evaluation is crucial as organizations strive for strategic and economic competitiveness, especially in the health care industry. Health care information system users, designers and project executives should find the proposed EHR maturity model useful in their future quest for evaluating and creating a health care information system that supports all involved stakeholders across the functions of coordinated care.
This dissertation research may provide a useful starting point on implementation maturity allowing health care organizations to assess their EHR system implementation maturity levels to serve multiple stakeholders within a process across different functions. The EHR maturity model may be useful for the evaluation of current technology within a health care organization and identifying the gaps between the supported processes and functions and those necessary for coordinated care with all involved stakeholders.
References


Chapter 1:

Introduction

1.1 Motivation

Perhaps the most significant expectation from Electronic Health Records Systems (EHR) is the ability to fulfill the varying needs and expectations of multiple stakeholders (Thornewill et al. 2011). Properly designed EHR systems are able to provide functional support to the different stakeholder groups within the same patient flow process. However, adoption of an EHR system alone is insufficient in order to realize the benefits to its fullest capacity. Evidence for failed EHR implementation in the literature abound (e.g. Southton et al. 1999, Zhang 2005a, 2005b, Aarts and Peel 1999, Berg 2001, Goddard 2000). The main reasons of such failures range from changed workflow and work disruption to perceived inefficiency and decreased productivity, which ultimately results in partial or complete abandonment and rejection of the use of the EHR system by some or all users.

Even though EHR is regulated and legislatively expected to implement and properly use certain system features, we see a lackluster implementation rate over time. Neither the national,
regional and practice type implementation rate are above 58% in 2012 (DesRoches et al. 2013, Robert Wood Johnson Foundation, 2013). Even basic EHR implementation to hospitals lags at 44% while comprehensive EHR system implementation is at only 17% in 2012.

Numerous research studies, especially in the medical informatics field, are based on the barriers of EHR system use (Tang et al. 2006, Simon et al. 2007). Simon et al. (2007) found in their survey of physicians that loss of productivity and disruption in processes are mentioned as main reasons for lack of EHR system use. Sykes, Venkatesh and Rai (2011) investigated the indicators that predict EHR system use in their multidisciplinary approach. Their work, however, focused primarily on physicians, therefore, lacking focus on other stakeholders. Greenhalgh et al. (2010) interviewed EHR users from multiple stakeholder groups, who initially adopted the product. The authors concluded that users tended to abandon the EHR system due to the fact that “functionality aligned poorly with their expectations.”

1.2 Research Problem: The “Implementation-Use” Paradox

Studies show that one of the main factors of information system implementations success is the actual system usage by its stakeholders (e.g. Devaraj and Kohli 2003). Consequently, limited EHR system use by its stakeholders impedes benefit realization and value creation. Furthermore, it has been found that the inefficient use and abandonment of current EHR systems are mainly due to poor system design (Sted & Lin 2009).

This dissertation research seeks to offer an answer to the above stated problem of low successful EHR implementation rate and system use by its stakeholders. Keen (1987) characterized research in the information systems domain as the "study of the effective design, delivery, use and impact of [IT] on organizations and society". In line with Keen's description of
IS research, this dissertation research proposes a design-theoretic model and offers a simplified implementation logic that different stakeholders will use to support their work functions.

Design Science (DS) is an outcome based research methodology in the information technology field. Artifacts development with emphasis on their functional performance is the aim of DS. Design science is a particularly beneficial approach for our purpose of proposing an EHR system design because of the pragmatic nature of our objective. We base our research on Walls et al.’s (1992) product aspect of Information System Design Theory (ISDT), while we propose extensions to their ISDT in the virtue of differentiating between organizational and system or design level abstractions. For example, a vague organizational level problem identification, such as "the system is not reliable" does not provide sufficient details to designers. However, design level problem identifications, such as "vital sign entries are not validated" would provide more specific information to designers. Similarly, when requirements are provided on the organizational level, they state the "how the system should work" aspect. However, system level requirements provide further details that designers and developers may use for feature selection that may provide remedy to the organizational level problems and requirements and answer the "what features would support the organizational level requirements" question. Furthermore, we propose a context independent implementation logic that evaluates the level the artifact fulfills the requirements on both the organizational and the system design levels.

1.3 Theoretical and Practical Importance

This dissertation research advances the existing design science literature in the information systems domain and considers both the conceptual and practice oriented perspectives. We
develop a design-theoretic model, in which we clearly distinguish between organizational and kernel levels. In doing so, we provide the additional details necessary for designers to identify the design requirements and features that specifically address the organizational challenges. The design-theoretic model developed in this dissertation research will have tremendous practical implications to all stakeholder groups and IT professionals. Users will benefit from the better system design particularly addressing their explicit needs, while system designers will benefit from the sound methodology and conceptual roadmap to assist them in proper system feature selection.

This dissertation research also fills the gap in literature in regards to the system design aspect of a successful EHR implementation. Current literature exploits the behavioral aspect of successful vs. unsuccessful EHR system implementations in various environments. The actual system design considering security/accountability, availability, and portability in response to a multi-stakeholder requirement has not been scrutinized before. In addition to the practical lead of the research, we follow and extend upon design theory from the relevant information systems literature. Accountability meta-kernel and auditability meta-design have escaped researchers’ scrutiny, which we find a crucial considering what a heavily regulated industry healthcare is from federal to state, local and organizational level regulations.

1.4 Organization of this Essay

The following sections begin with an overview of design research literature, and the theories and models the prominent works develop. Then, we identify the common objectives and components they include to build up their theories and models. This will set the ground for us to introduce the gap in the literature and the need for kernel level assessment and feature selection.
that define the design requirements and the embedded characteristics. Additionally, we argue that system implementation and evaluation should be context independent; therefore, we propose general implementation parameters that simplify the implementation logic regardless of the context. For example, implementing an EHR system at a primary care provider is comparable to that at a multi-campus hospital. However, system features should support the stakeholders through the same set of standards at both healthcare organizations.

Once the artifact design has been created, we will validate the importance of the perceived gap in satisfaction with the artifacts and its relationship to openness to frequently using an EHR system based on expectations of satisfaction with existing EHR system characteristics. For this purpose, we use data that we collected through a survey from different stakeholder groups in the healthcare industry.
Chapter 2:

Theoretical Background

2.1 Design Theory

We draw upon the information systems design theory to understand the EHR system design and propose a more advanced EHR system. Design theory is particularly appropriate for this purpose due to the multi-stakeholder context, where different design requirements are dictated by the groups of stakeholders. Following the product design aspect of Walls et al.’s (1992) information systems design theory (ISDT), we propose a design framework for multi-stakeholder alignment in EHR systems.

Information systems design research history spans almost half a century notably tracing back to Herbert Simon's publication of The Sciences of the Artificial in 1969. Information Systems (IS) consists of a body of existing and newly generated knowledge that aims to help in finding solutions to problems. These problems relate to analyzing, planning, developing and implementing information systems in organizational settings to increase efficiency and support operations, in general. IS employs an array of approaches and methods that involve both the technical (Benbasat and Zmud 2003), user, and organizational (Mingers and Willcocks 2004) aspects of a system to ensure its successful implementation and use (Iivari, Hirschheim and Klein 2004).

Design theory has been developed within the IS discipline to guide artifact creation methodology as opposed to scientific theories, which aim to understand phenomena occurring
naturally (Dubin 1978). IS, as a discipline, entails the use of artifacts in both the technological and human systems and investigates phenomena arising as the two interact (Lee 2001). Simon (1996) defines artifacts as “man-made as opposed to natural” and its artificial creation is central in Orlikovski and Iacono’s (2001) definition. However, they add that “IT artifacts are not static or unchanging, but dynamic”. In addition, they also add that IT artifacts are always embedded in “some time, place, discourse, and community”. Benbasat and Zmud (2003) add that artifacts are not only embedded in a structure within a context, but also IT artifacts are “application of IT to enable or support some task(s)”. Hevner et al. (2004) broadly define IT artifacts as “constructs (vocabulary and symbols), models (abstractions and representations), methods (algorithms and practices), and instantiations (implemented and prototype systems).

As previously stated, purposeful artifacts are designed and built to solve problems. Walls et al. (1992) pointed out the two distinct design theory characteristics: (1) the theoretical base and (2) methodological guidance for practitioners. Additionally, the authors reasoned that three related components define the design theory: (1) a set of requirements for a class of design problems, (2) a set of system features (or the principles and steps to identify the features) to meet these requirements, and (3) guiding principles for the design process to ensure that the system features selected will meet the requirements.

The properly planned creation of these artifacts is vital to ensure they meet the users’ requirements and needs. IS distinguishes itself from other disciplines by being the professional domain that has the knowledge base to design, create and use the artifacts based on IT. This body of solution-oriented knowledge goes beyond just understanding the problem and provides solutions with relevance to practitioners (Van Aken 2004).
Goal orientation is another key element that is required in a design theory according to Walls et al. (1992). They contend that the support to achieve the desired goal is the purpose of design theory rather than directly achieving the goal itself. The previously mentioned technical and social aspects of an information system require the design theory to guide the relationship between the goal orientation and artifact properties. For example, the user requirements to achieve a goal are defining artifact properties while the method ("how to") of creating the artifact is guided by the design theory.

Design research gained momentum in the 1990's and a number of researchers (Nunamaker and Chen, 1991; Walls et al., 1992; March and Smith, 1995; Hevner et al., 2004; Adams et al., 2004) defined and set the ground for Design Science (DS) to be a sought after tool within the IS research community. While the pioneers of IS design science research have had differing purposes, there have been common elements or components in their approaches (Peffers et al., 2006). They all start out start identifying the problem on theoretical bases. Walls et al. (1992) translate the identified problems into meta-requirements, which are objectives of the system. The central piece in design science is the actual design and development of the system, in which step the objectives are supported (Walls et al., 1992), and some researchers (Nunamaker and Chen, 1991) further define the development process itself. The exposition and formal evaluation of the developed artifacts are common across most researchers with different levels of emphasis.

2.2 Kernel Theory

Walls et al (1992) established the notion that theories lay the ground for design science. Furthermore, they suggested that theories from the natural and social sciences should be the foundation of ideas and govern the design of artifacts; therefore, kernel theory is an essential
characteristic of design theory. In the context of EHR system design, we consider kernel theory to be the guiding principle on which we base our problem identification, solution formulation, kernel design, and the testable hypotheses. Every step of our design-theoretic model will revisit the kernel theory and justify its need for a proper artifact creation.

The choice of our kernel theory is driven by Gregor and Joness (2007) direction that the chosen theory needs to provide explanations, predictions, and it needs to be testable. Kernel theory is a building block of the Design Theory. Therefore, we will depict it through its representation for our design-theoretic model.

### 2.3 Alignment Theory

The choice of our kernel theory will be the alignment theory on which we base our design-theoretic model. For the purposes of our kernel design, we follow Nadler and Tushman’s (1980) definition of alignment as the shared understanding and degree of which goals, demands, needs, objectives of one component are consistent with the same of other component within an organization.

In our EHR system design we propose to align the kernel across multiple stakeholders and their expectations from the system. System characteristics are standardized, collective representations of a system. System features are more customized for a particular user group. Users, however, have to agree that a certain characteristic is important to include in a system in order to have the desirable feature available for them, even if it is only used by one user group and not by the other. Aligning the users’ objectives on the system characteristics and providing a design model are the aims of our design-theoretic model, in which Alignment Theory is further discussed.
Chapter 3:

Design-Theoretic Model Development

Theories guide knowledge creation through general guidelines as opposed to providing explicit guidance. For example, following an information system design theory will provide the methodology to design any systems regardless of the environment and platform in which it is used or the specific task for what it is designed. However, for good fit in different contexts, it requires further modification or elaboration (Kasper, 1996; Markus et al., 2002).

We found this modification necessary in the healthcare domain context and we base our research on adapting and extending Walls et al.'s (1992) Information System Design Theory product aspect in three ways by reference to other notable sources. We find that this modification will provide a more complete design model that will help to guide the process of understanding the general organizational level needs and transform them to a set of system design centric requirements. Furthermore, our proposed design model will provide a detailed guide to artifact creation that solves the organizational problem.

Our first proposed modification to Walls et al.'s (1992) ISDT is adding a more system specific problem identification through the assessment of existing systems' kernels. This follows DeLone & McLean's (1992; 2003) widely accepted concept of IS Success Model, in which system quality and the system's attributes are identified as a precursor for system use and its impact on the individual and organization. Furthermore, other researchers start their design theory by need (Rossi et al., 2003) and problem (Hevner et al., 2004) identification and data collection and analysis (Eekels and Rozenburg, 1992). Gregor and Jones (2007) pointed out the
importance of a designer's understanding of the problem, which is challenging through an organizational level problem description. Sarker and Lee (2002) argued that IS design theory should have a prominent goal of reducing system developers' uncertainty in regards to allowable system features and development activates and thus increasing the system development success.

We found it imperative to assess the kernel on a system level, rather than the vague organizational level. Therefore, kernel assessment is the design centric problem identification, which allows designers to depict the problem on the system level, which may provide more specific requirements to designers.

Second, we further define organizational level concept to system level concepts. Walls et al.'s (1992) meta-requirements are on a functional level, which do not state the specific methodological steps that provide system developers proper guidance. Therefore, an additional step is proposed, the meta-kernel, which is a system and design oriented abstraction that defines a product and its embedded characteristics. This system level requirement specification step follows the suggested "relevance" guideline in Hevner et al.'s (2004) DS Research Guidelines and Eekels and Roozeburg's (1991) requirements design step, on which the evaluation is based, in their scientific research design cycle.

Third, we added kernel exposition, adapted from Gregor and Jones (2007) eight stages of design theory and Nunamaker and Chen (1991) experimental component. Their design theory includes the implementation process in addition to the artifact creation and we felt that the kernel exposition is important in order to formulate the kernel design not only in theory, but also in practice instantiations. However, we do not provide specific implementation guidance; rather we
suggest general implementation parameters to help IS managers to simplify the implementation logic regardless of context.

In summary, we extended on Walls et al.'s (1992) ISDT by adding the Kernel Assessment as the design centric problem identification activity, the meta kernel as design centric abstraction that defines system characteristics, and the kernel exposition as context independent implementation logic. We graphically represent our design-theoretic model in Figure 1.
<table>
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<tr>
<th>Design Theory components from Relevant DS Research and Proposed Extensions</th>
<th>Objectives</th>
<th>Definition</th>
<th>Level</th>
<th>Source</th>
<th>EHR System Design Steps</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2. Kernel Assessment</strong></td>
<td>Gap Identification</td>
<td>A design centric problem identification</td>
<td>Design</td>
<td>Proposed</td>
<td>Different stakeholder groups have divergent expectations from EHR system</td>
</tr>
<tr>
<td><strong>3. Kernel Theory</strong></td>
<td>Solution Objectives</td>
<td>Theoretical foundation from a kernel perspective for the design goal, its embedded characteristics and that the goal is met</td>
<td>Design</td>
<td>Walls et al., 1992</td>
<td>Alignment theory - Different stakeholders interface differently with the same system</td>
</tr>
<tr>
<td><strong>4. Meta-Requirements</strong></td>
<td>Organizational level Concept</td>
<td>Organizational level abstractions that characterize the design features</td>
<td>Organizational</td>
<td>Walls et al., 1992</td>
<td>Hospitals/users want a system that: (1a) protects patient medical history (1b) adheres to compliance regulations (2) supports their work function in an effective and efficient manner (4) shares clinical data across other systems</td>
</tr>
<tr>
<td><strong>5. Meta Kernel</strong></td>
<td>System level Concept</td>
<td>A system and design oriented abstraction that define a process and its embedded characteristics</td>
<td>Design</td>
<td>Proposed</td>
<td>Hospital requirements translate to the following design requirements: (1) Security/Accountability (2) Availability (3) Portability/Scalability</td>
</tr>
<tr>
<td><strong>6. Meta-Design</strong></td>
<td>Design</td>
<td>Class of design centric artifacts that meet the design concepts</td>
<td>Design</td>
<td>Walls et al., 1992</td>
<td>The following artifacts attribute to the design requirements: (1) Confidentiality, Data Integrity, Responsibility, Auditability (2) Data Availability, Efficiency, Effectiveness, Satisfaction (3) Interoperability, Interconnectedness, Transparency</td>
</tr>
<tr>
<td><strong>7. Kernel Exposition</strong></td>
<td>Experiment, observe, evaluate</td>
<td>A context independent implementation logic that validates the design goal and the artifact.</td>
<td>Organizational</td>
<td>Proposed</td>
<td>Evaluation whether the designed system is secure/accountable, portable, and usable to a level that users would be using it more frequently.</td>
</tr>
</tbody>
</table>

**Figure 1. – Design-Theoretic Model adapted from and extended upon Walls et al.’s (1992) ISDT**
The following seven activities have been the product of Walls et al.'s (1992) ISDT components, other design research literature and our proposed design model elements. We cover each element in detail in regards to their objectives, their use in other Design Models, their definitions, scope level, relevant literature, and their application in EHR system design with practical examples.

