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# Communications of the Association for Information Systems

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## Information Systems and Healthcare XXX: Charting a Strategic Path for Health Information Technology

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### Abstract:

Despite both the slow diffusion of information technology (IT) throughout health organizations and the high cost of implementation, organizations must focus on key strategic applications that deliver high quality care at lower costs. Identifying the strategic applications that support important healthcare processes is challenging. In this article we propose a framework for developing this high level perspective of strategic health information technology (HIT) applications. We then classify into the components of the framework numerous HIT applications and initiatives reported in the media. Based on an existing framework, we identify two critical dimensions that capture two important characteristics of a healthcare delivery process, namely, the degree of mediation and the degree of collaboration. A healthcare process with a high degree of mediation involves a large series of activities in a sequential manner. Processes with a low degree of mediation “understand” that most participants in care delivery contribute directly, often simultaneously, to the final result. The underlying principle for this dimension is the level of functionality of the application. The degree of collaboration refers to the extent to which information is exchanged among the participants in a process. Depending on the degree of exchange, one can identify processes as having higher or lower degrees of collaboration. The underlying principle for this dimension is the degree of interoperability among the applications. Strategic HIT applications lie on a continuum path from a low-high degree of mediation to a low-high degree of collaboration. Our examples show that healthcare delivery organizations evolve their HIT from ad-hoc isolated systems to interoperable, integrated digital health systems. The strategic framework provides a high level perspective of HIT while assisting in the evaluation of potential HIT candidates for implementation.

**Keywords:** collaboration, functionality, health information technology (HIT), interoperability, mediation, strategic framework

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## I. INTRODUCTION

The rapid developments in health information technology (HIT) in recent years have led to a proliferation of applications [Chaudhry et al. 2006; McGrath 2006], ranging from electronic health records to clinical decision support systems. However, in today's complex, multi-payer, multi-provider healthcare world, healthcare delivery organizations have to do more than merely integrate information intra-enterprise. Be it a small clinic or a large hospital, it is not enough for a healthcare organization to implement an internal electronic health record system if the system does not connect to outside participants in the healthcare delivery process: the pharmacy, home care service, laboratory and so on. Healthcare delivery organizations have to make their organizational systems interoperable with the systems of other enterprises: other healthcare and business processes, other applications, and a diverse array of computing devices [Brailer 2005; Chaudhry et al. 2006; Melvin 2008; Walker et al. 2005]. For a clinic, interoperability can promote safety, reduce errors, provide clinical decision support and improve continuity of care. For a hospital or larger organization, interoperability can help apply preventive strategies to larger populations and partner fully with patients and families or caregivers [AHRQ 2007].

Accepting that there is a need in our society for higher-quality patient care and better tools for meeting public safety goals, interoperable HIT offers great potential as a tool for accomplishing higher standards of care and public safety than we currently achieve. However, the diffusion of information technology (IT) throughout health organizations has been slow [Jha et al. 2006] and the cost of implementation high [Lohr 2006]. Eventually, though, organizations will have to focus on key strategic applications, including interoperable, longitudinal electronic health records that will deliver high quality care [Thompson and Brailer 2004; IOM 2003].

Identifying the strategic applications that will support important healthcare processes is a challenge, but one of which upper management in the business of healthcare must be mindful. As more and more healthcare delivery organizations adopt information technologies that result in healthcare transformation [Kilo 2005], we will see improvements in the system of care. Among these improvements will emerge "proactive planning for population care" with queries and follow up with subpopulations; and "whole patient view for planned care" wherein all pertinent information is available in one place [AHRQ 2007]. The former addresses public health management such as disease surveillance and pandemics, while the latter focuses on the wellness of the patient in totality including preventive care. As it moves from "discrete interventions" to "care cycles," the delivery of care begins to encompass the full life cycle of care [Porter and Teisberg 2006]. What follows, as HIT meets its potential of making the healthcare system more responsive to consumers and involving consumers more actively than ever in their own healthcare, is "value-based" competition in which healthcare providers compete based on the quality of care provided. Thus, there is need for a high-level perspective on this strategic endeavor.

In this article, a framework is proposed to help develop this high-level perspective. Two critical dimensions are conceptualized to capture the properties of a strategic HIT application: *degree of mediation* and *degree of collaboration*. A healthcare process with a high degree of mediation involves a large series of activities in a sequential manner (e.g. an office visit), while processes with a low degree of mediation require most participants in care delivery to contribute directly—often simultaneously—to the final outcome (e.g. critical emergency care). The underlying principle for this dimension is the level of *functionality* of the application. That is, does the application have a low functionality (fewer capabilities) or a high one (more capabilities)?

For the degree of collaboration dimension, the participants in a process, regardless of the pattern of mediation, may exchange information with each other (e.g. to make care decisions) and make mutual adjustments (e.g. accommodate schedule) to facilitate the accomplishment of process outcome. Depending on the extent of such information exchange, one can identify processes having higher (e.g. clinical decision making support in real-time) or lower (e.g. simply transmitting lab report electronically) degrees of collaboration. The underlying principle for this dimension is the degree of *interoperability*, which is defined as the "ability to exchange health data between different systems and networks." Limited interoperability permits limited exchange of health data resulting in mere communication, whereas greater interoperability facilitates more advanced care, such as remote medicine or clinical decision support.