3.1 Problem/Need Discovery

We define this objective as a vague problem statement, research question identification and validation of the purpose of artifact creation. In this activity of a design theory the purpose of the research is identified and the problem is recognized. The magnitude and relevance of the problem will rationalize the artifact creation and its value and impact on the identified problem. A detailed assessment of the problem will ensure that the solution covers all of its aspects.

Design theory component from relevant literature:

All relevant notable DS research papers we investigated include some form of initial step that lays the ground for the research problem in the shape of problem identification or motivation. Hevner et al.'s (2004) first activity included problem identification, which they deem to be important and relevant. Rossi et al. (2003)'s first step is need identification, which may or may not be prompted through an existing problem. Jones and Gregor (2007) called their first step "purpose and scope" and they identify the type of system in this step. Some researchers from other disciplines suggest problem analysis (Archer 1984; Eekels et al. 1991).

Level:
Organizational level problem statement, which motivates researchers to expand on the problem in terms of the underlying challenges that result in the problem identified.

**EHR System Design Steps:**

In this component of the proposed conceptual model we identify the issue of low rate of EHR system use in comparison with its acceptance or implementation rate. EHR is regulated and legislatively expected to implement and properly use system features, we see a lackluster implementation rate over time. Neither the national, regional and practice type implementation rate are above 58% in 2012 (DesRoches et al. 2013, Robert Wood Johnson Foundation, 2013). Even basic EHR implementation to hospitals lags at 44% while comprehensive EHR system implementation is at only 17% in 2012.

However, this problem identification is provided on the organizational level, which does not provide enough details to system designers and developers to begin the proper meta-kernel selection. In order to get more specific details on the problem, a system level approach is needed.

### 3.2 Kernel Assessment

We define this objective as design centric problem identification. It is imperative to understand the organizational level problem on the system design side with particular focus on the cause of the organizational level problem. This is the step where designers assess the kernel as the general problem statement does not provide this information. For example, if the problem statement on the organizational level state that the system doesn't work properly, the designers are not able to select system features and characteristics to remedy this issue. Assessing the
kernel may provide additional details, for example, if the data is not being validated properly, the kernel level assessment is imperative as the data validation problem is on the kernel level.

Further investigating the problem through kernel assessment, designers may start identifying the context of the problem. If different user groups are identified in the system use, system designer may determine that these different user groups expect different validation rules and expect the same data to be entered, retrieved, and displayed differently. For example, if a patient is entered into the system, an internal patient ID is assigned, to which his or her records will be linked. The name will also be displayed in addition to other identifiable information, such as date of birth. At check-in, the patient states his or her name, while the physician or nurse enters or retrieves the patient information based on the internal patient ID. Furthermore, if the patient care continues at a different healthcare organization, the patient may be assigned another internal ID, to which the original ID is cross-referenced. This example of data validation signifies the importance of assessing the organizational level problem on the kernel level in its appropriate context. Only such system design level assessment can uncover the problem on the kernel level that aids the designer to assess requirements and chose the proper system features in the subsequent steps of system design.

Proposed Extension to Walls et al.’s (1992) ISDT:

Kernel Assessment - Previous literature in design science did not separate problem identification from the organizational level. We argue that context on a general level needs to be identified and kernel level assessment is necessary in order to properly move forward with appropriate requirement gathering and feature selection.
System design level

**EHR System Design Steps:**

The need to assess the EHR kernel is prompted by the fact that a single EHR system has multiple stakeholders, each with its own warranted authority and operation. These stakeholder groups may have different and conflicting levels of engagement of the same process. Properly designed EHR systems are able to provide the functional support to the different stakeholder groups within the same process. Accommodating these varying stakeholder expectations require a carefully designed EHR system.

Kernel assessment across EHR systems assess the current kernel designs and identify the gaps where design limitations result in a system, which is misaligned on stakeholders' system expectations. We have previously identified process sequence blocks and their sets of activities in the patient-PCP encounter. Additionally, we categorized these activities according to the stakeholders' expectations and classified the level of convergence or divergence across stakeholders within each activity. If all four stakeholders shared the same expectations from the EHR system within an activity, the convergence rate is classified to be 100%. If three stakeholders shared the same expectations, while one stakeholder had a different objective within a particular process, the convergence rate is classified 75%, or the divergence rate is 25%. If all stakeholders had different objectives within an activity, therefore have differing expectations from an EHR system, we classified that activity with a 0% convergence rate, or a 100% divergence rate. We then averaged the equally weighted activity convergence rates within each process sequence blocks and determined the overall convergence rates on the process sequence block level.
In Table 1., we list the four kernel assessment sequence blocks with a sample patient flow or interaction process. Also, the overall convergence rate is indicated, which reveal a gap in existing EHR kernel designs, since the 100% convergence rate would indicate a perfectly aligned system in a particular process block.

<table>
<thead>
<tr>
<th>Kernel Assessment Sequence Blocks</th>
<th>Patient Interaction Processes</th>
<th>Level of Convergence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schedule / Administer Patient Visit</td>
<td>Administering Patient for Office Visit</td>
<td>42%</td>
</tr>
<tr>
<td>Collect &amp; Review Patient Medical Information</td>
<td>Collect and Integrate Clinical Information - Determination of urgency</td>
<td>50%</td>
</tr>
<tr>
<td>Diagnose &amp; Treat Patient</td>
<td>Analyze and Assess Symptoms and Test Results</td>
<td>54%</td>
</tr>
<tr>
<td>Reporting &amp; Follow-Up</td>
<td>Follow Up Care</td>
<td>27%</td>
</tr>
</tbody>
</table>

Table 1. Kernel Assessment Sequence Blocks, Sample Patient Interaction Processes and Stakeholder Expectation Convergence Levels

Below, we demonstrate the expectations of four stakeholder groups using a sample activity within each of the four process blocks, on which we demonstrate the differing expectations of the stakeholders from the EHR system.

Schedule / Administer Patient Visit

Administering Patient for Office Visit –

This activity involves confidential medical history retrieval and recording. The information is either retrieved from internal or external (other PCP’s) record system. Patients expect only the required information accessed and retrieved by only those PCP’s who are involved in the
patient’s care. It is critical to comply with information safeguard regulations and provide safeguard measures in a meaningful way upon audit.

- Primary Care Provider (PCP): This process is ideally administered in the EHR system, where PCP availability is managed at multiple locations. This requires that the EHR system works with all physical locations’ internal systems.

- Patient: The patient expects that their records are securely accessed and updated with visit details.

- Administrators: Administrators expect that only the necessary patient health history is accessed by the person scheduling the appointment.

- Auditors: Medical history is entered and stored in an EHR system and retrieved upon authorized access. Auditors assess the access log and ensure that only authorized personnel have access and the medical information amendments are properly logged.

Collect & Review Patient Medical Information (Beck et al., 2012)

*Collect and Integrate Clinical Information - Determination of urgency*–

Determination and act upon urgency is fundamental for proper care, which is not generally part of the primary care patient interaction process, they are usually part of ambulatory visits at urgent care facilities. The current and past health history availability is crucial for PCP’s to make proper judgments. The urgency check list guides and recommends actions, therefore the list need to be maintained and audited.
• Primary Care Provider (PCP): Upon reviewing admission notes or reason for visit, PCP needs to determine the urgency of treatment. For this purpose, PCP needs information available in an accountable manner.

• Patient: Provides accurate description of symptoms, if able to.

• Administrators: To ensure the availability of health history for the PCP, administrators need to enable timely synch and export of data from the practice management software to EHR. The availability of proper and updated information is crucial to treat high urgency cases.

• Auditors: The determination of treatment urgency is aided by the properly updated and presented urgency checks list. It is imperative to have this list audited by auditors and reports of the checks provided in a meaningful format.
Diagnose and Treat Patient (Moser, 2004)

Diagnosis – Analyze and Assess Symptoms and Test Results –

PCP’s assess and analyze the available information and identify the area of concern, while other areas are checked and identified as not affected by patient symptoms. All findings and reasoning are properly documented for auditing purposes.

- Primary Care Provider (PCP): Identifies problem areas based on initial examination. Records findings in medical records.

- Patient: Assists (if able) in condition assessment

- Administrators: Ensure proper and detailed recording of findings.

- Auditors: Audit for reasonably supported problem areas based on supporting facts and findings, auditing decision making aid system if available.

Reporting & Follow Up

Follow-up Care –

Based on patient condition and treatment assigned, follow-up treatment is scheduled usually at the time treatment is received. This follow-up is essential for PCP controlled patient care and reminder needs to be administered and monitored.

- Primary Care Provider (PCP): Medical history and details from previous visit(s) need to be available for PCP’s with access log in case of amendment.
• Patient: Effective EHR systems send follow up reminder to patient.

• Administrators: Reminder is sent to patient and follow-up fulfillment report is generated through EHR systems.

• Auditors: Follow up fulfillment report audit

In the course of the kernel assessment, it has become apparent that the kernel is incomplete. We discovered divergence across stakeholder groups’ needs; therefore, a properly designed EHR system needs to support these divergent needs. This dissertation research will follow methodological steps to discover the kernel level requirements of an EHR system that supports different stakeholder groups across processes. We investigate kernel level requirements across processes as process level requirements would require increased granularity. This, however, increases system customization, which we intend to keep on the kernel level.

3.3 Kernel Theory

Kernel theory enables the formulation of system requirements that fit the problem identified earlier in the design process (Walls et al. 1992, Markus et al. 2002). We define Kernel Theory in a design model as the theoretical foundation from a kernel perspective to govern the design requirements and their embedded characteristics to ensure that the design goals are met.

The identified problem will dictate the objectives of the solution. These objectives need to be specific in regards to how the problem(s) will be eliminated if the objectives are implemented through an artifact creation. These objectives may have theoretical bases that guide the identification of design prerequisites. An overarching theory may support the organizational objectives, but kernel theory supports the understanding of design objectives. While the theory
from natural or social sciences (Walls et al., 1992) or a practitioner theory-in-use (Sarker and Lee 2002) may not help designers to identify the class of goals or the requirements to which it applies, theory from a kernel perspective will help designer to identify the appropriate requirements on the meta level. Since we only specify context on a general degree, the kernel theory can guide the design requirements on a generalized level suitable for a wide range of design solutions. However, the ultimate goal is to limit developers’ options and therefore aim their attention to the requirements.

**Design theory component from relevant literature:**

Kernel Theory (Walls et al. (1992)

**Level:**

System design level

**EHR System Design Steps:**

Stakeholder interaction with an EHR system ranges from simple data entry to data manipulation and retrieval in different contexts and formats to support decision making. Different stakeholder groups interface with the EHR system in different ways. For example, the data input and category update of a physician or a nurse is different from that of an administrator. Unless a designer has a systematic understanding of the methods different stakeholders view, access, update, and interact with the system, it can leave a series of gaps in the system design where the interface might support one stakeholder groups' needs but does not support the needs and expectations of others. System development in a multi-stakeholder context requires the accommodation of the varying needs and objectives of the different user groups that are involved.
in a process; therefore, it has a major implication on the success of information systems implementation (Zhang et al., 2005). While this concept is familiar to researchers (Avison and Wood-Harper, 1990; Darke and Shanks, 1996; Jurison, 1994; Papazafeiropoulou et al., 2002; Pouloudi and Whitley, 1996, 1997), it has been neglected in practice (Jurison, 1994).

We selected alignment theory as the kernel theory of the EHR system design. Understanding the often differing stakeholder needs, the all-encompassing alignment theory can be used at a more micro level from a designer and developer perspective to create a system where the kernel is aligned based on the stakeholder needs. Alignment is the shared understanding and degree of which goals, demands, needs, objectives of one component are consistent of the same of other component within an organization (Nadler and Tushman 1980). The literature provides evidence of alignment being one of the central tenets to improved organizational performance (Beer et al. 2005, Miller 1992, Reich and Benbasat 1996).

In the first essay of this dissertation research we identified four process sequence blocks, which we also used in the kernel assessment. Each process includes different stakeholder groups, that interface with EHR system differently. In a properly designed EHR system these processes conform with certain organizational level requirements to allow stakeholders to use the system to their expectations. In order to meet these stakeholder expectations, the processes need to have proper system features implemented to support the organizational level processes. Since system features encapsulate processes, designers are able to link up the proper system feature with the correct organizational level process. The proper linkage will ensure alignment between stakeholders and system features. Figure 2 displays this link visually:
We previously identified the stakeholders and the activities they performed during the patient-Primary Care Physician (PCP) interaction. Collections of structured and sequential activities represent a group of processes, namely:

- Schedule / Administer Patient Visit
- Collect & Review Patient Medical Information
- Diagnose & Treat Patient
- Reporting & Follow-Up

The above processes need to be supported by proper system characteristics. For example, Schedule / Administer Patient Visit involves all stakeholders. A patient wants their records handled confidentially. Primary Care Physicians need to have the patients’ medical information available prior to administering the patient visit. Administrators must ensure controlled access to patient medical information. Auditors must ensure compliance with regulations in regards to accessing and handling patient medical information that is available within the healthcare organization network and information that is obtained outside of the network.
The identified patient encounter processes are represented by system characteristics, which are encapsulated by system features. These system features must support the needs and objectives of the stakeholders, which satisfies the definition of alignment. The system characteristics and features will be identified through the organizational requirements in the succeeding elements of our design-theoretic model.

3.4 Meta-Requirements

Walls et al. (1992) suggests that meta-requirements should be formed in an abstracted fashion to support the design theory's purpose of solving a class of problems. Therefore, the meta-requirements are still on the meta level, but inferred from the problem identified and are in light of the guidance of the solution objectives, to which the kernel theory is applied. For purposes of this dissertation research, we define meta-requirements as organizational level abstractions that characterize the design features. The organizational level is supported by user oriented representation of objectives without system oriented details given. It is the system-designers’ responsibility to tie in the appropriate system level class of artifacts that will meet these organizational level meta-requirements.

We propose that the linkage between organizational level and system level abstractions is the meta-requirements, which includes the organizational level processes and the very same processes need to be supported by the information system. System features represent processes through characteristics and the subsequent elements of our proposed design-theoretic model will methodically explore what these system features are. Figure 3 visually demonstrates the meta-
requirements as a linkage between the system and organizational level processes.

![Diagram of meta-requirements as a linkage between organizational and system level processes]

*Figure 3. Meta-requirements as a linkage between organizational and system level processes*

**Design Theory component from Walls et al.’s (1992) ISDT:**

Meta-requirements

**Level:**

Organizational

**EHR System Design Steps:**
Walls et al. (2004) highlights the importance of literature and provides examples from existing technology that supports the meta-requirements proposed in their design. We derived the meta-requirements from the kernel theory and the patient-PCP processes identified earlier.

Meta-Requirement #1a: Multi-stakeholder EHR system design must encompass the patient privacy and patient record confidentiality in regards to providing timely and authorized access to the patient medical information.

When a healthcare organization expands or clinical structure changes, the information system needs to be able to handle the additional access request from a variety of stakeholders. It is especially true for an EHR system that shares patient information across different stakeholders within an organization across business units and across organizations through patient care delivery. Granting and auditing the proper access to these increasing number and variety of stakeholder is a major task of healthcare practice administrators and auditors. Access control does not only mean that patient medical information needs to be protected from unauthorized access, but also providing proper access to the right information to the right person(s). For example, a patient almost died in an advanced medical facility with state-of-the-art information system when the nurse was blocked access to the patient’s records to obtain critical medical information or obtain medication from the pharmacy due to a concurrently logged in doctor (Collins, 2009).

Existing research on secure information system design considers security an "afterthought" and little work addresses the fundamental requirements and goals of information system security during system design (Siponen et al. 2006, Mouratidis et al., 2005). EHR systems should not only control physical and system access but also should monitor and audit
workstation use and actions. Administrators ensure the policies and procedures are in place for proper system use and employees are trained properly, but the system design should guarantee further safekeeping by having automatic log-off after certain time of inactivity or ensure that certain job functions can only access the systems from designated work stations. For example, a volunteer should not be able to access any patient information and print jobs should be sent to only properly designated printers at locations where only authorized persons may access the printouts.

Meta-Requirement #1b: Multi-stakeholder EHR system design needs to adhere to compliance requirements that can be tracked and audited internally and externally at any time. Managers must choose a system, which tracks the actions of its users for the purposes of system audits. Siena et al. (2010) stresses the importance of compliance adherence in the healthcare domain during system design and operations through incorporating accountability and auditability and the collection of assigned responsibilities to social and system actors.