The proposed framework is used to show how various types of HIT may be utilized to alter the characteristics of a healthcare process. In addition, the framework can assist in evaluating the potential of candidate HIT and in charting a strategic path to HIT.

The rest of this paper is organized as follows: Section II introduces the principle of functionality as it relates to HIT. Section III discusses the principle of interoperability. Section IV develops the strategic framework for HIT, drawing on the work of Teng et al., [1994] and extending the framework of Raghupathi and Tan [2002]. Section V describes specific examples in the context of the framework. Section VI discusses the scope and limitations of our study. Section VII offers conclusions.

## II. HIT FUNCTIONALITY

The *functionality* of an application refers to its capabilities. An application can focus on a single capability, such as patient scheduling or results management. Or, it can possess multifunctional capabilities, such as those in a longitudinal electronic health record that includes electronic documentation, computerized provider order entry, and decision support [IOM 2003]. The level of functionality of an application usually impacts the degree of mediation. Applications with limited functionality reflect a high degree of mediation since the underlying processes in the workflow are fairly independent of each other. Each process may be supported by a specific application. This limitation leads to a series of sequential activities since the applications are disparate and unconnected. It follows that the lower the level of functionality, the higher the degree of mediation.

Typically, applications that support billing and administrative processes are likely to be more mature since they are well defined and routine [IOM 2003]. The operational benefits, such as increased efficiency, are easy to document [Chaudhry et al. 2005]. As important as these improvements are, though, once accomplished they have limited potential to generate significant, continuing improvements over time. Using HIT to improve the “system of care” will offer large and ongoing opportunities for enhancements, including optimizing the care team and involving patients and families as partners in care [IOM 2003].

To achieve higher levels of functionality, organizations need to spend more time on designing HIT applications with the objective of improving the overall “system of care” and less time on the operational or documentation improvements that may reduce certain kinds of errors and waste [IOM 2003] but do not improve the “system of care.” What will improve it are initiatives that take an overview approach to care. “Proactive planning for population care,” “queries and follow-up with subpopulation,” and “whole patient view for planned care” are objectives that require that all pertinent information be available in one place [IOM 2003]. A longitudinal electronic health record is one example of this type of multi-capability application. Such an application can provide care and information specifically tailored to the needs, preferences, and medical challenges of each individual and also apply preventive strategies not just for the individual but for entire populations as well. A multi-capability application has the potential to reduce the degree of mediation by consolidating activities in the process.

A good example is the implementation of an imaging capability (VistA Imaging) at Veterans Administration (VA) department facilities. VistA Imaging is believed to have enhanced the individual electronic medical record system by enabling multimedia data, such as radiology images, to be linked to a patient’s electronic medical record (EMR). These collective enhancements to VistA resulted in a comprehensive, integrated EMR for each patient, viewable by all of the department’s clinicians at all of its healthcare facilities and obviating the need for paper records [GAO 2008].

Some HIT applications, those with multiple capabilities, can help with both collaboration *and* mediation. Reminder systems help to prevent errors, and they can also support implementation of a robust model of care. A reminder system can alert a provider to a drug allergy or remind her to perform certain screening or preventive care. The result is an increase in the overall value of a provider encounter with a patient. Report writing is another function that has relevance in both areas. Reports can reduce errors by focusing on compliance with currently expected practice; they can also be used as a flexible tool for learning that is available to all.

## III HIT INTEROPERABILITY

*Interoperability* is “the ability of health information systems to work together within and across organizational boundaries in order to advance the effective delivery of healthcare for individuals and communities [HIMSS 2005].” This capability is important because it allows patients’ electronic health information to move with them from provider to provider, regardless of where the information originated. Data is available across the continuum of care for overall improvement efforts. Interoperability allows the primary care office to connect to specialty care, emergency room, general hospital, urgent care clinic, dental office, laboratory, pharmacy, radiology, and other healthcare stops. This connectivity facilitates enhanced clinical decision support [Brailer 2005; Halamka et al. 2005b; IOM 2003; Walker et al. 2005]. In fact, the study by Walker et al. [2005] showed that considerable savings, to the tune of \$77 billion, is possible from the exchange of health information and interoperability via reduction in redundant tests and reduction in delays and costs associated with paper-based ordering and reporting of results.

Interoperability also has the potential to enable real-time reporting of the status of public health, bioterrorism surveillance, quality control and results of clinical trials [Brailer 2005]. The strategic framework of the department of Human and Health Services promotes the development of interoperability through the use of regional health information organizations (RHIOs) and a national health information network (NHIN) [Gold and Ball 2007; Melvin 2008]. Bates [2005] affirms, “achieving interoperability of clinical information will be key to making electronic health record use a cornerstone of practice.” Examples of health information networks in the U.S. include the states of California (<http://calrhio.org>), Massachusetts (<http://www.maehc.org>), Delaware (<http://www.state.de.us/dhcc/information/dhin.shtml>), and Maine (<http://www.hinfont.org>). Also, Santa Barbara (California), the Indianapolis area and the greater Boston area all support patient information exchanges, including among multiple and often competitive entities [Halamka et al. 2005a]. Canada, the U.S., and U.K. are examples of countries with national level initiatives under way [Eckman et al. 2007].