The HIPAA Privacy Rule is a federal regulation, which also enables state laws to ensure proper handling of Patient Health Information (PHI). Covered entities, such as health plans and payers, healthcare clearing houses, and healthcare providers share information among themselves and they must ensure that the shared information is handled by the proper safeguarding measures (45 CFR Parts 160 and 164). Entities that improperly handle PHI can be charged under criminal law. For example, providers are required to obtain patient consents before sharing their information with third parties (45 C.F.R. § 164.510 (2008)), require providers to issue privacy notices and details on how patient information are used and shared (45 C.F.R. § 164.520(a) (2008)), and allow patients to access their health records and designate restrictions on their use (45 C.F.R. §§ 164.520, 164.522 (2008)). When a patient record is accessed for non-medical or
non-permissible reasons, it can be classified as breaching the HIPAA Privacy Rules. University of California at Los Angles Health System agreed to pay a significant settlement to two publicly well-known patients when it was proven that the entity employees looked up their medical information on several occasions for non-permissible reasons (HHS.gov, 2011).

Meta-Requirement #2: Multi-stakeholder EHR system design should include user satisfaction through supporting their work functions in an efficient and effective manner and ensuring that information is available for the users to support their work function.

According to Zhang and Walji (2011), an EHR system needs to increase efficiency and productivity, increase ease of use and ease of learning, increase user retention and satisfaction, decrease human errors, decrease development time and cost, and decrease support and training cost. Different stakeholders construe system differently in terms of how it can support their work. PCP’s might want an efficient system so they do not get distracted from talking to patients and they can quickly and efficiently document patient visit notes. Also, PCP’s need medical records available for review to make sound decisions. On the other hand, administrators might want an effective system that appropriately allows proper user access and log useful audit trails. Auditors want a system that they can properly audit for regulatory compliance. Patients need a system, in which they can find their appointment information and can conveniently order refills so that they do not need to make an additional visit or call the practice during the day. Also, patients want their medical records available even if they go to a different provider in a different network. It can reduce costs if retesting can be eliminated by using recent medical information from other providers.
It is recognized that system developers’ perspectives differ from that of users (e.g., Jiang, Klein, & Discenza, 2002; Landauer, 1995). Developers want a well interfaced system or “bug free” software but having the efficient or effective way of achieving a user goal requires specific directions to them. These specific directions stem from the organizational level requirements but system designers need to further define it on the system level.

Meta-Requirement #3: Multi-stakeholder EHR system design needs to account for the disparate health data from the nation's many healthcare organizations and provides and enable the universal exchange and reuse of operational clinical data stored in different EHR systems.

Blobel (2006) proposes a "future-proof EHR system" architectural approach, which could guarantee a scalable, flexible, semantically interoperable, and portable EHR system. The author proposes this approach through the deployment of meta-languages and the separation of platform-independent and platform-specific models.

The patient healthcare delivery process encompasses multiple providers. These providers are not prepared to share information even though they are willing to do so. Chaudhry et al. (2006) found that the majority of providers had custom developed, vendor-driven software that is not designed to share information with other providers’ medical information systems. These systems are mostly designed for internal use and had no ability to connect with other internal systems or external providers found Powner (2005) and Powner & Koontz (2005) in their survey. Even EHRs were found not to interface well with other system (Himmelstein and Woolhandler, 2005). Bates (2005) found that EHR systems in most PCP offices are not designed to handle internal transfer of clinical information, such as lab results or radiology results, which are critical to patient care.
3.5 Meta-Kernel

The actual design of a class of artifacts directly supports the concepts identified in the meta-requirements. For the purposes of this research, we define meta-kernel as a system and design oriented abstraction that defines a process and its embedded characteristics. Meta-kernels further clarify the system requirements to the developers and provide additional details to limit developers’ options and therefore aim their attention to the requirements.

The meta-kernels step in our proposed design-theoretic model is primarily concerned with the identification of the system characteristics that satisfy the organizational level meta-requirements identified in the previous model element. Evaluating the meta-requirements and the literature that supports their needs, we propose that the following meta-kernels will satisfy these organizational level meta-requirements:

- Security / accountability
- Availability
- Portability

<table>
<thead>
<tr>
<th>Meta-kernel</th>
<th>Meta-requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Security/Accountability</td>
<td>Ensure the privacy and integrity of patients medical records and provide timely and authorized access to them.</td>
</tr>
<tr>
<td></td>
<td>Adhere to compliance requirements that can be tracked and audited internally and externally at any time.</td>
</tr>
<tr>
<td>Availability</td>
<td>Support user work functions in an effective an efficient manner.</td>
</tr>
<tr>
<td>Portability</td>
<td>Account for the disparate health data from the nation's many healthcare organizations and provides and enable the universal exchange and reuse of operational clinical data stored in different EHR systems.</td>
</tr>
</tbody>
</table>

Figure 4: Meta-kernels that satisfy the meta-requirements
These meta-kernels represent system characteristics that encompass the processes that stakeholders perform during their job functions. For example, an administrator requires the system to assist the regulatory compliance efforts; therefore, the system must possess characteristics that support this requirement. It is important to note that meta-kernels do not describe the specific feature sets but provide a class of possible features that need to be evaluated based on user needs. Figure 5 visually demonstrates how the meta-kernels fit into the proposed EHR system design through system characteristics.

![Figure 5: Meta-kernels as system characteristics](image)

**Design Theory component from Walls et al.'s (1992) ISDT:**

Meta-kernel

**Level:**

Design level
EHR System Design Steps:

The aim of meta-kernels is to translate the organizational level requirements to system characteristics oriented options, that ensure the right system characteristics.

3.5.1 Security/Accountability

The use of information systems provokes security risks, which may arise from various sources, such as accidental disclosure, internal and external breaches, especially in the age of the Internet (Rindfleisch, 1997). As patient medical information is becoming digitized and transmitted across departments and organizations, patients’ privacy is even more prone to threats (Mercuri, 2004) and new safeguarding measures need to be considered during system design. In his empirical study, Johnson (2009) found a growing trend of “data hemorrhages” in the health sector, which leaves healthcare organizations vulnerable to financial and security threats. The author prompted for better monitoring and information controls to suppress this trend.

An important precursor to proper security design is through the understanding of business objectives and the way information is used across the various business processes (Halliday et al. 1996; Alberts and Dorofee 2003; Suh and Han 2003; ITGI 2005; McAdams 2004). We previously defined the processes that involve multi-stakeholder groups and information sharing across departments and business entities.

System security is exemplified in the healthcare setting. The data hosted is classified as protected health information (PHI), which can be linked to a specific individual. In addition, this information is not only housed within an organization, but also expected to be shared with other healthcare systems through information networks or exchanges. EHR, through its sole purpose,
isexpected to link a number of standalone systems to aid the information sharing across healthcare providers. This prompts for a particularly careful and well-designed security measures within the EHR systems.

Information and privacy concerns within the healthcare sectors received regulatory response through the enactment of HIPAA’s Privacy Rules (2003) and Security Rules (2005). Despite the enactment of the HIPAA Security Rules an AHIMAA survey a year later (2006) only found 25% of the surveyed hospitals to comply with security regulations. This issue is partially organizational change management related that attempts to implement and institutionalize processes that protect medical information (Huston, 2001) in response to emerging regulations. Technology also needs to support the organizational effort of regulatory compliance by providing the features required for the process. The previously identified meta-requirement describes the security part of the security/accountability meta-kernel.

In the context of EHR, privacy breaches or even accidental disclosure of private information to an unauthorized party can cause severe psychological, economic, and social adverse effects for patients (Dimitropoulos et al. 2011, Ancker et al. 2012). Privacy infringements involving EHR happen with disturbing frequency. For example, in 2008 a file was stolen, containing over 2 million patient health and financial information, from a third party hired by the University of Miami Health Systems to manage their data warehousing. Similarly, several thousand University of California San Francisco Medical Center patients’ information was accessible online for three months. It is estimated that several hundreds of thousands of patients become the victim of identity theft each year (Graham 2008).
The U.S. National Information Systems Security Glossary defines "Information Systems Security" as the protection of information systems against unauthorized access to or modification of information, whether in storage, processing or transit, and against the denial of service to authorized users or the provision of service to unauthorized users, including those measures necessary to detect, document, and counter such threats.

Designing and implementing safeguarding measures is a continuous process of identifying potential security risks and implementing countermeasures (Alberts and Dorofee 2003; ISO/IEC 2000; ITGI 2005; NIST 2004). An important precursor to proper security design is through the understanding of business objectives and the way information is used across the various business processes (Halliday et al. 1996; Alberts and Dorofee 2003; Suh and Han 2003; ITGI 2005; McAdams 2004).

The meta-requirement for regulatory compliance translates to the accountability part of the security/accountability meta-kernel. We define accountability as the ability of an EHR system to be able to trace a series of actions and processes performed by one or more users leading to a change in the input, process and/or output. An EHR system that can report all process owners and users with specific duties and their history of specific system-level interactions (including access, input, and reporting) would be an auditable EHR system.

We have previously mentioned examples from the rich literature that theoretically and empirically highlighted the advantages of EHR systems among healthcare organizations. However, the risks and liabilities associated with the use of this complex and important technology, especially in light of the digitization and extensive patient information sharing, received significantly less attention in the EHR systems research. Government control is
warranted through federal regulations, which are designed to ensure safety and quality of EHR systems in addition to state level agency and local clinical guidelines.

In spite of the centrally and locally regulated guidelines, stories have been surfacing that criticize the EHR systems for putting patients at risk. For example, software glitches in the U.S Department of Veterans Health Administration’s EHR system exposed patients to potentially fatal dose of heparin, a blood thinner (Yen, 2009). Another incident resulted in erroneous medical order list and delivered the wrong medication to patients (Cook and O’Connor, 2005) due to problem with the hospital’s pharmacy order system’s incomplete and corrupted backup tape.

The potential that EHR systems enhance healthcare also carry unique responsibilities. The morphing regulations require internal processes and auditing a dynamic environment (Silverman, 2008). HIPAA compliance demands organizations to continuously assess their operational and internal controls within and across departments, business units. Security/accountability functional areas, such as data security (Huston, 2001), availability (Peterson et al., 2005) authentication (Chao et al., 2005), network interfacing (Huston 2001) and disaster recovery processes (Dynes 2009) are need to not only comply with regulations, but also accommodate multi-stakeholder objectives. Furthermore, audit trails need to be properly logged and made available for internal and external auditing and evaluation (Peterson et al., 2005). The appropriate controls and policies need to be implemented for maintaining the proper safeguards of patient medical records (Mercuri, 2004).

The above regulatory obligations necessitate organizations to comply through the technology they choose to implement and use. The design requirements for an EHR system in
regards to regulatory compliance must align appropriately with the meta-requirements previously identified.

### 3.5.2 Availability

Availability in this dissertation research is approached from two different angles: (1) the availability of information that enables users to make sound decisions, and (2) the availability of the system for the users to perform their job function in an effective and efficient manner. The latter approach overlaps with the concept of usability, but coupling with data availability we proceed with a common concept of system availability. In this concept we describe availability as the requirement for users to perform their job function with a system that meets their expectations for usability. Therefore, usability in our research approach is a subset of availability. Usability as a concept in the context of human-computer interaction, has been of interest and center of debates for decades, commencing in the 1980’s, when computers became more prevalent and available to a wider range of user groups (Miller & Thomas 1977, Bennett 1984, Eason, 1984, Shackel 1984 and 1991, Bevan 1995 and 2001, Thomas & Macredie 2002, Hornbaek 2006). Ovaska (2011) defines usability as a goal of software engineers as it is a precursor of software use.

The literature defines usability in a number of ways, mostly driven by the different views on human-computer interaction, such as product-oriented view, user-oriented view, and interaction-oriented or user performance view (Bevan et al. 1991).

The product-oriented-view’s focal point is the ergonomic attributes of the product. For example, the ISO 1991b defines usability as “a set of attributes of software which bear on the effort needed for use and on the individual assessment of such use ...”
The user-oriented view approaches usability from the user’s effort and attitude perspective: “The capability of the software product to be understood, learned, used and attractive to the user, when used under specified conditions.” (ISO/IEC 9126- 1, 2000). Eason (1988) defines usability from the ease-of-use perspective: “the degree to which users are able to use the system with the skills, knowledge, stereotypes and experience they can bring to bear.” The IEEE standard also follows the user-oriented view: “The ease with which a user can learn to operate, prepare inputs for, and interpret outputs of a system or component.” (IEEE Std.610.12-1990)

The interaction-oriented view is the most common (Rengger 1991), where the user’s interaction with the product is the usability quality measure. While the previous views were only usage and user oriented, in this view the contextual orientation emerges, in addition. The multipart ISO 9241 standard (ergonomics of human-computer interaction) contextualizes usability as the extent to which a product can be used by specified users to achieve specified goals with effectiveness (task completion by users), efficiency (task in time) and satisfaction (responded by user in terms of experience) in a specified context of use (users, tasks, equipment & environments). Brooke et al. (1990) and Choefel (2003) adopted this definition when they defined usability as the “effectiveness, efficiency and satisfaction with which specific users can achieve specific sets of tasks in a particular environment”.

Given the amorphous nature of the definition of usability, usability and availability as a perceived trait becomes even more acutely convoluted when considering multiple uses or stakeholders within a particular system. In general, considering the user’s interaction with the
product, we can conclude that system availability is the extent to which goals are achieved with effectiveness, efficiency and a level of satisfaction. However, when different user groups use the same system in different contexts, it is expected that these groups perceive the same system and particular feature differently. Therefore, we tie these system level requirements as a possible solution for the organizational level meta-requirements: multi-stakeholder EHR system design should include the user satisfaction through supporting their work functions in an efficient and effective manner.

The challenge of system availability is that it merely depends on the context a system is used, which define the nature of system characteristics and its attributes. EHR systems are known for their complexity and multiple stakeholder involvement (Ash 2005). Availability is perceived differently by these diverse groups of stakeholders. For example, from a primary healthcare provider’s perspective, availability requires an efficient patient encounter recording and quick access to patient’s medical history. From an administrator’s perspective, availability requires the ability to comply with the regulations, to run custom reports and to ensure meaningful use. From the patients’ perspective, they expect that the primary healthcare provider is aware and be able to access the latest medical history and lab results. From the auditor’s perspective, availability of an EHR system requires the assurance that regulatory compliance (HIPAA, DICOM, Title 21 CFR Part 11) is in place and accessible and properly enforced while stakeholders are using the system.

3.5.3 Portability

Information systems may be used in different environments and on different platforms for the same functional purposes. In order to reduce design and development costs, using the same
source-code is inevitable for a portable system. System designers need to consider the meta-
requirement and they need to account for the disparate health data from the nation's many
healthcare organizations. This would enable providers to universally exchange and reuse
operational and clinical data stored in different EHR systems. We propose that portability and
scalability meta-kernels of an EHR system conform to this meta-requirement.

The National Institute of Standards and Technology (NIST) defines portability as a
software source code which is compilable for a variety of CPUs and platforms and the ease with
which a module can be made to run on another platform. It is especially important for vendors to
consider portability when designing an EHR system due to the variety of platforms hospitals may
use as their operating environment.

Medical practices need to decide whether they want to use a client-server-based systems
or cloud-based platforms. The former is the one, which has been most well known until recent
years, where software was installed on a server. The cloud-based system allows access to
software on a subscription basis but hosted and maintained by the vendor. EHR system designers
need to consider these two major environments and design their software to possibly
accommodate both of them.

A subset of portability is scalability, which has a unique characteristic as a properly
functioning software process (Laitinen et al. 2000) while it is changed in size or volume to meet
its users’ needs. Ross et al. (2008) define scalability simply as the ability to change the level of a
parameter. Scalability is important to be considered in parallel with portability as not only the
platform but also the user base volume is an important characteristic that has a wide range across
medical practices. A small provider’s office with few users need the same features as a large
hospital but probably would chose user based license, which can be expanded as the office grows. Similarly, a larger provider might scale down on certain practices but would want to keep the same EHR system. Also, exchanging patient medical information across other providers can change over time and a scalable system, which is portable or platform independent, can handle these meta-requirements.

3.6 Meta-Design

The meta-design element of our proposed design-theoretic model describes a class of design centric artifacts that meet the design concepts. For example, if availability meta-kernel is chosen for a particular meta-requirement, the availability meta-kernel needs to be evaluated for stakeholder needs. If all stakeholders require an efficient system to support their work function, then the efficiency meta-kernel will be considered by system designers to incorporate into the system design and give specific directions to developers on how to reach it. It could be defined as number of clicks it takes to complete a particular activity by that stakeholder. Another stakeholder might require a different attribute of availability meta-kernel. It is important to note that for the purposes of this research, we delineate the meta-kernels in a context independent setting, which allows greater flexibility to use our proposed design-theoretic model across multiple environments or platform. That is why we approach the system features on the meta-level in our kernel design.

Figure 6 demonstrates the elements of kernel design: meta-kernel and meta-design. Furthermore, the figure indicates how the kernel design gets embedded into a system through characteristics and features.
Figure 6: Kernel designs as system features

Design Theory component from Walls et al.’s (1992) ISDT:

Meta-Design

Level:

Design level

EHR System Design Steps:

The previously identified meta-kernels need to have the proper attributes in order to support the organizational level requirements. Meta-designs represent the system features, which characterize the system meta-characteristics.

Security meta-kernel
A distributed, intra- and inter-organizational system such as EHR stores and shares sensitive medical information and therefore needs to have advanced security and privacy features and organizations need to be held accountable for how their information system receives, stores and shares patient medical information. The HIPAA Security Rule, part of the Privacy Rule, defines the technical, physical and administrative responsibilities to safeguard the confidentiality and integrity of patient health information (45 C.F.R. §§ 164.302–164.318 (2008)).

HIPAA compliance arches beyond the matter of technology. Protection and maintenance of protected patient health information necessitates institutionalization of new structures and processes and possibly organizational change management (Huston 2001) since regulatory compliance and its enforcement creates an ever-shifting environment (Silverman 2008). Compliance with HIPAA mandates continuous cross-departmental and cross-functional internal control assessment of security and network communication (Huston 2001), confidentiality through encryption (Chao et al. 2005), and externally assessable audit trail (Peterson et al. 2005), disaster recovery plans (Dynes 2009) and controlled data access points to ensure data integrity (Mercuri 2004).

Security of information systems have a central objective of protecting the interest of those relying on the information stored within the information system through the assurance of information confidentiality, auditability, responsibility, and data integrity (Avizienis et al. 2004), which are also the measures of security as a system characteristic.

These technical, administrative and physical safeguards of HIPAA security standards aimed to protect the confidentiality and integrity of protected health information while providing opportunity for audits. Following the literature, for the purposes of this research, we propose that
security/accountability meta-kernel consists of the following meta-designs: confidentiality, data integrity, responsibility, and auditability.

3.6.1 Confidentiality

Confidentiality is the disclosure of information only to authorized persons, entities, and processes in the authorized method only at the authorized time. Data confidentiality has been identified as the highest ranked risk factor for both private and public sector (Khalfan 2004). For example, Campbell et al. (2003) among other researchers investigating similar effects (e.g. Kannan et al. (2007), Cavusoglu et al. 2004; Acquisitie et al. 2006; Gatzlaff and McCullough 2010) found in their longitudinal study that unauthorized access to confidential data causes a statistically significant negative impact on firms’ stock market returns.

In healthcare, confidential data breach may cause lawsuits and loss of trust in the technology infrastructure and ultimately in the healthcare organization (Michelman 2009). Compliance to the number of regulations in regards to confidentiality increases the quality of care (Bates, 2002; Ball, 2003) and administrative complexity for the stakeholders (Meingast et al., 2006; Rindfleisch, 1997).

Weitzner and Abelson (2008) suggest that transparency may facilitate the identification of confidential data misuse, which reassure patients on the proper access of their protected health information. However, increased transparency has an adverse effect on confidentiality. Most healthcare providers assign internal patient identification numbers that could lessen the possibility of linking protected health information to patients. However, this approach may demonstrate a serious hindrance in the interoperability of various health information systems and impacts accuracy rates in lining patient records. Network of these systems provide the backbone
of EHR and the information that should be able to follow the patient at the point of care. This example underlines the tension between compliance and practice and the interest of one stakeholder obstructs the work of other. Administrators and auditors ensure the compliance of confidential patient information handling, but this effort increases the data communication complexity.

Secure communication of patient information between providers must provide the mechanism that ensures the confidentiality and integrity of auditable transactions, through multi-authenticated links. Document sharing across providers takes place through standardized IHE cross-enterprise data sharing (XDS), which facilitates the secure registry, distribution and access of patient information. Document storage takes place in the repository, where documents are posted and from where document can be retrieved through document retrieval requests. For quick access, repositories register the document metadata in the registry with a link to the document. Upon a consumer initiated registry, the stored query meets the criteria of a requested document and the document is retrieved from the document repository.

To ensure the proper audit of document access, each nodes of the XDS affinity domain must ensure that an audit and security mechanism is enabled. XDS affinity domains are those healthcare providers that agreed to share information on a common infrastructure, such as EHR.

This short description of data sharing across providers emphasizes the increasing complexity of security with the increase of nodes and patient cross-reference lists. With increasing popularity and productivity of mobile devices in healthcare, comes more risk of data confidentiality as those devices are easier to misplace and more likely targets of theft.
3.6.2 Data Integrity

Information technology outsourcing has been on an upward trend in the past decade. This phenomenon includes the use of third party vendor for services that was provided internally (DiRomualdo and Gurbaxani 1998; Gurbaxani 2007), especially since the increasing popularity of cloud computing (Carmel and Agarwal 2002; Hayes 2008). This approach, however, poses enormous risk on data integrity as it is housed and managed off site by a third party and results in significant loss of control. Therefore, in order to comply with health information regulations, use of third party vendors for patient data storage is on a descend, even though under the HITECH Act of 2009 third-party vendors are directly fined if they are found to knowingly violate the HIPAA privacy and security rule (Brown 2009).

Reliance on data accuracy is imperative in a healthcare setting (Lau 2004). Data integrity provides trustworthy life-saving information for PCP’s. Integrity is the preservation of accuracy and completeness of information (OECD) or prevention of unauthorized modification (Dhillon & Backhouse 2000). Patient identity mistakes are identified as the leading cause of improper treatments causing adverse effects, including death, which is traced to the decentralized healthcare delivery networks (Kohn 1999). Ensuring data integrity, however, goes beyond just system capabilities; the proper, regulated workflow needs to guide the work process.

Protection of data integrity is primarily an IT function. However, it is becoming more and more challenging in the healthcare setting as more internal and external boundaries are removed (Smith et al., 2007) in order to enable information flow to support cross-departmental and cross-enterprise collaboration.
Information flow across healthcare organizations and functional departments involve numerous groups of stakeholders with different levels of data dependencies. Patients must be reassured that their protected health information has not been altered by anyone knowingly or unknowingly. Data integrity is central to patient trust in the healthcare organization. Patients’ trust can be increased if a script from their visit is shared or read-only access is given to them. While this increases trust, the data confidentiality might be put at risk as remote patient log-in might increase the probability of stolen passwords. Patient data entry must be limited to the time of patient interaction, which is also recorded in the audit trail and in the metadata. This process leaves PCP’s with the drudgery of entering all details of patient encounter, coming up with diagnosis and treatment plan within the time allocated for the patient-PCP interaction. It might leave patient with the perception that PCP is more interested in filling out forms on the computer rather than listening to their description of health status. In the same time, doctors feel their efficiency is decreased due to the increased time of this process. Previously, handwritten notes or voice recorded dictations were handed over for translating services to enter the details electronically, mostly on a word processing program in free form text.

Administrators and auditors have deep interest in the proper documentation of patient encounter at the time of patient visit to ensure data integrity. The audit trail contains details on the user who created the encounter documentation and diagnosis with proper time stamp and other metadata information. Any alteration of information outside of patient encounter can be traced back to the user and fail the compliance audit.

Intentional or unintentional access to EHR can be limited by controlled stage access. This could be stakeholder role based ownership control and designated workstation access permission. For example, management could not only view and print but also edit patient information when
required. In case staff needs to access a patient’s record, designated workstations could reduce the risk of unauthorized access. If patient information needs to be edited, staff level user should have management approval, which is also recorded in the audit trail.

Organizations need to implement adequate privacy policies that ensure appropriate controls at all data access points to maintain data integrity (Mercuri, 2004) and system designers need to ensure these controls are available as system features.

3.6.3 Responsibility

For purposes of this research, responsibility is a system-level property that assigns ownership and control of one or more EHR policy and system-level processes. For example, an EHR system that can establish one or more parties in changing of the patient order entry process would signal process-level responsibility for the EHR system. While accountability examines a system's ability to accurately specify users who input and read from an EHR system, responsibility examines whether a system has a dedicated process owner who serves as a trustworthy gatekeeper, regardless of the number of users accessing the system. Thus, EHR responsibility allows the process owner to create various policies for various users with different degrees of accountability.

3.6.4 Auditability

For purposes of this research, auditability is the ability of an EHR system to be able to trace a series of actions and processes performed by one or more users leading to a change in the input, process and/or output. An EHR system that can report all process owners and users with
specific duties and their history of specific system-level interactions (including access, input, reporting) would be an auditable EHR system.

We previously elaborated on the importance and effects of responsibility and auditability as an attribute of the security/accountability meta-kernel.

*Portability meta-kernel*

Information systems need to adapt to changing demands of their users through platform independence while allowing for shared operating processes. In a healthcare setting, real-time medical information should be shared across different platforms and systems, which is an extremely important design consideration for EHR systems. We propose the following Portability/Scalability meta-kernel characteristics to consider these system requirements: interoperability, interconnectedness, transparency.

3.6.5 Interoperability

Primary healthcare providers can make more educated decision if more up-to-date information is available for them (Bates et al., 2001; Tange et al., 2006). Information sharing and the need for up-to-date information in the healthcare environment have always been demanded but only in the recent years has is started to become a reality. Enabling interoperability among healthcare systems and especially in EHR system is vital to achieve this system feature. Interoperability represents the ability of systems to exchange information for operational use (IEEE, 2013). Interoperability is defined by ISO (ISO TC 215, ISO/TR 20514, 2005) as “the ability of two or more applications being able to communicate in an effective manner without compromising the content of the transmitted EHR”. For our research, we define interoperability
as the ability of an EHR system to connect with other systems in order to provide an EHR service. For example, the ability to connect with and receive real-time information from a public database of disease breakouts is vital for a healthcare institution. While access to such information might have been previously available, we argue the importance of this database to be connected directly to the EHR system to warn PCP’s when identifiable symptoms are entered.

An EHR system should be able to interface with various types of databases and read various types of file formats. While it is important how data is entered, managed and displayed with an EHR system, the proper transition and sharing of this data is the interoperability foundation of an EHR system. The international standard for EHR interoperability (ISO 13606) provides details for the interoperability among heterogeneous and legacy systems. ISO 13808 provides the requirements, not the specifications, for an EHR architecture that supports using, sharing and exchanging patient medical information as electronic health records across entities, health sectors and modes of healthcare delivery.

While the Health Level 7 (HL7) Clinical Document Architecture (CDA) is a generic message structure for individual clinical document-exchange, the previously mentioned ISO 13606 has broader architecture formalism. System designers need to consider the interoperability standards beyond the federally regulated requirements as healthcare organizations have growing demand for equity of access and real time, quality information. In addition to sharing meaningful medical data and the integration and safe use of protocols and alerts, EHR interoperability should also enable patient access to educational materials and engage patients and their families.
System designers need to ensure that proper standards are used for connecting systems and properly choose the appropriate ones. Currently there are multiple standards available for different purposes:

- **HL7** – health informatics interoperability for clinical data exchange
- **HL7 CDA (Clinical Document Architecture)** – XML based clinical document (e.g. discharge notes) exchange model
- **HL7 CCD (Continuity of Care Document)** – Patient information snapshot delivery to the next step in patient care (CCR defined data)
- **CCR (Continuity of Care Record)** – Clinician and patient accessible transportable set of basic patient health information
- **ELINCS (EHR-Lab Interoperability and Connectivity Specifications)** – standards for lab result reporting
- **IS**
- **EHR Vendors** – Data fields are defined for their proprietary applications

Depending on the type of information and communication, the standards may vary. The proper EHR design should also consider a standard interface that is used across multiple products but map to the proper fields in the EHR. Industry specific interoperability standards are detailed in the Healthcare Information Technology Standards Panel (HITSP), which encompasses Interoperability Standards (01-158) for information exchange and standards for data accuracy and system capabilities. For example, IS 01 is the Electronic Health Records Laboratory Results Reporting Interoperability Specification (IS), which defines specific standards to support the interoperability between electronic health records and laboratory systems. In addition it defines
standards for secure access to laboratory results and interpretations in a patient-centric manner (hitsp.org). This IS provides guidance on how to integrate existing standards for specific requirements. Following the guidelines provided for the organizational level requirements and for the meta-kernels ensures that the IS actors and actions are considered in the context required for proper interactions. For example, business actors could be the EHR system, the laboratory, data repository, patient locator services, and action may be the received laboratory result integrity check. The interoperability requirement, therefore, may be a confirmation from the EHR system that laboratory results were received in a complete and unchanged format (HITSP.org). Notifications to clinicians in regards to available lab results require information to pass from the laboratory system to the patient locator service and to the EHR system. These interconnected healthcare systems must properly communicate and transfer information in order to fulfill the organizational level requirements.

While interconnectedness is an attribute for portability, it is only operational in a healthcare environment if security concerns are truly considered during the system design. Dimitropoulos & Risk (2009) found that interoperable systems of health information exchange (HIE) are challenged by organizational-level practices, policies, local and federal laws that govern the privacy and security of protected patient medical information. They recommend that organizations agree on a common set of widely shared policies as healthcare stakeholders were concerned of losing patient information while exchanging data. Non-standardized systems that exchange information put sensitive information at risk and uniform identification of patients, auditable security of data is needed during transmission or at rest (Jhnson & Appari, 2008).

We recommend that system designers break down the matching and mapping among systems and the integration definitions are standardized using HITSP healthcare standards.
3.6.6 Interconnectedness

Systems interconnectivity offers benefits such as reduced operating cost, improved efficiency, greater functionality, and centralized data access. NIST defines interconnectivity as the direct connection of two or more systems for the purpose of data and information resources sharing. For purposes of this research, interconnectedness is defined as the number of systems that are connected together with the EHR system to provide an EHR service. Providers often must make decisions without access to complete up-to-date patient health history, to which a connected EHR system have potential remedy (Kohn, 1999; Leape, Bates, & Culen, 1995).

Stakeholders might need data from different resources to meet the demand of high quality and sustainable care in a distributed healthcare environment. Using the previous example from HITSP interoperability standards for clinician laboratory order request and receiving the result requires the following interconnected systems: EHR system, laboratory systems, locator services, data repository. These four systems are involved from the time clinician places a lab order and until the results are sent back. The proper interfacing standards and authentication logs are captured for audit purposes that administrators and auditors need to use to ensure that data is transferred across these systems with authenticity and integrity. Figure 7 displays a simplified route of laboratory result integration into EHR. Of course, system actions, such as confirmation of receipt, validation of data, log receipt, parsing, and exception list are not indicated among other mandatory system steps while communicating information.
### 3.6.7 Transparency

For purposes of this research, transparency is defined as the ability of a system to seamlessly integrate multiple system-level operations and processes such that a user does not feel that one or more independent systems and processes are interconnected to provide them a service. For example, a transparent EHR system can seamlessly integrate with multiple independent drug-databases over the cloud and pull the information in real-time without the physician feeling a sense of lag or requiring separate sign-ons.

Multiple sources of information require the ability of a system to “translate” identifiers that are used for the record as aliases. System level design specification needs to include such actor to create, maintain and provide a list of patient identifier cross reference entities. It will ensure that patient information will be properly referenced when requested in a different format. For example, laboratory services might know the patient record as an internal patient ID, however, when previous results are being queried from the data repository, the locator services indexed a previous ID, which was assigned by a different campus on a different system. Also,

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**Figure 7: Clinician Laboratory Order Request - System Interconnectedness (HITSP.org)**

<table>
<thead>
<tr>
<th>Event</th>
<th>EHR systems</th>
<th>Laboratory Systems</th>
<th>Locator Services</th>
<th>Data Repository</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process Lab Order</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transmit test results to</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ordering physician</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Notify locator service of</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>result (send result location)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>for lab test result location</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>indexing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
the patient might schedule an appointment using his or her social security number. These identifiers need to be cross referenced among each other in order to refer to the same patient.

Transparency ensures that multiple systems provide information while the user experiences a single-system use (Razi et al. 2009). In the background, however, information is queried and provided across multiple internal or external databases. If the user is not required to log into another system, we consider it highly transparent system integration. On the contrary, if a user is aware that he or she is being redirected to another system and in addition the user is required to separately log into this/these additional system/s, we consider that system integration low transparent.

While transparency enhances user experience, the audit log captures the details of each system access and the information requested or entered/modified. This is especially important when a user is able to access multiple systems with a single sign-on and system level design requirement is the proper role based security profile and access and action privileges.

\textit{Availability meta-kernel}

“Build it and they will come”, a phrase used to describe a utopian product development standpoint portraying the unnecessary effort of meeting user need. Of course, it is rarely the case with information systems as the offering of technology continues to progress in a rapid rate. Users do not only expect an easy-to-learn and easy-to-use system, but also it is expected that technology aids users’ productivity. Since we proposed applying usability as a subset of availability meta-kernel, we will accept Dix et al.’s (1993) and Nielsen et al.’s (1994) attributes of usability: effectiveness, efficiency, satisfaction and learnability (see Figure 8), for the purposes of this research. However, we will propose the former three as part of availability meta-
designs. We decide to not include learnability for two reasons: (1) it is highly subjective attribute and with a robust system such as EHR, resistance of change may be an influential factor that is difficult to account for when measuring a system’s usability, (2) it is omitted in most technical definitions, such as Standard ISO 9241, which defines software usability as: software is usable when it allows the user to execute his task effectively, efficiently and with satisfaction in the specified context of use.