The degree of interoperability impacts the degree of collaboration. To the extent the exchange of health information is within the organization or between independent systems, it reflects a lower degree of interoperability. While this may permit an organization to function cohesively internally, it does not allow improvements in the overall system of care. On the other hand, a higher degree of interoperability is achieved when the organization’s systems are connected to external systems. A greater level of care is enabled since data about the patient or the population as a whole is available in integrated fashion. Therefore, a higher degree of interoperability leads to greater collaboration.

Of course, interoperability has its challenges, too. First, interoperability benefits are highly dispersed across many stakeholders. In an overhaul of HIT, some of these stakeholders could lose from disruption of long standing industry practices, particularly vendors who rely on custom integration of their products for revenue and who use lack of interoperability as a customer retention strategy. Second, the negative network externalities and first-mover disadvantage that penalize early adopters make it difficult to synchronize the behavior of the market so that interoperability can gain a foothold. Third, the lack of completely agreed upon standards prevents more entities from moving towards higher degrees of interoperability [Brailer 2005].

#### IV. A STRATEGIC FRAMEWORK FOR HIT

For our framework, we have elected to adapt the broad principles of the work of Teng et al. [1994] in the area of business process reengineering (BPR). According to them, two important dimensions capture the features of a business process: the degree of mediation and degree of collaboration.

A process with a high degree of mediation involves a large number of steps in a sequential manner, while processes with a low degree of mediation have most of the participants contribute directly, often simultaneously, to the final outcome. For the degree of collaboration dimension, the participants in a process, regardless of the pattern of mediation, may exchange information with each other and make mutual adjustments to facilitate the accomplishment of process outcome. Depending on the extent of such information exchange, one can identify processes having higher or lower degrees of collaboration. (pp. 9-10)

Teng et al. suggest that their framework explains how different types of information technologies may be used to modify the features of a business process through BPR [Teng et al. 1994].

Accordingly, we suggest that the method by which various functions are orchestrated to accomplish a healthcare process, that is, the functional integration of a process, can be differentiated along the two dimensions: degree of mediation and degree of collaboration. To note, various healthcare processes (e.g. verify patient insurance, process admission data) and the HIT applications that support them are well documented in the literature [IOM 2003]. Indeed, many of the processes—such as those related to administration, billing, and scheduling—are similar to processes in other industries [IOM 2003]. The critical issue is identifying the level of functionality and degree of interoperability of the HIT application that impact the degree of mediation and degree of collaboration. This understanding in turn modifies the healthcare process itself. For example, in the relationship between outpatient providers and pharmacies, an integrated system could reduce the number of medication-related phone calls for both clinicians and pharmacists. It can also improve clinical care by facilitating the formation of complete medication lists, thereby reducing duplicate therapy, drug interactions, and other adverse drug events, not to mention medication abuse. As well, it could enable automated refill alerts, offer clinicians easy access to information about whether patients fill prescriptions, and complete insurance forms required for some medications. In addition, it could help identify affected patients in the event of drug recalls, uncover new side effects, and improve referral processes [Walker et al. 2005]. Therefore, mediation is reduced (reduction in number of activities), and collaboration is enhanced (e.g., clinical decision making).



Raghupathi and Tan [2002] also describe two key dimensions of systems integration that are useful in developing the strategic HIT framework: *internal integration*—the degree to which systems and technologies are integrated within an organization; and *external integration*—the degree to which systems and technologies interface with outside organizations. Simultaneously, Porter and Teisberg [2006] reiterate, “every activity in the care delivery value chain can be enhanced and made more efficient with IT.” They further point out, “More broadly, IT provides the backbone for collecting, compiling, and utilizing information on patients, activities, methods, costs, and results for each patient across the cycle of care and across time. As care delivery moves from discrete interventions to care cycles, and from silos to integrated teams, IT only becomes more important.” The central theme that runs across the various frameworks is the need for ‘interconnected systems,’ be they internal to the organization (intra-enterprise) or external to the organization (inter-enterprise).

Keeping in mind the underlying key threads of functionality and interoperability that pervades the literature, we develop below our framework drawing on these and the other pieces of work. To reiterate, our primary adaptation is from Teng et al. (1994). We first introduce the notion of the functional integration of healthcare processes.

### Functional Integration of Healthcare Processes

Depending on the level of functionality and the degree of interoperability, the manner in which various healthcare processes are configured to accomplish a goal—that is, the functional integration of a healthcare process—can be distinguished along the two dimensions: the degree of mediation and degree of collaboration.

#### The Degree of Mediation Dimension of a Healthcare Process

Many functions are involved in a typical healthcare process. Scheduling a patient visit to a clinic, for instance, may involve the verification of the patient’s personal information, the confirmation of physician availability for that date/time, the validation of insurance, and so on. Each participating function has inputs and outputs. The outputs either directly facilitate the outcome or serve as inputs to other stages of the process. For example, an output for scheduling a patient might be a confirmation printout giving details of the visit, or it might trigger the insurance verification function. It might do both. This input-output relationship may involve the actual transfer of a physical object from one function to another (e.g. a patient is transferred from the E.R. to the I.C.U.) as well as the movement of medical equipment (e.g. mobile X-ray equipment is moved into a patient’s room). Or it could be the production of a document by one function to authorize actions in another function (e.g. insurance authorization/referral prior to consultation with a specialist or pre-certification for certain prescriptive medications prior to filling the prescription). The extent of the sequential flow of input and output among the functions in a healthcare process constitutes the degree of mediation dimension of the process. A healthcare process at the very high end of this dimension is associated with a large number of intermediate steps performed by various functions contributing indirectly to the process outcome. Some healthcare processes (e.g. Process Admissions) may involve several indirect steps such as verification of patient data, insurance pre-certification, creation of a patient chart, and pre-admission lab work, and can be seen to cluster around the high end of the mediation dimension.

At the other end of the spectrum, several functions contribute directly to the process outcome without the mediation of sequential steps. For example, a primary care physician can draw blood for lab work or take a chest X-ray of a patient in the office itself without the patient having to first go to a lab and then to an X-ray diagnostic center. Essentially, the two activities contribute directly to the diagnostic process. Between the two ends of the spectrum, there are levels of granularity, including less indirect steps, and a combination of both, indirect and direct steps [Teng et al. 1994].

#### The Degree of Collaboration Dimension of a Healthcare Process

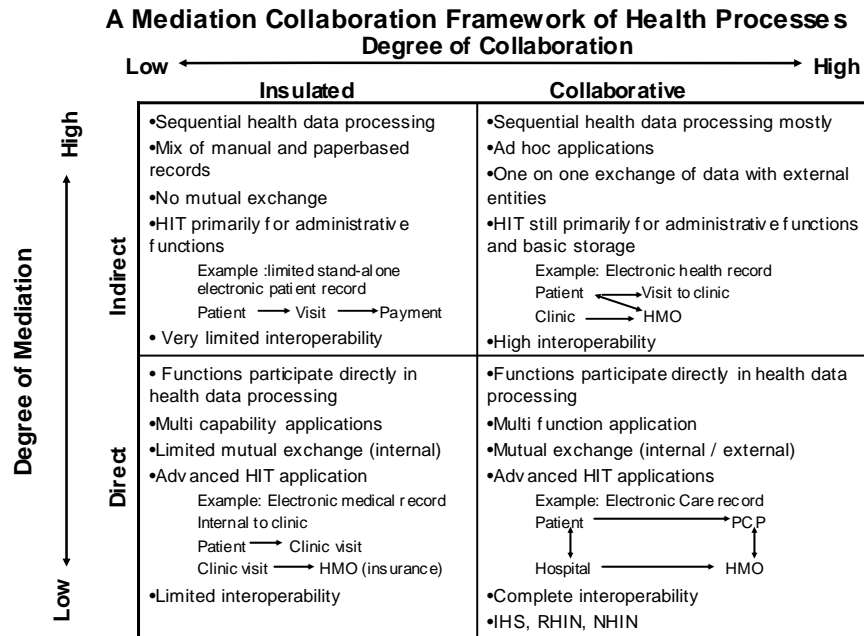
The second dimension of healthcare processes refers to the extent of collaboration between functions through information exchange and negotiation within the same process. Similar to the degree of mediation, the degree of collaboration can range from low (insulated) to high (collaborative). The nature of information exchange between two functions can range from mere communication to interactive exchange. For our purposes, more collaboration entails interactivity and some kind of clinical decision support (participants exchange information to make diagnostic or treatment decisions, for instance). It is not a simple flow of information. The concept of interoperability plays a critical role here. A patient may visit an optometrist independent of a visit to a cardiologist; or a patient is scheduled for bowel surgery, which involves a high degree of collaboration between the GI and the surgeon. In this scenario, collaboration involves making clinical decisions.

Processes supported by HIT with relatively low collaboration may have negative effects, for example, they may duplicate functions (e.g. verification of patient data) in various processes. Ideally, healthcare delivery organizations will gradually move from a low-collaboration model to a high-collaboration model. A fully collaborative model reflects interoperability, a key and necessary ingredient for the success of HIT [Brailer 2005]. Take for example a medium-

sized physician-run health clinic. This clinic may start with a standalone electronic health record system for internal use. The workflow processes—such as prescription call-ins, insurance authorization or obtaining a lab report—are typically performed manually via phones, postal mail and faxes to transmit health information. As the clinic becomes integrated into a wider health system, and in turn into a regional health information network, the electronic health record evolves into a longitudinal health record with full digital interoperability [Overhage et al. 2005], extended via service-oriented architecture (SOA), Web services or other types of HIT. The degree of collaboration with external systems is enhanced leading to a collaborative environment. The result is an improvement in the quality of healthcare (by the elimination of duplication of paperwork and decreased medical errors) and lower costs.

### A Functional Integration Framework of Healthcare Processes

The two dimensions give rise to a framework that suggests four healthcare process models of HIT: indirect-mediation/low-collaboration, indirect-mediation/high-collaboration, direct-mediation/low-collaboration and direct-mediation/high-collaboration. The framework is shown in **Figure 1**.



**Figure 1. Mediation-Collaboration Strategic HIT Framework [adapted from Teng et al. 1994; Raghupathi and Tan 2002]**

**Indirect-mediation/low-collaboration.** There is no mutual exchange of health data. A mix of manual processes, paper-based data and limited applications, primarily in administrative functions, characterize this model. A limited, stand-alone electronic patient record is typical. The applications, if any, are mostly internal to the healthcare delivery organization, and of limited capability. Additionally, these applications may be independent of each other. The model is therefore characterized by limited functionality such as that in an electronic patient record (EPR) that generally refers to computer-based clinical data of an individual that are location specific and kept by a single physician office or practice, community health center or possibly an ambulatory clinic [Prott, 2007].