This standard provides answers to the following questions with regards to usability attribute measurements:

- Effectiveness: How well can a user goal be achieved through the system use?
- Efficiency: What resources are consumed while achieving these goals?
- Satisfaction: How do users feel about the system they use to achieve their goal?

In our meta-designs, we recommend solutions to common healthcare system usability concerns, such as:

- Eliminate the need for duplicate entries by cross populating screens in problem lists and progress notes while checking for data validity.
- The system should easily allow visual integration of a problem with a particular clinical event (lab result, imaging, medication… etc.)
- Recording a new problem should follow logical steps and require minimal number of clicks while providing straightforward and familiar terminology and directions.
3.6.8 Effectiveness

Effectiveness as an attribute of usability is defined as “the accuracy and completeness with which specified users can achieve specified goals in particular environments” (ISO 9241). In the context of the information systems, we can define effectiveness as the degree to which an interface facilitates users in accomplishing their tasks and goals. This definition encompasses Hamilton and Chervany’s (1981) goal centered view in regards to how well the objectives are
achieved. They measure effectiveness on the use process and user performance. Effectiveness of an information system is also viewed as the precursor of system use and satisfaction (Srinivasan 1985, Bailey and Pearson 1983, Cheney et al. 1986, Igbaria 1990). In an EHR system, effectiveness can be measured by the “success rate” or “task completion rate”. For example, how well a new patient profile or lab order can be created in EHR is measured by the system effectiveness. Success rate measures the task accomplishment percentage, while task completion can be measured per unit. Success must be defined to establish benchmark for the system effectiveness, which affects usability. This could be a defined end point that needs to be reached, such as the confirmation page.

The system design should anticipate user path-deviation and have integrated checks for them. For example, a user in the belief that he or she completed a task, but did it incorrectly, the system should identify it as error, based on built in path-deviation checks. For example, if a healthcare practitioner (HCP) orders an incorrect drug for a patient, the system should check for the previous entries of symptoms, diagnoses, drug history and allergies. If the ordered drug does not support the patient and illness parameters, it should raise a flag. Therefore, drug order should not be allowed in a free text field, rather in a drop down controlled query format.

The above example of built-in error checks are only possible through a pre-set cognitive workflow, where the information entry is in a sequential order. This methodology will most likely not meet most HCP’s way of documenting patient encounter and ordering prescriptions. Therefore, this method might be perceived as a hindrance on the HCP’s efficiency, but it will be effective by reaching the set goal of prescribing the proper medication without any (or significantly reduced) error rate. The learning curve of a new workflow might be significant; therefore, the design should closely follow the standard methodology of patient encounter.
This same example from the administrator’s perspective allows them to administer the meaningful use of the system’s core objectives, such as record demographics, vital signs, smoking status, drug interaction check, active medication list, etc. Administrators will also have an easy visibility on audit-trail of a patient encounter with system generated audit log.

Patients benefit from this process by ensuring of increased safety. However, they might perceive this computerized order entry during their visit disruptive from their interaction with the HCP. In addition, patients might perceive that their protected health information is outside of their control and they might perceive decreased transparency. Allowing patients to access the audit log and give consent might reduce their concern on this manner.

Following the controlled query driven workflow allows auditors to have a simplified audit process to ensure compliance.

The above example of a system feature use highlights how different stakeholders perceive and are affected by the same system characteristic.

3.6.9 Efficiency

Efficiency refers to ratio of output divided by input and grew out of the economic discipline. Previous researches suggest that efficiency is a major part of usable and useful technology (Davis 1989, 1993; Venkatesh 2000, Venkatesh et al. 2002). The definition of efficiency identifies the rate or speed in addition to the effectiveness. The ISO definition emphasize the resources needed for task completion: “the resources expended in relation to the accuracy and completeness of goals achieved”. In addition to minimized resource, such as time, the consistency of responses is also an important measure of efficiency. These elements are also
central to determine one’s productivity; therefore, being efficient is necessary for being productive.

In order to measure efficiency, a dependent variable, such as time, must be operationalized, which can be consistently and reliably measured, therefore, help to identify inefficient processes. In the context of EHR, an efficient use of the system consists of successfully reaching a goal in the least amount of steps. Therefore, system design needs to enable users to follow a basic, optimal path, and opportunities for deviations are limited.

Recording patient’s breathing problem, for example, is stemmed from a predefined problem list under symptoms/problems. Selecting the breathing problem symptom should open up possible descriptions of the problem instead of a free form text box, where the PCP enters “painful respiration”, for example. Selecting a pre-defined symptom allows the PCP to codify the patient’s words and the system remind the PCP to ask for status, severity, certainty, etc. This might hinder the PCP’s efficiency by clicking and finding the proper codified version of the patient’s description. However, linking the clinical codes to the description forces the PCP to deliberate and consider the possible other options the system provides on a granular level, while narrowing the symptom list. This increases patient safety and the effectiveness of treatment identified. While selecting from the available symptoms in a drop-down menu may not be as fast as writing down few words, it can match the efficiency once the learning curve passes.

The order of operation matters in terms of audit trail, therefore the audit log helps administrators and auditors with the audit process. Since PCP’s cannot proceed from a screen until all designated health checks are completed, it greatly increases the success from the audit perspective, on the other hand, it might decrease efficiency. The patient feels that a thorough
check is performed since all symptom-related questions will be asked and recorded. Even a mistaken click will be checked by cross validation to ensure that the input is lined up with the previous entries.

Similar to effectiveness, patients, administrators and auditors perceive efficiency of an EHR system differently, which results in different level of value recognition.

3.6.10 Satisfaction

Numerous studies have proved that satisfaction of system users is a key component to IS success (Szajna & Scamell 1993, Al-Khaldi & Wallace 1999, DeLone and McLean 1992). End user satisfaction is also suggested to be a deciding factor on software choice with relatively similar features (Henderson et al. 1995). Measuring satisfaction includes subjective measures such as the user’s individual perception on usability and acceptability: “the comfort and acceptability of the work system to its users and other people affected by its use” (ISO 9241).

There are several software usability measures developed where users can input their subjective assessment on usability based on their satisfaction. The System Usability Scale (SUS) has received positive recognition and been applied by a number of researchers (Brooke 1996, Lewis and Sauro 2009). Other such method is the Software Usability Measurement Inventory, which requires “Agree”, “Don’t Know”, or “Disagree” input from users on 50 subjective statements.

User satisfaction in a healthcare setting is imperative for implementation success (Murrf and Kannry 2001, Van Der Meijden et al. 2003) and failures are also often associated with unsatisfied users (Lawler et al. 1996, Massare 1993). EHR often replaces paper and pencil PCP
notes, which requires an enormous adjustment within the new workflow of care. Many healthcare professionals view this change as obstruction to their work and decreased productivity (Chin and McClure 1995, Chin and Krall 1997, Tiemey et al. 1993). This disruption is difficult to overcome in a high-pressure workplace, where time is a scarce resource and a new EHR system may be perceived as inefficient.

Administrators might share the frustration of PCP when inconsistent or missing data shows up in the EHR system, therefore the compliance and reporting efforts are inadequate. Similarly, auditors will not find the audit process valuable if PCP’s are working around the system due to low satisfaction rate. Low satisfaction of the system will most likely lead to low usage and the information in the system will be of no value. Patient satisfaction largely depends on the information included in the system and if PCP’s does not enter the notes directly in the system, the patients will lose trust that the notes might be incorrectly entered later on, perhaps by another person.

On the other hand, proper training and incremental implementation of an effective and efficient system will increase the likelihood of satisfied users. Satisfaction largely depends on the system and information quality (DeLone and McLean, 1992); therefore, a properly designed quality system needs to be implemented that supports user operation with minimal disruption.

3.6.11 Data Availability

Organizational information resources house enormous amount of data, including sensitive customer and corporate information, especially in the healthcare industry (Houston 2001). In addition to safeguarding this data from unauthorized access, availability of data is critical for sound decision making (David 2002, Bakersville & Siponen 2002).
Availability ensures the accessibility and usability of data, information, information systems on a timely basis in the required manner (OECD) or simply the prevention of unauthorized withholding of data or resources (Dillon & Backhouse 2000). The 44 U.S.C., Sec. 3542 also includes the timely use of data “Ensuring timely and reliable access to and use of information”.

One of the greatest benefits of EHR is the real-time data availability through the integration of other healthcare systems. This collection of health information is of utmost importance for PCP’s to provide quality care. However, this collection of information raises patients’ concern of unauthorized access (Anderson 1995, 1996). While the HIPAA Privacy Rule (45 C.F.R. § 164.510 (2008)) ensures that patient consent is needed to share their information with third party, in an emergency situation, in order to save patient’s life, such permission is overruled. For example, if an unconscious patient is brought into the emergency care, even if accompanied by a relative, quick access to information such as whether the patient has hypertension or taking blood thinner can mean the difference between saving or losing the patient. Such situations require confidentiality risk over limited data availability (Lovis et al. 2006).

Multi-stakeholder involvement in patient care requires data availability to a variety of functional groups. Patients recognize the value of information systems in primary care (Ornstein & Bearden 1994, Ridsdale & Hudd 1994); however, they express their worries about the availability of their health history to employees working in the system and the insurance companies.
Availability of patient health information decreases the needs to duplicate lab works, in case a patient visits a PCP outside of her previous provider’s network. This eliminates unnecessary financial and time burden for the patients. PCP’s can bring confident decisions and EHR can ensure that PCP’s, who are involved in a patient’s care base their decisions on uniform sets of data. Administrators need to ensure that the care organization’s EHR system has the up-to-date patient information at the time of patient care and it is traceable for compliance purposes. In addition, a healthcare organization’s administrator needs to put forward the required safety measures to ensure that patient information entered at the place of care is only accessible by PCP’s who are part of the continued care only, besides emergency circumstances. Auditors need to be able to audit the system for safeguard measures concerning patient health information communication with the only required providers. Ensuring proper data availability may require implementing measures such as authentication and interoperability checks and data standards implementation (Win et al. 2002).

Data availability to the right person at the right time requires tight-fitting connection between data communication and application security services. Measures for mutual authentication processes can ensure that only the appropriate stakeholder access the information with accountability on the use of patient health information. Information availability to insurance firms is inevitable on a certain level due to billing purposes. However, patients often face the dilemma of disclosing more details of their medical history in order to get a better quote for premiums. In this case, the disclosure is voluntary.

3.7 7. Kernel Exposition

Proposed Extension to Walls et al.’s (1992) ISDT:
Kernel Exposition

The final element of our design-theoretic model is the kernel exposition. For purposes of this research, we define kernel exposition as a context independent implementation logic that validates the design goal and the artifact. In order to see whether the artifact solves the problem identified on the organizational level, include it in an activity where the designed artifact features are tested against the problem. This element is the formal evaluation of the artifact through implementation parameters to help IS managers to simplify the implementation logic regardless of content.

Level:

Organizational and System Level

This element is on the organizational and design level since the system is connected with the business needs and proposes the benefit to the organization. The literature has similar elements but none of the existing works are on both the organizational and system level. Hevner et al. (2004) define this element in their design science research guidelines as “effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies.” Walls et al. (1992) similarly concentrates on system level validation in their testable hypothesis element of their ISDT: “used to test whether the meta-design satisfies the meta-requirements”. Gregor and Jones (2007) mainly focused on the artifact implementation rather than the organizational impact in their eight components of design theory: “A physical implementation of the artefact that can assist in representing the theory both as an expository device and for purposes of testing.”
3.7.1 Theoretical Base: Expectation-confirmation theory

There are number of theories that explain the role of expectations. For purposes of kernel exposition we use expectation-confirmation theory (ECT) (Oliver 1980). ECT posits that post-purchase satisfaction is greatly dependent on how the perceived performance is coupled with the expectation one put in a product. Satisfaction is greatly dependent on the moderating effect of positive or negative disconfirmation between the expectation and the actual performance (Spreng et al 1996, Oliver 1980). Unmet expectations result in disappointment and conversely, when experience meets or exceeds expectations will result in satisfaction, which is greatly dependent on the disconfirmation of expectations. Various domains utilized expectations confirmation theory (Kotter, 1973, Robinson, 1996, Wanous, 1992) and numerous studies confirmed the theories’ assumptions (e.g. Cardozo, 1965; Cohen and Goldberg, 1970; Phillips, 1998).

In the context of EHR system design, we use the expectation-confirmation theory in regards to the kernel exposition objectives: experiment, observe, evaluate. During our questionnaire to professionals, we requested their perceived importance of certain EHR system features and we also requested their perceived satisfaction with this feature. The higher negative correlation between importance and satisfaction indicated greater level of disappointment (disconfirmed expectation), since their expectation was not met while the feature was deemed to be important. This observation of users’ perception of system feature provided us with an opportunity to evaluate the system they currently use and recommend enhancements to system designers at the exact point of where users expectations are not met, therefore left them dissatisfied with a particular system feature.
In the next sections we will propose a model that supports the kernel exposition’s artifact validation. We develop hypotheses and using empirical data, we will validate the model and hypotheses on a pooled and on each of the stakeholder role levels.
Chapter 4:

Model Development and Hypotheses

After the detailed introduction of meta-kernels and meta-designs, we construct a model that helps us establish the relationship between the meta-characteristics (meta-kernel) and the openness to frequently using (OTU) a healthcare system based on expectations of satisfaction with that system characteristic. For this purpose, we refer to the first essay of this dissertation research, where we described the data collection and the factor extraction to identify the three groups that represent the items loaded under them using principal component method. Therefore, for Openness to Frequent Use (OTU) based on expectations of satisfaction with existing EHR characteristics, we will consider the following three factors:

- Confidentiality
- Usability
- Portability

For the satisfaction with an existing system characteristic, we will consider the system characteristics we identified as meta-kernels, namely:

- Security/accountability
- Availability
- Portability

In the next chapter of this dissertation research, we will identify the system features that are loading under each system characteristic, using principal component method. That will confirm
whether we suggested the proper system feature under the corresponding system characteristic during our meta-design sections (meta-kernel and meta-design) of our design-theoretic model. For the purposes of this dissertation research, we investigate the effect of satisfaction on the openness to frequently using an EHR system based on expectations of satisfaction. Since we collected data on user satisfaction with existing healthcare system features, we will attempt to establish the theoretic link to the openness to use based on expectations of satisfaction with existing EHR characteristics that represent the features in question. These linkages will be abstracted in the model and represented through hypotheses and we will confirm or reject them using the data collected.

Figure 9 depicts the model we propose and hypotheses with their suggested direction of effects. The professionals to whom we administered our questionnaire were asked to base their experience on existing healthcare system features, not only on EHR systems. The reason for this is twofold: (1) EHR systems are not widely implemented, it is the ultimate goal of healthcare industry based on President Bush’s Executive Order of 2004; (2) we propose a design for EHR systems utilizing the design theory, based on the shortcomings of existing healthcare systems. We use empirical evidence to support the shortcomings of and need for certain system level features and their collective representations: system characteristics. Hence, our hypotheses will use the term ‘EHR system’.
4.1 Availability and Portability (H1 & H2)

In the previous section we covered in detail what meta-designs represent system availability and portability. Now we establish the association between these two meta-characteristics based on how users may perceive the portability system characteristic based on system availability.

Stakeholders, who require information shared across different systems to support their job function, have expectations towards portability system characteristic (meta-kernel). If the expectations are met, users are satisfied with data portability. Since data portability is a collective
representation of different system features (meta-designs), such as interconnectivity and interconnectedness, users expect that these features are represented to their expectation of satisfaction.

The safeguarding measures of patient medical information is crucial because of its considerable economic, social and psychological harm to individuals if it is accessed by unauthorized party(ies) (Dimitropoulos et al. 2011, Ancker et al. 2012). With distributed health networks and patient care, pooling data into a central repository to increase data availability is an important part to support sound decision making for proper care (Bates et al., 2001; Tange et al., 2006). However, healthcare system users who need this information quickly for proper diagnosis and treatment plan, are intolerant for cumbersome security measures to access the repository from their primary healthcare system. Therefore, data availability needs to come with a balance between providing the right information to the right person at the right time without the burden of multi-step validation procedures across multiple information systems where the information is located.

Interconnected healthcare systems need to be interoperable with each other especially because of the multiple file format in which they store information. While front-end users don’t experience the portability of the system they use directly, they assess portability based on data availability (Padhy et al. 2011).

In a healthcare organization, stakeholders need supporting information available while they may or may not be aware that the data they retrieve is pooled from internal or external repository(ies). Satisfaction with data portability is directly related to data availability, since stakeholders measure their satisfaction based on whether or not they receive the required
information. Therefore, we posit that increased satisfaction with data availability leads to increased satisfaction with data portability for stakeholders in a healthcare organization.