In Walker et al.'s 2005 taxonomy of interoperability, this model is at *Level 1* and involves the use of nonelectronic data, such as mail and telephone.

**Direct-mediation/low-collaboration.** This model is an improvement over the indirect-closed scenario wherein electronic medical records (EMR) of limited functionality are introduced for internal clinic use. The relationships with external entities are still, for the most part, performed manually. While the focus is generally speaking still internal, key applications may “talk” to one another within specific units (such as EMR), and physician order-entry systems may be connected. Thus, the functionality is greatly enhanced. An EMR generally refers to computer-based clinical data of an individual that are location specific and kept by a single healthcare organization, such as a hospital, acute care facility, or regional health authority [Protti 2007] that has interaction with other departments, such as the laboratory or radiology. Still, there is limited interoperability. In Walker et al.'s [2005] taxonomy, this model resides at *Level 2*, which utilizes machine transportable data: data that is transmitted in a nonstandardized format via any one

of several basic technologies, including fax, PC-based exchange of scanned documents, and so on. Note, too, that this transmitted content is not digitized and therefore cannot be changed. In this quadrant, as IOM [2003] suggests,

It is assumed that providers (i.e. ambulatory care settings, hospitals, and nursing homes) will focus on (1) the capture of essential patient data already found frequently in electronic form, such as laboratory and radiology results; (2) the acquisition of limited decision support capabilities for which software is readily available in the marketplace (e.g. order entry, electronic prescribing); and (3) the generation of reports required by external organizations for quality and safety oversight and public health reporting. (p. 11]

**Indirect-mediation/high-collaboration.** This model is moving toward interoperability with systems external to the organization. For example, some clinics can access lab work results and insurance information via Web interfaces or by logging into remote systems. Third-party providers may also step in to enable connectivity, such as remote hosting of records or an electronic exchange. An example of an HIT is electronic health record (EHR) that generally refers to computer-based clinical data of an individual that are available across multiple locations. It is sometimes referred to as a *longitudinal health record*, which includes data about the individual from a number of different interoperable EMRs and EPRs. An EHR is shared across jurisdictions, such as primary care and secondary care [Protti 2007]. In Walker et al.'s [2005] taxonomy, this model is at *Level 3*. It is more advanced and involves structured messages containing nonstandardized data requiring some translations across vocabularies (e.g. free text, HL 7 messages). However, functionality is still of low capability. Applications are ad hoc and focus on basic administrative functions and storage of patient data. In the context of the IOM [2003] statement,

...in the near term, providers' applications should (1) allow for the capture of defined sets of health information; (2) incorporate a core set of decision support functions (e.g., clinical guideline support, care plan implementation); and, (3) support the exchange of basic patient care data and communication (e.g. laboratory results, medication data, discharge summaries) among the care settings (e.g. pharmacies, hospitals, nursing homes, home health agencies, etc.) within a community. (p. 11)

**Direct-mediation/high-collaboration.** Strategically, this model is the most desirable for full-scale interoperability. The strategic path lies in the continuum of applications from indirect-low to direct-high with levels of granularity. This model is characterized by high functionality with multi-capability applications that integrate many of the functions. An electronic care record (ECR) is an example of HIT here [Protti 2007]. It is an emerging term that generally refers to computer-based data of an individual that are available across multiple locations. More specifically it is seen as a record that is shared by healthcare practitioners and social services professionals (e.g. homecare, eldercare) and needs an IHS or RHIN infrastructure.

As per Walker et al. [2005], this model is at *Level 4* interoperability, which is associated with the exchange of information across different applications but using the same formats and vocabularies. The system of care is supported by interactive decision support. At the Cleveland Clinic the sequential flow of patient-related documents among many departments has been drastically altered through the use of HIT (imaging technology, web services, e-health) that enables the many participants in the patient care process to perform different activities on the same document concurrently (say, on an EHR). For example, when a specialist electronically orders a CT scan for a hospital-admitted patient, the order is seen by the radiology department (equipment availability/insurance pre-certification), scheduling department, and internal transportation. In addition, the relevant nurses' stations are alerted. This type of model is mostly found in large integrated health systems, RHINs, and the NHIN itself. In the IOM's [2003] taxonomy,

...in the longer term, fully functional (functionally integrated) applications such as the longitudinal EHR will be available and implemented by some health systems and regions. It may take considerably longer for all providers to be using a comprehensive EHR system that provides for the longitudinal collection of complete health information for an individual; immediate access to patient information by all authorized users within a secure environment; extensive use of knowledge support and decision support systems; and extensive support for applications that fall outside immediate patient care (e.g. homeland security, public health, clinical research). (pp. 11-12)

Conversely, the least desirable model is one of indirect-mediation/low-collaboration wherein processes in the workflow are disconnected and repetitive, leading to redundancy.

Today's increasingly uncertain healthcare environment, characterized by a complex multi-payer system, has led to a proliferation of processes and functions that are incompatible with each other across healthcare delivery





organizations. As a result, duplication and errors are common. To mitigate this challenge, the functional integration of typical healthcare processes can be reworked or reengineered to minimize the amount of mediation while increasing the collaboration among participants.

The functional integration framework facilitates the identification of the significant features of various healthcare processes that may be modified by HIT applications. The process-HIT application candidates can be plotted on a continuum from the indirect-closed model to the direct-open model to identify those that have the potential to increase collaboration and decrease mediation. Organizations may incrementally shift emphasis from individual HIT applications within the organization to more interoperable, connected applications.

### **Reducing Degree of Mediation through HIT**

Healthcare delivery organizations can redesign their processes from an indirect scenario with many intervening steps to a direct scenario that allows several functions to be executed independently. This is enabled by multi-capability functionality. Analogous to “one-stop shopping,” the hospital admittance process can include simultaneous processing of insurance authorization (e.g. for impending surgery), retrieval of a patient’s chart from the primary care physician’s office (e.g. the electronic health record) and linkage to the patient’s pharmacy to obtain a prescription history. The potential of distributed or federated systems based on service-oriented architecture (SOA) [Raghupathi and Kesh 2007] and web services [Raghupathi and Gao 2007] to reduce mediation can be examined. For example, a unified patient view can be obtained by performing a query off the distributed patient-related databases. Or, a health “service” can be invoked from an Enterprise Service Bus (ESB) within the integrated health system. Other distributed systems such as digital imaging and storage applications, longitudinal electronic health record systems, telemedicine, and ehealth could also be applied to significantly reduce the degree of mediation in a healthcare process. As Teng et al., [1994] suggest, “the use of shared computing resources to reduce the mediation level is a powerful testimony to the distinctive value of IT in creating a public good, i.e., a common resource to be accessed by multiple functions.” Following their discussion, in the case of healthcare, the shared health data (via interoperability) is not abandoned upon usage but retains value. For example, a collection of electronic health records can be ‘data mined’ for additional research into disease and drug patterns and relationships [Fonseca 2004; McGee 2006a].

A second characteristic of the shared information resource, according to Teng et al., is “its ability to provide comprehensive information that facilitates the accomplishment of process objectives on a more global basis.” One example is the recent emphasis on various types of regional health information networks (RHINs) and the development of a national health information network (NHIN) for the dissemination and sharing of aggregate health data, such as in pandemic tracking and bioterrorism surveillance [Halamka et al. 2005b; Loonsk et al. 2006].

### **Enhancing Degree of Collaboration through HIT**

Quite different from the mediation dimension where the input-output relationships often emerge due to a need, the collaboration between the functions themselves may be optional. In the scenario of a medium-sized clinic implementing an electronic health record, the clinic will be self-sufficient in its patient information processing. However, the functions of lab processing, insurance authorization, and so on, may still be manual. That is, the external relationships are not yet interconnected. This makes the HIT-enabled collaboration value-added as healthcare delivery organizations move towards integrated digital health systems, which in turn enhance RHINs and the NHIN. For example, greater collaboration takes place via e-mail communication between physician-patient and physician-specialist. Another example is the use of e-prescription between physician-pharmacy. In these examples, while there are no noticeable changes in the degree of mediation between the functions, an increase in collaboration nevertheless occurs.

Therefore, while healthcare delivery organizations may implement numerous HIT applications, their potential for success lies in the use of standards-based telecommunications technologies and the Internet in providing interoperability with the resultant collaboration. A notable example is the outsourcing of the radiologist’s ‘reading function’ to other countries. The digital images are either uploaded to a shared, secure Web site or sent as e-mail attachments to radiologists in remote locations, enabling the access to and reading of the images. The patient is also given access (replacing the physical X-ray film or even a CD-ROM); in this way a high level of open collaboration occurs between physician-patient-radiologist. Simultaneously, each participant can continue to work on the various aspects of the process, for example, billing for the X-ray, ongoing diagnosis and treatment and additional testing.

The following section classifies various publicly reported applications into one of the four models based on broad criteria described in section 4.1.3. We point out that classifications were based on a subjective assessment by the authors and not on any empirical or quantitative method. First though, we provide background information on the status of HIT adoption as per numerous studies.

## V. EXAMPLES OF THE FOUR MODELS

### Background Discussion

Prior to positioning various HIT endeavors into the four quadrants, we provide a summary of the state-of-the-art view of HIT applications. We generally looked at efforts consistent with the “core functionalities” identified by the IOM [2003]: these include health information and data (e.g. well-designed, Web-based interfaces); results management (electronic storage and reporting of laboratory and radiology procedures); order entry/order management (e.g. computerized provider order entry—CPOE); decision support (e.g. computerized clinical decision support); electronic communication and connectivity (e.g. e-mail and Web messaging); patient support (e.g. online education, telehealth); administrative processes (e.g. electronic scheduling system); and, reporting and population health management (e.g. electronic tracking and monitoring, aggregate electronic reporting).