*Hypothesis 1: Satisfaction with availability is positively associated with satisfaction with portability.*

The openness to frequently using a healthcare system is based on whether it satisfies certain expectations of its users. It can be tied back to whether or not that feature is important for the user. For example, in a multi-stakeholder context, one stakeholder group might prefer a system feature, while the other group prefers a different one to support their job function. However, they agree that the collective representation of similar system features, the system characteristic representing those features, is important for all of them. In particular, patients might prefer that their medical information from other healthcare systems are available to the doctor during the review of relevant information, so that they do not have to retake tests or having the risk of improper diagnosis due to missed information about the patient’s prior health records. On the other hand, doctors may want information from other systems of similar conditions, so that they can assess patterns and treatment options. However, they both agree that portability is important for them in order to be open to use a healthcare system if it meets their expectations of satisfaction with the portability system feature.

Dissatisfaction with a system characteristic impacts the use of the system. DeLone and McLean’s widely cited work, the IS Success Model (1992) also confirms that system use is dependent on the satisfaction with the system. Therefore, if a system provides the required features to the expected satisfaction, a user group is more likely to use it. It is especially true if the user group is satisfied and the feature is important to support their job function. For example,
if PCP’s are concerned about not having their patient’s medical records available for review, therefore dissatisfied with portability, it signals that this system characteristic is important for them but less likely will use a system that exhibits portability meta-characteristics that is perceived unsatisfactory. In turn, providing a healthcare system that meets the PCP’s expectations of satisfaction with portability meta-characteristic will likely result in the usage of that system. We, therefore suggest that the decrease in satisfaction of a meta-characteristic will increase the likelihood of a system use if that characteristic performs to the expected satisfaction of the users, given that the feature is important to the user. We assume that decrease in satisfaction is correlated with a level of importance, which in turn suggests openness to use if expectations of satisfaction are met. Therefore, we hypothesize:

Hypothesis 2: Decrease in satisfaction with portability will increase the likelihood of the openness to frequent use (OTU) of an EHR system based on met expectations of satisfaction with portability.

4.2 Security/Accountability and Confidentiality (H3)

Digitized patient medical records are stored and shared across departments and patient’s privacy is more prone to threats (Mercuri 2004). The importance and challenges healthcare organizations face in regards to security and accountability has been detailed in the meta-kernel section of this dissertation research. Here, we establish the connection between satisfaction or dissatisfaction with security/accountability and the openness to frequent use of a healthcare system if user expectations of satisfaction with confidentiality are met.

The security/accountability construct shares their indicators with OTU confidentiality; therefore we posit that they have an effect on each other. For example, it is essential that auditors
and administrators explore methods and establish policies that protect the confidentiality of
patients’ medical records in an accountable manner (Walker et al. 2008). In order to enforce and
audit such policies, they need a support system that requires users to obey them. The importance
of such meta-characteristic of a healthcare system may be demonstrated with the lack of
satisfaction and it is shown that use of an information system is directly related to the satisfaction
with it (DeLone & McLean 1992). Consecutively, to increase the openness to frequent use of a
healthcare information system, such as EHR, largely depends on whether or not users may
expect that it will perform to their expected level of satisfaction. In regards to security and
accountability, a decrease in satisfaction assumes importance and the openness to frequent use of
a healthcare information system depends on whether users expectations of satisfaction is
confirmed through the confidentiality meta-characteristic of the system. Hence, we posit:

_Hypothesis 3: Decrease in satisfaction with security/accountability will increase the likelihood of
the OTU of an EHR system based on met expectation of satisfaction with confidentiality._

4.3 Portability and Usability (H4)

As we previously discussed, interconnectivity and connectedness of systems to provide the
information necessary is suggested to drive the openness to use a system based on portability
meta-characteristic. The question arises: would users consider a system usable if it meets their
expectations of satisfaction with portability? While portability offers connection to other
systems, a user may believe that it helps with their tasks in an efficient and effective manner.
This is measured with the observed variables of portability and usability, we propose that:
Hypothesis 4: Increase in OTU of an EHR system based on met expectations of satisfaction with portability will increase the likelihood of OTU of an EHR system based on met expectations of satisfaction with usability.

4.4 Confidentiality and Usability (H5)

Openness to use a system based on the expectations of satisfaction with confidentiality is measured by auditability, responsibility, confidentiality, and data integrity. These system features, however obstruct system usability perceived by users (Yen and Bakken 2012). It might be the result that strict and compliant security measures make the system difficult to continuously use without interruption. For example, doctors criticized their healthcare system’s usability due to the fact that they had to swipe their security badge overly frequently or they got logged out of the system while reviewing patient information (personal interview in March, 2014). This process level protection of confidentiality conforms to internal and external policies, but disrupts workflow and reduces the usability of the system, therefore we hypothesize:

Hypothesis 5: Increase in OTU of an EHR system based on met expectations of satisfaction with confidentiality will decrease the likelihood of OTU of an EHR system based on met expectations of satisfaction with usability.

4.5 Stakeholder Role as moderator (H6)

As Dorr et al. (2007) found, EHR system designs lack multi-stakeholder support. The varying stakeholder expectations based on their work functions and objectives drive their needs differently for system features and was reviewed in detail in the first part of this dissertation.
research. We will, therefore, propose the stakeholder role to be a moderator on the relationships among system characteristics and the expectations of satisfaction with system characteristics. The varying stakeholder preferences drive the needs for different features and their use in different processes (Ravichadran and Rai 2000, Hirscheim & Klein 1994). Hence, we propose:

Hypothesis 6: Stakeholder role moderates the relationship between EHR meta-kernel characteristics and openness to use the same meta-kernel characteristic.
Chapter 5:  

Instrument Development  

5.1.1 Kernel exposition unit of analysis

The characteristics and features of information systems are of unequal importance to different user groups. Some features are used by one group while not by another, since they often represent customized, user group dictated needs. However, the information system characteristics are the collective representations of needs across multi-stakeholder groups. Identifying the underlying characteristics, which represent the system features that satisfy all stakeholders, is crucial for a successful EHR system implementation.

We will confirm through principal component analysis that certain system features are grouped under a common system characteristic (Carr, 1992; Gorsuch, 1983). These characteristics that represent a group of system features may have some relationship to each other based on expectation of satisfaction with the particular characteristics. Furthermore, these characteristics may have an effect on the openness to use the EHR system. We are investigating the relationship between EHR system characteristics and openness to use a system if certain characteristics meet users’ expectations of satisfaction with that characteristic.

Revisiting the data from the first essay of this dissertation research provides the basis for our kernel exposition. We collected the perceived importance of and satisfaction with healthcare information system features across processes from healthcare professionals and from patients with experience with healthcare systems. While we discovered the gap between importance and
satisfaction in our first part of this dissertation research, this part will discover the *expectation of satisfaction* with certain system features.

The correlation matrix of indicators displays a predominantly negative and statistically significant correlation between importance of and satisfaction with the same feature within the same process. This indicates the level of dissatisfaction with a particular system feature as increase in perceived system feature importance will have decrease in perceived satisfaction. For example, Table 2 displays the accountability meta-kernel’s meta-designs and their indicators. (For full correlation matrix across all meta-kernels and meta-designs, please see Appendix A). Stakeholder responses suggest that their expected satisfaction for the responsibility system feature (meta-design) requirement is important and their perceived satisfaction is lacking that expectation. Similarly, they reported that their satisfaction falls short of their expectation, which is reflected in the meta-design importance-satisfaction correlation matrix.
Table 2: Importance and Satisfaction Correlation Matrix

The negative correlation between importance and satisfaction surfaces the exact point of system level granularity within EHR system characteristics and features where users find the system lacking their expectations. It also helps to identify the non-value added cost that could negatively impact organization-wide openness to frequently using an EHR system across stakeholder groups. A negative correlation highlights a “much needed” understanding of the dissatisfaction of users with particular system features across the entire patient flow process on a granular level.

In order to properly measure the designed artifacts, we retain the items that measure stakeholders’ satisfaction of the meta-design. Stakeholders were asked to rate their perceived satisfaction with the same meta-design across the four major processes of patient flow: (1) Scheduling patient visit, (2) Reviewing patient medical records, (3) Diagnosing and treating
patients, (4) Reporting and Follow-Up. While the identified eleven meta-designs were measured in the questionnaire across the four processes, we plan to retain only those items that are grouped together and exhibit a statistically supported underlying structure.

5.1.2 Data Reduction and Validation

Respondents were asked to identify their perception of satisfaction with healthcare system features across patient flow processes. The 44 indicators included eleven meta-designs that we described in the meta-design section of the Design-theoretic Model across the four patient flow processes. We utilized factor analysis in SPSS version 22 for Windows to identify the “intercorrelated” observed indicators, which load under a common factor (Field, 2000: 424). We employed principal component analysis (PCA) method to extract the factors, and followed it with a varimax (orthogonal) rotation (Gorsuch, 1983: 205). The interrelationship among variables is best studied through factor analysis, which includes a variety of correlational analyses (Carr, 1992; Gorsuch, 1983). A section of the descriptive statistics of the indicators is presented in Table 3 below, the entire table can be found in Appendix A due to its size.

<table>
<thead>
<tr>
<th>Meta-kernel</th>
<th>Meta-Requirement</th>
<th>Process</th>
<th>Mean</th>
<th>SD</th>
<th>Variance</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Security/Accountability</td>
<td>Confidentiality</td>
<td>Scheduling</td>
<td>3.5180</td>
<td>0.936</td>
<td>0.874</td>
<td>-0.275</td>
</tr>
<tr>
<td>2</td>
<td>Security/Accountability</td>
<td>Confidentiality</td>
<td>Review</td>
<td>3.4350</td>
<td>0.926</td>
<td>0.858</td>
<td>-0.058</td>
</tr>
<tr>
<td>3</td>
<td>Security/Accountability</td>
<td>Confidentiality</td>
<td>Diagnosis</td>
<td>3.2280</td>
<td>1.007</td>
<td>1.014</td>
<td>-0.041</td>
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<tr>
<td>4</td>
<td>Security/Accountability</td>
<td>Confidentiality</td>
<td>Report</td>
<td>3.3890</td>
<td>0.942</td>
<td>0.888</td>
<td>-0.051</td>
</tr>
<tr>
<td>5</td>
<td>Security/Accountability</td>
<td>Integrity</td>
<td>Scheduling</td>
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</tr>
<tr>
<td>6</td>
<td>Security/Accountability</td>
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<td>Review</td>
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<td>0.730</td>
<td>-0.094</td>
</tr>
<tr>
<td>7</td>
<td>Security/Accountability</td>
<td>Integrity</td>
<td>Diagnosis</td>
<td>3.5060</td>
<td>0.920</td>
<td>0.862</td>
<td>-0.086</td>
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<tr>
<td>8</td>
<td>Security/Accountability</td>
<td>Integrity</td>
<td>Report</td>
<td>3.5650</td>
<td>0.996</td>
<td>0.990</td>
<td>-0.257</td>
</tr>
</tbody>
</table>

Table 3: Descriptive statistics and correlation matrix for the indicator variables

Testing for multicollinearity, we employed the Bartlett’s test of sphericity ($\chi^2$ (55) = 881.13, p<0.001), which indicated that principal component analysis (PCA) was adequate for the data, the correlation matrix, in fact, is not an identity matrix. The Kaiser-Myer-Olkin (KMO)
measure of sampling adequacy is a high value of 0.858. This indicates that the data will factor well as the items will be able to be grouped into a smaller set of underlying factors.

We selected three factors to extract due to the fact that we have three meta-kernels that the factor indicators were meant to measure. Factors with scores of >0.6 were retained in accordance with Hair et al (2010). The reliability statistics (Cronbach’s alpha) is 0.866, which indicates a high level of internal consistency for our scale and exceeds the recommended 0.7 value (DeVellis, 2003; Kline, 2005).

Construct validity evidence of self-reporting satisfaction with meta-kernels is supported as items loaded together measuring the same constructs, which we labeled as security/accountability, portability, and availability (see Table 4.).

<table>
<thead>
<tr>
<th>observed indicators</th>
<th>Factors</th>
<th>Security/Accountability</th>
<th>Portability</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auditability</td>
<td>A_Au_S_4</td>
<td>.616</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Responsibility</td>
<td>A_Fl_S_1</td>
<td>.631</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Responsibility</td>
<td>A_Fl_S_4</td>
<td>.653</td>
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<td>A_Au_S_3</td>
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<td></td>
<td></td>
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<td>Responsibility</td>
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<td></td>
<td></td>
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<td>Responsibility</td>
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<td>.591</td>
<td></td>
</tr>
<tr>
<td>Confidentiality</td>
<td>S_C_S_4</td>
<td>.609</td>
<td>.613</td>
<td>.617</td>
</tr>
<tr>
<td>Interconnectedness</td>
<td>P_Lc_S_4</td>
<td></td>
<td>.617</td>
<td></td>
</tr>
<tr>
<td>Interconnectedness</td>
<td>P_Lc_S_2</td>
<td></td>
<td></td>
<td>.619</td>
</tr>
<tr>
<td>Interconnectedness</td>
<td>P_Lc_S_3</td>
<td></td>
<td></td>
<td>.624</td>
</tr>
<tr>
<td>Interoperability</td>
<td>P_Lc_S_1</td>
<td></td>
<td></td>
<td>.668</td>
</tr>
<tr>
<td>Interoperability</td>
<td>P_Lc_S_2</td>
<td></td>
<td></td>
<td>.673</td>
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<tr>
<td>Interoperability</td>
<td>P_Lc_S_3</td>
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<td></td>
<td>.673</td>
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<tr>
<td>Availability</td>
<td>S_A_S_2</td>
<td></td>
<td></td>
<td>.706</td>
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<tr>
<td>Availability</td>
<td>S_A_S_3</td>
<td></td>
<td></td>
<td>.686</td>
</tr>
<tr>
<td>Efficiency</td>
<td>U_Ec_S_3</td>
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<td></td>
<td>.673</td>
</tr>
<tr>
<td>Availability</td>
<td>S_A_S_4</td>
<td></td>
<td></td>
<td>.593</td>
</tr>
</tbody>
</table>

Table 4: Indicator loadings for the latent independent variables
A scree test and eigenvalues also suggested 18 factors indicators with face validity. Seven items loaded in the first factor that we labeled after the meta-kernel, on which the conjointly loaded items suggested to measure the perceived satisfaction: security/accountability. The items are (1) responsibility during all four patient flow process, (2) auditability during diagnosis/treatment and reporting processes, and (4) confidentiality during reporting. These observed variables describe the expected satisfaction with security/accountability of an existing healthcare information system.

Similarly, seven items loaded on the second factor that we labeled portability due to the communality in its factor indicators: (1) interconnectedness during all four patient flow processes, and (2) interoperability during reviewing patient medical information, diagnosing and treating patient, and reporting and follow-up processes.

The third factor we labeled availability and the following four factor indicators loaded on it: (1) data availability during reviewing patient medical history, diagnosing and treating patient, and reporting and follow up processes; (2) efficiency during diagnosing and treating patient flow process.

The three factors and their indicators support our meta-kernel and meta-design part of our Design-theoretic Model.

Once the point of dissatisfactions are identified, it is imperative to surface the magnitude of the impact between the satisfaction of existing system characteristics & features and consequential openness to frequently use the aforementioned characteristics and features that lie at the core of any EHR investment.
5.2 Dependent variables

Our EHR design perspective uses stakeholders’ openness to use (OTU) based on expected satisfaction of specific EHR meta-kernels. Openness to use is defined as the willingness of a stakeholder to engage in frequent use of EHR meta-kernels.

For the purposes of this dissertation research we attempt to correspond OTU to specific EHR meta-kernels namely:

- OTU based on expectations of portability
- OTU based on expectations of confidentiality
- OTU based on expectations of overall usability

The indicators of the above three dependent variables have been grouped using principal component analysis in SPSS and the details can be found in the first essay of this dissertation research. The factor indicators are observed through the questionnaire administered to healthcare professionals and patients who have experience using healthcare information systems.

5.2.1 OTU Based on Expectations of Confidentiality/Accountability

Openness to use based on expectations of confidentiality/accountability is defined for the purposes of this dissertation research as the willingness of a stakeholder to engage in frequent use of an EHR system because it meets their expectation of the system’s confidentiality/accountability meta-kernel.

The factor indicators for OTU based on expectations of confidentiality/accountability consist of: (1) responsibility, (2) integrity, (3) confidentiality, (4) auditability. These indicators
collectively measure the expectations stakeholders have for a system to meet their needs for confidentiality/accountability in order to more frequently use it.

5.2.2 OTU Based on Expectations of Usability

Openness to use based on expectations of usability is defined for the purposes of this dissertation research as the willingness of a stakeholder to engage in frequent use of an EHR system because it meets their expectation of the system’s usability meta-kernel.

The factor indicators for OTU based on expectations of usability consist of: (1) effectiveness, (2) efficiency, (3) satisfaction, (4) transparency. These indicators collectively measure the expectations stakeholders have for a system to meet their needs for usability in order to more frequently use it.