The systematic review by Chaudhry et al. [2006] reveals that 24 percent of all studies on the effect of HIT in cost, efficiency and quality were from four benchmark institutions, namely, the Regenstrief Institute, Brigham and Women’s Hospital/Partners Health Care, the Department of Veterans Affairs, and LDS Hospital/Intermountain Health Care [Chaudhry et al., 2006]. Their comprehensive study also indicates the main application types reported were decision support aimed at providers (63 percent), electronic health records (37 percent) and computerized provider order entry (13 percent). Additionally, the specific functional capabilities of systems identified in the reports included electronic documentation (31 percent), order entry (22 percent), results management (19 percent) and administrative capabilities (18 percent). They also report that only 8 percent of the described systems had specific consumer health capabilities, while only 1 percent had interoperability and data interchange capabilities [Chaudhry et al. 2006].

Interestingly, the applications assessed by the benchmark institutions had several common traits: all their applications were multifunctional and include decision support; they were developed internally by research experts; and they all added functionality incrementally over time [Chaudhry et al. 2006]. Jha et al. [2006] report in their study that approximately 24 percent of physicians used an electronic health record system in 2005. However, only 9 percent was estimated to use electronic health record systems with functionalities such as electronic prescribing. They also confirm that solo or small physician practices had far lower adoption rates compared to larger practices. They also estimate 5 percent of hospitals had CPOE although data was limited [Jha et al. 2006]. Sidorov [2006] also reports that according to a National Health Care Survey, electronic health record systems were in use in 17 percent of physicians’ offices, 31 percent of emergency rooms, and 29 percent of hospital outpatient departments in 2003.

In another study [Gans et al. 2005], the authors evaluated the rate and process of HIT and electronic health record systems adoption by medical group practices by conducting a national survey conducted in early 2005 and followed up with interviews and site visits. They estimated that approximately 14.1 percent of the 34,490 group practices had electronic health record systems. They conclude “the fraction of practices that have implemented electronic health record systems varies greatly by practice size, somewhat by specialty type and ownership, and minimally by region.” This is interesting because 80 percent of physicians work in small practices but account for 88 percent of all outpatient visits [Lee et al. 2005]. All in all, the results of the study imply that various HIT types are being adopted slowly but gradually. A few large organizations dominate the range of implementations, but interoperability is poor in these applications. The next section gives examples of initiatives that fall into the indirect-mediation/low-collaboration model (“indirect-low”).

### Indirect-Mediation/Low-Collaboration Model

**Table 1** summarizes the examples in this model. In an example of aggregate data in this quadrant, a survey by Miller et al., [2005] showed that nearly all providers used an electronic health record for basic tasks such as prescribing, documenting, viewing, and messaging within the practice. Almost everyone used it for billing assistance. On the other hand, hardly any providers used the electronic health record for reporting (e.g., patient lists or provider performance), patient-provider communication or communication from providers in the practice to those outside it [Miller et al. 2005]. A medium-sized clinic, North Fulton Family Medicine, in Atlanta, began using electronic medical records software in 1998 to eliminate annual transcription costs of \$110,000. Since then, the practice has reduced the number of workers needed to manage patient charts. In addition, the practice can now use the system to ensure that patients are receiving preventative care such as vaccines [Havenstein 2006b]. Boston’s Partners Healthcare is also at the forefront in the implementation of a range of HIT, including content management software to share clinical best practices, expert systems for medication dosing and biomedical projects to improve clinical decision support [McGee 2006a].

St. Joseph’s Hospital Health Center, a 430-bed facility with 6,000 employees in Syracuse, New York, has planned to complete work on a new \$1 million digital records and storage system. St. Joseph’s started the project to speed up

and expand access to medical records and radiology charts. The new system uses a picture archiving and communications system (PACS) that saves and searches medical photographs. The technology will allow physicians and lab technicians to access patient data and X-rays in seconds via a web portal. They expect the return on the \$1 million investment in about three years [Mearian 2005].

**Table 1, Examples in the Indirect-Low Model**

Organization/location	Application, Initiative, Project	Reference
North Fulton Family Medicine - Georgia	Electronic health record	Havenstein [2006b]
Partners Health - Massachusetts	Range of HIT applications	McGee [2006a]
St. Joseph's Hospital, New York	Picture Archiving and Communications System (PACS)	Mearian [2005]
GreenField Health - Oregon	Clinical information system	Kilo [2005]
Baptist Medical Center South - Florida	Clinical support via wireless devices	King [2005]
Oklahoma Heart Hospital - Oklahoma	Electronic health record system	Musich [2005]
Concord Hospital – New Hampshire	E-records project	Mcgee [2005a]
North Bronx HealthCare Network – New York	PACS	Webster [2004]
Harvard Pilgrim HealthCare – New England	Data warehouse for clinical support	Williams [2004]
Humana - Kentucky	Business intelligence for claims analysis	Pratt [2006a]
Fallon Clinic - Massachusetts	Group practice management with electronic health record	Musich [2006]
Children's Hospital of Pittsburgh	Access to clinical information	Clark [2004]
HIP Plan of New York	Automated medical records system	Hulme [2004]
Mayo Clinic - Minnesota	Data mining application	Fonseca [2004]
Geisinger/IBM - Pennsylvania	Clinical decision intelligence system	Mcgee [2006c]

In another example, Kilo [2005] describes the HIT initiatives at GreenField Health in Portland, Oregon. According to the author, patient care required “e-mail connectivity” with the electronic health record. The comprehensive clinical information system included several components such as electronic health record, practice management system, customized encounter forms, disease registries, secure messaging and connectivity, Internet portal for patients, online clinical information, practice decision support, patient decision support, electronic diagnostic technology; scanning, network faxing, interfaces with laboratory, radiology, and hospital systems, medical group intranet, patient e-newsletter and telecommunications systems. However, it must be emphasized that this type of system must facilitate the flow of health information to and from the outside [Kilo 2005].