5.2.3 OTU Based on Expectations of Portability

Openness to use based on expectations of portability is defined for the purposes of this dissertation research as the willingness of a stakeholder to engage in frequent use of an EHR system because it meets their expectation of the system’s portability meta-kernel.

The factor indicators for OTU based on expectations of Portability consist of: (1) interconnectivity, (2) interconnectedness. These indicators collectively measure the expectations stakeholders have for a system to meet their needs for portability in order to more frequently use it.
5.3 Independent Variables

For the purposes of this dissertation research, we view the perception of satisfaction with a certain healthcare system feature based on its perceived importance as an indicator of current system usage. Consequently, we hypothesize that if meta-kernels fall short of users’ expectations, they will find workarounds or abandon the system.

We collected perceived satisfaction with current system features (meta-designs) and factored the ‘inter-correlated’ items together in the earlier ‘Data Reduction and Validation’ section. The three independent variables, therefore, are: (1) availability, (2) portability, and (3) security/accountability.

In the next chapter, we empirically validate the hypothesized relationship between the latent variables.
Chapter 6:

Model Validation & Results

In our dissertation research the constructs were measured by reflective indicators and we used AMOS software for Structural Equation Modeling (SEM) to test our hypotheses. All constructs have multiple indicators as we deduced from the questionnaire items earlier.

Model Fit: We retained the unstandardized estimates as recommended for variables with unequal variance (Kline 2010) and earlier the Levene’s test failed to confirm the null hypothesis that states that the groups have equal variances. Composite reliability and average variance extracted cannot be dependably computed as those values use standardized values. We take the factor loading statistical significance, chi-square values significance and root-mean-square error of approximation along with GFI to ensure that the data fits our proposed model.

The root-mean-square error of approximation (RMSEA) is 0.67 which is above the recommended 0.05 (Browne & Cudeck, 1993) and indicates an acceptable error of approximation. The goodness of fit (GFI) is 0.853, which is above the recommended 0.8 value (Baumgartner & Hombur, 1996), and also above the permissible level of 0.7 in certain model complexity and sample size combinations (Hair et al. 1998), which we agree that the sample size is not optimal (N=168) with the number of indicators we use in this model (k=28). The Chi-square test yields a value of $\chi^2=686.7$ (df=345), $P<0.001$, which does not reject the null hypothesis of an overall good fit.

Independent variables of the overall model across all stakeholders
The path estimates are displayed and the critical ratios are statistically significant (P<0.001) in the measurement model of the independent variables. We deduced the items to keep in the measurement model earlier in this dissertation research.

Satisfaction with security/accountability of existing healthcare systems is best indicated by responsibility when diagnosing and treating patient, and scheduling patient as their estimate loadings are 1.297 and 1.226, respectively. Auditability is also a good indicator during diagnosis and treatment of a patient process. The highest loadings reveal that stakeholders together expect more responsibility meta-design to be present in a system during the above processes.

Satisfaction with portability of existing healthcare systems is best indicated by interoperability during the patient medical history review process and interconnectedness during the same patient flow process. This indicates that stakeholders find meta-design of a system most important during diagnosis and treatment in regards to system portability. The dependence of data availability is clearly explained by the fact that relevant medical information during diagnosis and treatment is inevitable through interconnected systems and stakeholders expect more in regards to this meta-kernel.

Satisfaction with availability of existing healthcare systems is best indicated by data availability during diagnosis and treatment, and reviewing patient medical history. It is in line with the expectations of “the right information at the right time for the right person” as indicated by the other two constructs’ factor loadings. Stakeholders collectively expect that a system has data available during the review of patient medical history and diagnosis and treatment, but not satisfied with the current feature in existing information systems.
Table 5: Estimate loadings of the independent variables in the measurement model

Measurement model loadings of the dependent variables across all stakeholders

The path estimates are displayed and the critical ratios are statistically significant (P<0.001) in the measurement model of the dependent variables. We deduced the items to keep in the measurement model in the first part of this dissertation research.

OTU based on expectation of satisfaction with usability of EHR systems is best indicated by satisfaction and transparency, their estimate loadings are 1.47 and 1.226, respectively. These indicators properly represent the stakeholders’ expectation of satisfaction with these features as they are open to frequently use a system if it is built to their satisfaction and the externally connected databases seamlessly provide access to data. It is aligned with the expectations of satisfaction with data availability as well.

OTU based on expectation of satisfaction with confidentiality of EHR systems is best indicated by auditability and confidentiality with estimate loadings of 1.02 and 1.005.
Stakeholders are expected to be satisfied with a system that exhibits higher level of auditability and confidentiality.

OTU based on expectation of satisfaction with portability of EHR systems is best indicated by interconnectedness. Stakeholders expected to be satisfied with a system that is connected to other databases and system, and that is aligned with the lack of satisfaction of this system feature.

### Table 6: Estimate loadings of the dependent variables in the measurement model

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Indicators</th>
<th>Estimates</th>
<th>S.E.</th>
<th>C.R.</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>OTU Usability</td>
<td>Efficiency</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Effectiveness</td>
<td>1.02</td>
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<td></td>
<td>Transparency</td>
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<td>0.168</td>
<td>7.281</td>
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</tr>
<tr>
<td></td>
<td>Satisfaction</td>
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<td>0.18</td>
<td>8.155</td>
<td>***</td>
</tr>
<tr>
<td>OTU Confidentiality</td>
<td>Confidentiality</td>
<td>1.005</td>
<td>0.092</td>
<td>10.945</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>Integrity</td>
<td>1.02</td>
<td>0.096</td>
<td>10.641</td>
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</tr>
<tr>
<td></td>
<td>Responsibility</td>
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<td>0.084</td>
<td>11.242</td>
<td>***</td>
</tr>
<tr>
<td>OTU Portability</td>
<td>Interoperability</td>
<td>1.304</td>
<td>0.153</td>
<td>8.532</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>Interconnection</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Table 6: Estimate loadings of the dependent variables in the measurement model*

**Structural model estimate loadings of the latent (unobserved) variables**

All path estimates of the latent variables loaded statistically significantly (p<0.001, except p<0.05 for availability to portability). The associations of the latent variables are indicated through the estimates direction and magnitude. The corresponding hypotheses are reviewed whether or not the loadings support them. Table 7 provides a summary of the estimate loadings and the hypotheses confirmation.
Table 7: Estimate loadings of the dependent variables in the structural model

<table>
<thead>
<tr>
<th>Construct</th>
<th>Construct</th>
<th>Hypothesis → supported?</th>
<th>Estimates</th>
<th>S.E.</th>
<th>C.R.</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability</td>
<td>Portability</td>
<td>H1 → YES</td>
<td>0.185</td>
<td>0.091</td>
<td>2.052</td>
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</tr>
<tr>
<td>Portability</td>
<td>OTU_P ortability</td>
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<td>0.145</td>
<td>-3.32</td>
<td>***</td>
</tr>
<tr>
<td>Security /</td>
<td>Accountability</td>
<td>H3 → YES</td>
<td>-0.662</td>
<td>0.144</td>
<td>-4.59</td>
<td>***</td>
</tr>
<tr>
<td>OTU_P ortability</td>
<td>OTU_U sability</td>
<td>H4 → YES</td>
<td>0.73</td>
<td>0.104</td>
<td>7.056</td>
<td>***</td>
</tr>
<tr>
<td>OTU_C onfidentiality</td>
<td>OTU_U sability</td>
<td>H5 → YES</td>
<td>-0.114</td>
<td>0.092</td>
<td>10.945</td>
<td>***</td>
</tr>
</tbody>
</table>

Hypothesis 1:

Satisfaction with availability of existing healthcare systems is an important tenet across stakeholders. Patients want their medical records available when calling to schedule, so no delay is necessary while provider’s office collects the latest medical records from other providers. Furthermore, it can be cost saving as well, as redundant tests will not be necessary if a recent result is sufficient. Providers need data availability while reviewing patient medical history and diagnosing. Administrators and auditors need data availability especially for reporting and auditing purposes.

Data availability itself is important but it is expected to be portable as well, else the availability is limited. The path loading of 0.186 across all stakeholders supports the hypothesis and can be generalized that satisfaction with availability of EHR systems is positively associated with satisfaction with portability of EHR systems.

Hypothesis 2:
Portability is a construct that is measuring the satisfaction with interconnectedness and interoperability. As previously deduced, all stakeholders have a great interest in access to information from outside of the main system, especially if patient records are needed from other providers/systems.

The importance-satisfaction correlation matrix indicated predominantly negative correlations between importance and satisfaction. Openness to use a healthcare system if portability meets users’ expectation is reflected by importance. Therefore, the negative correlation between satisfaction with portability and the openness to use a system if portability meets users’ expectation is reflected with a negative association between the two constructs. The -0.481 factor loading confirms this negative association and we can conclude that stakeholders collectively find a system more appealing if a feature, with which they are currently dissatisfied is designed to support their needs.

**Hypothesis 3:**

Satisfaction with security and accountability reflects users’ perceptions of existing system’s capabilities in regards to auditability, responsibility, and confidentiality. These system level meta-designs represent the protection of privacy of a patient and the accountable retrieval and modification of such sensitive information. Patients are concerned that their medical information might be accessed by unauthorized parties, while doctors are held accountable for their actions with patient’s information. Audit trails include detailed information about the access of patient information and administrators ensure that proper role-based security access is in place. Auditors want to have available access logs and other audit trail information, on which they can run reports to ensure proper security is in place in an accountable manner.
Openness to use a healthcare information system based on the expectation of satisfaction with confidentiality has very similar indicators to security/accountability. Therefore, we can assume that stakeholders, who are dissatisfied with the security/accountability system feature, will likely be willing to use a system if it meets their expectations of confidentiality.

The negative association between satisfaction with security/accountability of an EHR system and the openness to use a healthcare system based on expectation of satisfaction with confidentiality, if this feature meets user expectation confirms our second hypothesis. The more dissatisfied a stakeholder is with the security/accountability system feature, the more important that feature it is for their job function. Consequently, they are more open to use a system (such as EHR) if that system represents security/accountability to their satisfaction.

*Hypothesis 4:*

Portability of a system also reflects its ability to retrieve information from outside systems. When information about a patient is urgently needed, quick access to such data could avoid delay in providing proper treatment and consequently save the patient’s life. Therefore, it is not surprising that stakeholders collectively deem a system usable if portability meets their expectations of satisfaction. The factor estimate of 0.73 reflects this positive association and confirms our fourth hypothesis.

*Hypothesis 5: OTU based on expectations of satisfaction with confidentiality is negatively related to OTU based on expectations of satisfaction with usability.*

Protecting sensitive information requires proper security measures within an information system. Besides the back-end security, the front-end or user side is also affected. When a system
requires multiple log-ins and reconfirming of authority by re-swiping access card or re-entering password every 30 seconds may increase security but reduce user positive experience with such system.

Therefore, we hypothesized that increased expectations of satisfaction with confidentiality reduced the openness to use a healthcare system based on expectations of satisfaction with usability. The negative factor loading of -0.114 lends support to this hypothesis and establishes the inverse relation between these two variables.

Hypothesis 6: Stakeholder role moderates the relationship between EHR meta-kernel characteristics and openness to use the based on the expectations of satisfaction of same meta-kernel characteristic.

While the full model considered the stakeholders collectively, we hypothesized that stakeholder roles moderates the relationship between EHR meta-kernel characteristics and openness to use the same meta-kernel characteristic. We argue that there is a difference between system features across processes based on the role the stakeholders represent.

While the full model was examined for all previous hypotheses, we will break down the model into sections to test each hypothesis separately and investigate whether stakeholder role changes the factor loadings and the direction and magnitude of loading estimates between the latent variables. Another reason for breaking down the model is the limited sample size we have for each stakeholder groups.
Even though the reduced models had smaller sample size, they exhibited better GFI than the overall model, most of them had GFI>0.9 and RMSEA <0.7. All reduced models had statistically significant Chi-square test (p<0.001)

The hypothesis only called for stakeholder role moderation between meta kernels (characteristics) and the OTU based on the expectation of satisfaction with the same meta-kernel but we will investigate whether stakeholder role moderates the other latent variable relationships as well.

_Stakeholder role as moderator (H6) for Hypothesis 1_

The overall model exhibited proper fit (GFI > 0.9) and the estimates were statistically significant (P<0.001). Satisfaction with availability of existing healthcare systems is positively associated with satisfaction with portability of existing healthcare systems is confirmed with a factor loading of 0.22. Below, the figure displays the highest factor loadings (highlighted) for all stakeholders collectively and for each stakeholder separately.

The highest factor loading for satisfaction with availability of existing healthcare systems have a variation across stakeholder groups. While patients and administrators exhibit interconnectedness during diagnosing and treating patient process as the most important indicator, PCP’s find interoperability during reviewing patient medical history to be the best indicator of satisfaction with portability of an existing healthcare system. This indicator is also the best for across all stakeholder groups. Auditors find interconnectedness to be the best indicator during the same process.
While there is a degree of variation in regards to highest estimates across stakeholder groups, the direction of path coefficients stayed the same, therefore, indicating positive association between satisfaction with availability of existing healthcare systems and satisfaction with portability of existing healthcare systems. Patients exhibited the strongest path coefficient and PCP’s the weakest. This signals that patients feel better cared for if all of their medical history is accessible and available at the time of their care, while PCP’s seem not to associate data availability with system portability that closely. They seem to trust the internally available data and not rely on external accessibility.

It could be grounds of further investigation why PCP’s don’t correlate data availability with connectivity with other systems.

<table>
<thead>
<tr>
<th>H1 - Satisfaction with availability is positively associated with satisfaction with portability.</th>
<th>All stakeholders</th>
<th>Patients</th>
<th>PCP’s</th>
<th>Admins</th>
<th>Auditors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constructs</td>
<td>Indicators</td>
<td>Patient Flow Process</td>
<td>Estimates</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portability</td>
<td>Interconnectedness</td>
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<td>0.22</td>
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<td>Interconnectedness</td>
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<td>0.84</td>
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<td>Interconnectedness</td>
<td>Diagnosing and treating patient</td>
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<td>0.96</td>
<td>0.38</td>
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<tr>
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<td>Interconnectedness</td>
<td>Reporting and follow-up</td>
<td>0.87</td>
<td>0.83</td>
<td>0.39</td>
</tr>
<tr>
<td></td>
<td>Interoperability</td>
<td>Scheduling patient visit</td>
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<td>Interoperability</td>
<td>Reviewing patient medical history</td>
<td>1.09</td>
<td>0.94</td>
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</tr>
<tr>
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<td>Interoperability</td>
<td>Diagnosing and treating patient</td>
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<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Availability</td>
<td>Data Availability</td>
<td>Reviewing patient medical history</td>
<td>1.31</td>
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</tr>
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<td>Data Availability</td>
<td>Diagnosing and treating patient</td>
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</tr>
<tr>
<td></td>
<td>Data Availability</td>
<td>Reporting and follow-up</td>
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<td>2.02</td>
<td>1.24</td>
</tr>
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<td>Efficiency</td>
<td>Diagnosing and treating patient</td>
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<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Availability -&gt; Portability</td>
<td></td>
<td></td>
<td>0.22</td>
<td>1.59</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Table 8: The moderation effect of stakeholder role on the relationship between portability and availability

**Stakeholder role as moderator (H6) for Hypothesis 2**

The factor loadings of satisfaction with portability of existing healthcare systems slightly vary across stakeholders groups. PCP’s responses indicated that the best indicator of satisfaction
with portability is interoperability during reviewing patient medical records, which is the same as the best indicator of all stakeholders’ responses collectively. PCP’s need access to patient information while reviewing patient medical records.

Patients’ and administrators’ responses imply interconnectedness during diagnosis and treatment the strongest indicator for satisfaction with portability. They want to ensure that the diagnosis and treatment is based on all available information to limit the possibility for improper diagnosis and treatment due to lack of information. Auditors’ responses indicate that interconnectedness during reviewing patient medical history is best indicator for satisfaction with portability.

The negative correlation between satisfaction with availability of existing healthcare systems and OTU based on expectation of satisfaction with portability is confirmed across all stakeholders. Auditors have the strongest negative path coefficient, which may indicate that their dissatisfaction with portability of an existing healthcare system has the greatest effect on their openness to use a system (such as EHR) if portability satisfies their needs. It can further be concluded that importance of portability system feature is rated the highest among auditor stakeholder groups. We argue that it is due to reporting reasons, since auditors want to ensure that they have access to all auditable information across all systems within their practice.

The lowest loadings for patients (path coefficient of -0.09) may be due to the fact that patients did not rate portability of high importance. Therefore, their level of dissatisfaction is not significant and they are not indicating that they are more open to use a system if their expectation
of satisfaction with portability meets their expectations.

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Indicators</th>
<th>Patient Flow Process</th>
<th>Estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portability</td>
<td>Scheduling patient visit</td>
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</tr>
<tr>
<td></td>
<td>Reviewing patient medical history</td>
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<td>Reporting and follow-up</td>
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<td></td>
<td>Interoperability</td>
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<tr>
<td>OTU_Portability</td>
<td>Interoperability</td>
<td>0.87</td>
<td>1.53</td>
</tr>
</tbody>
</table>

Table 9: The moderation effect of stakeholder role on the relationship between portability and OTU_portability

Stakeholder role as moderator (H6) for Hypothesis 3

Patients’ and auditors’ responses reveal that auditability during diagnosis and treating patients is the strongest indicator for satisfaction with security/accountability of an existing healthcare system. They both want to ensure that it can be traced back who accessed or updated patient records and auditability system feature ensures this.

PCP’s and administrators share the concern that patient records are laying around, computer screens left open on hallway where other employees and patients walk through. Their responses indicate that the best indicator for satisfaction with security/accountability of an existing healthcare system is responsibility during reviewing patient medical records and diagnosing / treating patients.
The hypothesized negative association between satisfaction with security/accountability of existing healthcare systems and the OTU based on expectation of satisfaction with confidentiality of existing healthcare system, if security/accountability meets users’ expectations is confirmed across all stakeholders. The strongest negative path coefficient is represented by administrators; they indicate that they would very likely be open to use a system if it meets their need of security/accountability. It can be concluded that they are not satisfied with security/accountability in their current system and they deem this system characteristic very important. Therefore, administrators are looking for this feature in a healthcare system (such as EHR) in order for them to use it.

On the other hand, the lowest level of coefficient among PCP’s seem to indicate that they rated this feature as not important (importance rating $\bar{x}$ for PCP’s = 2.9 vs. administrators’ $\bar{x}$ = 4.3), therefore they are not likely to be open to using a healthcare system that exhibits this system characteristics.

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Indicators</th>
<th>Patient Flow Process</th>
<th>All stakeholders</th>
<th>Patients</th>
<th>PCP’s</th>
<th>Admins</th>
<th>Auditors</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>

|$H3$ - Decrease in satisfaction with security/accountability will increase the likelihood of the OTU of an EHR system based on met expectation of satisfaction with confidentiality.

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Indicators</th>
<th>Estimates</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>Integrity</td>
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<tr>
<td></td>
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</tr>
<tr>
<td></td>
<td>Audibility</td>
<td>0.97</td>
</tr>
</tbody>
</table>

Table 10: The moderation effect of stakeholder role on the relationship between security/accountability and OTU_confidentiality
Stakeholder role as moderator (H6) for Hypothesis 4

System usability has different perceptions across user groups (Jiang, Klein, & Discenza, 2002) and even within user groups as managers seem to be less concerned about this system characteristic (Morris and Dillon 1996). In a healthcare information system, openness to use based on expectations of satisfaction with usability is best indicated by transparency according to responses by all stakeholder groups but patients. It allows us to argue that while stakeholders in the healthcare organization have to access multiple information systems with possibly different software and log-on credentials, patients usually access their portal and they are not facing the inconvenience of multiple log-on requests across systems. Patients responses indicated satisfaction as the best indicator for openness to use a system based on expectations of satisfaction with usability, which probably translates to the granularity of information they are able to access and the extent to which they are able to use the system to manage their care. It is important to realize that patients use a very different depth and breadth (even though they should have access to all their medical records (Annas 2003) it remains to the discretion of healthcare provider (Reti et al. 2010)) of information and the extent they can use the system is much more limited than that of users within the healthcare organization.

Administrators’ path coefficient is the strongest (0.71), which suggests that if they are open to use a healthcare information system based on their expectations of satisfaction with portability, they are more likely to be open to use the system based on their expectation of satisfaction with usability. In short, portability system characteristic is an indicator of usability for administrators as they will be able to ensure that the other stakeholders get their work done effectively and efficiently and reducing the error rate if they have access to external systems.
Conversely, PCP’s openness to use a healthcare information system based on satisfaction with portability is lesser of an indicator whether they are open to use a system if it meets their expectations of usability.

**Table 11: The moderation effect of stakeholder role on the relationship between OTU_portability and OTU_usability**

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Indicators</th>
<th>All stakeholders</th>
<th>Patients</th>
<th>PCP’s</th>
<th>Admins</th>
<th>Auditors</th>
</tr>
</thead>
<tbody>
<tr>
<td>OTU_Protability</td>
<td>Interconnectedness</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Interoperability</td>
<td>0.72</td>
<td>4.69</td>
<td>0.28</td>
<td>0.71</td>
<td>0.74</td>
</tr>
<tr>
<td>OTU_Usability</td>
<td>Efficiency</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Effectiveness</td>
<td>1.06</td>
<td>0.87</td>
<td>1.84</td>
<td>1.22</td>
<td>0.69</td>
</tr>
<tr>
<td></td>
<td>Satisfaction</td>
<td>1.04</td>
<td>2.01</td>
<td>0.59</td>
<td>0.9</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>Transparency</td>
<td>1.37</td>
<td>2.43</td>
<td>2.65</td>
<td>1.22</td>
<td>1.2</td>
</tr>
</tbody>
</table>

**Stakeholder role as moderator (H6) for Hypothesis 5**

The strongest indicator of openness to use a healthcare information system based on expectations of satisfactions with confidentiality seems to be responsibility for all stakeholder groups but for auditors, whose answers suggest that the best indicator is confidentiality. It suggests that most stakeholder groups find it important that users of an information system are ensured that a dedicated process owner is in place to ensure proper policies are in place.

Somewhat surprising that the auditors’ responses did not result in responsibility being the strongest indicator for OTU based on expectations of satisfaction with confidentiality. The strongest indicator is confidentiality, which may be because auditability’s path coefficient has been fixed during model validation and it might have been the actual strongest indicator.
The strongest indicators of openness to use a system based on expectations of satisfaction with usability seems to be different for almost all stakeholder groups. Patients reveal that satisfaction is the best indicator of whether they are open to use a system. It is understandable as patients most likely will only use limited functionalities and they want to have an easy to understand user interface. PCPS’ answers suggest that effectiveness is the strongest indicator, which can be explained by the fact that they have limited time with the patient and they want an effective user interface that captures the relevant information properly. Administrators’ and auditors’ answers indicate that transparency is the strongest indicator whether they are open to use a system based on expectations of satisfaction with usability. Since these two stakeholder groups are running reports, they want to have relatively simple access to information across multiple systems without constant log in and credibility checks.

The path coefficients reveal an interesting, yet expected difference in the direction among stakeholder groups. While patients and PCP’s indicated that they are less likely to find a system usable if it is satisfying their requirements of confidentiality, administrators and auditors expressed the contrary by indicating that they are only considering a system usable if it satisfies the expectations of confidentiality. This can be understood by knowing that while patients and PCP’s understand the importance of confidentiality, they do not feel that it is positively correlated with usability as it may hinder them from achieving their goals of using the system effectively and to their satisfactions. On the other hand, administrators and auditors, who are the gatekeepers of policies and ensuring proper handling of sensitive medical information, indicate that they are only open to use a system based on usability if it is also satisfying their expectations of confidentiality. In short, it is important to have confidentiality system characteristic in place in order to find a system usable.
Table 12: The moderation effect of stakeholder role on the relationship between OTU_confidentiality and OTU_usability

Chapter 7:
Discussion and Contribution

7.1 Theoretical Implications

This dissertation research contributes to the design theory literature by revisiting Walls et al.’s (1992) information system design theory (ISDT) and other notable design science works (e.g. Rossi et al. 2003, Hevner et al. 2004, Adams et al. 2004). We investigate the ‘building blocks’ of existing literature in regards to design science and suggest system and process level enhancements. We propose kernel level assessment and feature selection that define the design requirements and the embedded characteristics. Once the artifact design has been created, we validate the suggested artifact through our design-theoretic model. We empirically validate the importance of the perceived gap in satisfaction with design artifacts and its relationship to openness of EHR system use through a survey to different stakeholder groups in the healthcare
industry, which satisfies the kernel exposition. Our research is the first to use design theory to propose a model for EHR system design.

We supported our empirical validation with the expectation-confirmation theory (Oliver 1980). We employed the steps suggested by Oliver: (1) expectation formation, (2) perceived satisfaction, (3) confirmation or disconfirmation. We extended these steps with the notion that expectation of satisfaction with existing features drives openness to frequently using a system, which is the confirmation. Users confirm their satisfaction with openness to use a system while they confirm their dissatisfaction by not being open to using a system.

We exposed a number of areas, through the design-theoretic model and the empirical validation of artifact creation, where system designers need to align stakeholder expectations in order for them to more likely use the system. For example, while patients and PCP’s perceive a secure system decreasing their openness to frequently using it, administrators and auditors believe that increased measures ensuring confidentiality make a system more usable. This discrepancy highlights the varying expectations of satisfaction and system designers need to have customized meta-features while the meta-characteristics are aligned across all stakeholders.

The empirical validation of our design-theoretic model considering each stakeholder separately fills the gap in the literature, where this level of granularity has not been present. We are able to demonstrate the satisfaction and expectation of each stakeholder and that there is a difference on system feature level, which must be considered if an information system in multi-stakeholder context is considered.

System features have been the subject of previous EHR studies but a comprehensive feature and characteristic set proposed in our dissertation research has not yet been provided to
the best of our knowledge. Especially the accountability meta-kernel and auditability meta-design has escaped researchers’ scrutiny, which we find crucial building blocks of properly designed HER system considering what a heavily regulated industry healthcare is across federal, state, local and organizational level regulations.

### 7.2 Methodological Implications

Although the research methods used in this dissertation research were known before, some aspects provide extension to the existing literature. First, we identified the healthcare stakeholders in the first part of this dissertation, on which groups no previous multi-stakeholder research were based. This allowed for more targeted analysis on a granular level and elicit more specific conclusion.

Furthermore, the approach of combining kernel exposition and the expectation confirmation theory does not have previous precedent. This approach allows for the understanding of the implications of decrease in satisfaction on the expectations of satisfaction with existing EHR system characteristic. In addition the openness to frequently use a system is sought after topic in other information system domains, such as the technology acceptance, where this approach may have merit to further investigate.

### 7.3 Practical implications

Grounded in the design theory and expectation-conformation theory, this dissertation research carries significant practical implications to organizations that currently use or plan to
use an EHR system. From user expectations of satisfaction to vendor selection, our design-theoretic model provides guidance for proper usage of characteristics in a multi-stakeholder context.

7.3.1 Implications for executives, project leaders and decision makers

Organizations invest tremendous amounts of money in information systems to enhance productivity and generate positive returns on their investment (Furneaux & Wade 2011). This investment decision and system choice is often made by executives, who are not the primary users and not considering whether all user groups’ expectations are satisfied through the collective characteristics of a system of choice (Morris and Dillon 1996).

With our design-theoretic model, decision makers may evaluate the meta-characteristics that their system must include in order to support various needs, such as compliance adherence, portability, and usability. Based on our empirical validation, they can assess user expectations and properly align the characteristics that represent the features supporting the diverse needs of users. Executives are measured by the success of their organization, which is greatly dependent on the information system they chose to support their operations and employees’ work functions. Unless these executives fully understand their employees’ expectations, they will most likely not be able to make a sound decision on the proper EHR system selection.

During vendor selection process, it is inevitable to understand the need from users, especially in a multi-stakeholder context. Proper demonstration of EHR system features within a particular characteristic may lead decision makers to ensure that the chosen system will support their users’ needs even if they are different from a particular system characteristic. Our model shows the relationship among the perceived satisfaction based on current experience with a
healthcare system and its effect on the openness to use a system based on that characteristic if it meets users’ needs.

Furthermore, we investigated the moderating effect of stakeholders as the overall model considered all stakeholders together and suppressed the important implications of the associations between variables from different stakeholder groups’ perspectives. This is a tremendous help for executives and decision makers to understand their employee’s needs not only on the system level but also on the process level.

We propose general implementation parameters that simplify the implementation logic regardless of the context. For example, implementing an EHR system at a primary care provider is different from that at a multi-campus hospital. This flexibility in our model allows project managers to apply our design-theoretic model at a variety of EHR implementation and vendor selection projects.

7.3.2 Implication for designers and vendors

The development of software applications went through a shift in the past decade, where designers and software vendors realized that users’ perception of the system and the actual usage should be the main concern while designing software. As users’ productivity greatly depends on the actual use of the system (Davis et al, 1989), organizations have demanded usable and understandable systems that justify their financial investments (Brynjolfsson, 1993).

Software companies design and build software to support a particular work function or multiple functions across the organization. The more functions they support, the less support they provide in a multi-stakeholder context (Gomaa 2011). This has a large negative impact on
their software usage as stakeholders, who feel that their job function is not supported will be less open to use the software.

Our design-theoretic model lays out the elements in comprehensible sections to provide guidance for EHR system design methodology. The EHR system design steps on which we elaborated clearly marks the consecutive steps required starting with problem discovery that they plan to solve, followed by the gap identification and choice of proper kernel theory. The meta-kernels and meta-designs we propose are supported by the kernel exposition through empirical evidence, including the stakeholders moderating effect. This methodological rigor will not only provide guidance for software designers but also ensure that they can create an EHR system with custom feel for their users while the organization is supported across the variety of processes and functions.

Also, our design-theoretic model helps designers and developers to translate organizational level and kernel level requirements. This may provide further details that designers and developers may use for feature selection that may provide remedy to the organizational level problems and requirements and answer the "what features would support the organizational level requirements" question. In doing so, we provide the additional details necessary for designers to identify the design requirements and features that specifically address the organizational challenges. The kernel exposition approach is also of great support on understanding the connection between expectations of satisfaction and their effect on system use.

7.3.3 Implication for users

Software users expect that processes for performing their job functions do not change if a productivity or decision support system is adopted by their organization (Petter 2007). While
these processes change across job functions, the requirements are not always providing enough
details for software designers to ensure that all user groups are provided the support they require
from the software. Jiang et al. (2002) and Landauer (1995) recognized this through the difference
in perception of an information system between end-users and developers.

Our design methodological model has important implications for EHR system users as
well in several ways. If management solicits for user input to define meta-design, users may be
able to assess their work function and ensure that it is supported through the feature that they use
most often. Also, the kernel exposition provides a very clear overview for users on the
expectations of satisfaction based on the EHR system feature they find the most helpful to
perform their job functions. Understanding the importance of an EHR system feature may help to
project openness to frequent use based on the expectations of satisfaction of this EHR feature.
Understanding the implication of dissatisfaction with an EHR system feature may prevent failed
implementations and increase the plummeting EHR use.

Providing EHR system features to the users in a form that they will find that they meet their
expectations of satisfactions will reduce the numerous workarounds they may maintain. It not
only increases efficiency and effectiveness but also will reduce the risk of privacy and
compliance breaches for capturing patient information outside of the secure EHR system.
Chapter 8:

Limitations and Future Directions

This dissertation research is limited in scope and not free of shortcomings. These limitations may provide directions for future research within and beyond the domain of this research.

We followed Walls et al.’s (1992) ISDT closely, while there are several competing models and some were built on the shortcomings on Walls et al.’s model. While we provided extension on this pioneer model, we are not the first ones to point out its limitations and provide extensions to the model. It may be beneficial to revisit other models to investigate whether or not the proposed extensions to Walls et al.’s ISDT provide merit as well.

We have collected information through a questionnaire from a decent sample population representing each stakeholder groups. However, due to the large number of variables we observed, exploratory factor analysis may have experienced ‘underfactoring’, where large enough discrepancies between the model and data may not be significant (Humphreys 1975). Consequently, the model fit in CFA had to follow a more relaxed cut off values but within the literature suggested limits. Future studies may want to consider smaller number of variables or increase the sample population.

Similarly, we ran the CFA on a simplified model to test the hypotheses on the stakeholder level due to decreased sample size once we used stakeholder role as a grouping variable. It would be preferred to run the model in its entirety while observing estimates on the region level. We were, however, able to observe the expectations across stakeholder groups within a
hypothesis in regards to what indicator variable turned out to be the strongest and also the variation on path coefficient intensities.

We were unable to utilize the collected information on regions, which might have provided further direction on expectations from stakeholders based on what region they operate. It is an interesting objective to test whether regional regulations influence stakeholders’ expectations from an EHR system characteristic. It can be the focus of a future research itself. Additionally, due to the same reason, we were unable to capitalize on the healthcare institution type that we also collected.

As we investigated moderating effect of stakeholder role, some path coefficients revealed surprising magnitude. It would be worthwhile to investigate the underlying reason behind it, whether it is correlated to regions of the institute type from where data was collected.

In addition the openness to frequently use a system is sought after topic in other information system domains, such as the technology acceptance, where this approach may have merit to further investigate. The openness to frequent use of an EHR system based on the expectations of satisfaction with an EHR system characteristic has not been done in regards to investigating it as an actual system use trigger.
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