At Baptist Medical Center South (BMCS) in Jacksonville, Florida, physicians check lab results during their rounds using handheld wireless devices. They can also view X-rays, update charts, order prescriptions and send and receive mail. At the patients' bedsides, nurses use wireless devices to record progress notes and check doctors' orders. If they administer medicine or change a bandage, the supplies they use are electronically tracked and matched by bar code to individual patient records, enabling more accurate patient billing and automatic inventory replenishment [King 2005].

At Oklahoma Heart Hospital in Oklahoma City, caregivers have access to information in the Millennium System, an electronic health record type application, from multiple locations. They can pull up patient information in digital form, including medical images, medications, allergic reaction records, post-operative procedures, and consultations with other doctors [Musich 2005]. At Concord Hospital, a 295-bed, \$450-million-a-year facility in Concord, New Hampshire, an e-records project involves scanning and digitizing hundreds of thousands of pages of health records. McKesson, a medical products company, completed a nine-month medical imaging system project that saved Concord's X-ray films as digital files. Additionally, Concord uses McKesson's bedside bar code system, which has cut drug distribution errors by more than 90 percent [Mcgee 2005a]. Likewise, North Bronx Healthcare Network, one

of six regional networks established by New York City Health and Hospitals Corp. installed a Picture Archiving and Communications Systems (PACS) in the Jacobi Medical Center and North Central Bronx Hospital [Webster 2004]. It is reported as a result of its PACS, North Bronx Healthcare Network saved approximately \$2 million per year by eliminating the costs of film and paper-based reports. In a move towards direct-mediation/high-collaboration, a virtual private network (VPN) would allow outside experts located anywhere in the world can consult in cases.

A specific application in this model is the implementation of a data warehouse by Harvard Pilgrim Health Care, a New England Health Plan to spot disease trends. Each patient visit is coded and symptoms are entered into the system. Patients at risk are recent follow up communication with recommendations on disease management [Williams 2004]. Humana of Louisville, Kentucky uses business intelligence to analyze claims with clinical staff using it to recognize high users and underwriters using it to set group rates [Pratt 2006a].

Fallon Clinic, Worcester, Massachusetts, a group practice with 250 physicians at 20 locations in central Massachusetts was implementing Epic Systems' group practice management solution including an electronic health record system. The purpose was to "streamline manual tasks, improve patient care and save money [Musich 2006]." Their phased approach to implementation indicates a longitudinal progression toward interoperability (from indirect-low to indirect-high): the first phase involved setting up a practice management system including billing and scheduling; the next phase implemented an electronic health record system including laboratory order entry, telephone messaging, and electronic prescriptions. However, while the prescription was created electronically it had to be faxed to the pharmacy. The last phase was expected to set up provider documentation in the examination rooms [Musich 2006].

Children's Hospital of Pittsburgh has envisioned a scenario wherein a physician logs into a program on a laptop computer with a wireless network card that sits on a cart to access all the clinical information on patients, ranging from prior treatments to CT scan images and laboratory test results. Prescriptions are filled out online and transmitted to the pharmacy at another location within the same building [Clark 2004]. Another example of the indirect-low model is the effort of HIP Health Plan of New York, a not for profit health maintenance organization that provides several services including medical, laboratory and pharmacy to approximately 20,000 physicians. Their goal is to develop a "tightly integrated information sharing system for health services." An automated medical records system would form the backbone for this initiative that allows providers to follow up on HIP's one million members as they interact with the providers [Hulme 2004].

The Mayo Clinic in Rochester, Minnesota is also moving from an indirect-low model to a direct-high model with its innovative data mining application. It constructed a data repository to explore the large amounts of medical records that contained clinical information about the millions of patients. It is expected that once the "federated" data sources are integrated the system would perform data mining and diagnostic queries [Fonseca 2004]. Recently Geisinger in collaboration with IBM is building a "clinical decision intelligence system." The plan called for clinical data warehouses and analysis tools to help Geisinger boost the quality of care with data mining and decision support based on its large repository of patient records [McGee 2006c]. The following section gives examples of initiatives that are in the direct-mediation/low-collaboration model ("direct-low").

### Direct-Mediation/Low-Collaboration Model

**Table 2** summarizes the examples that characterize the direct-low model. Permanente, half of Kaiser Permanente, a nonprofit health plan that serves 8.2 million people in the U.S, has for 10 years maintained an electronic database, known as HealthConnect that includes comprehensive information on every patient's medical history, including doctor visits, test results and medications. It provides all its physicians with access to medical records through the database, enables the exchange of email with doctors through secure messaging, and the ability to make appointments online ([www.eetimes.com](http://www.eetimes.com); [ckp.kp.org](http://ckp.kp.org)).

Sutter Health in Sacramento, California, is committed to deploying an electronic health record network by the end of 2007. The new project expands on electronic health record technology already benefiting patients at five Sutter-affiliated physician organizations and hospitals. Caregivers will no longer need to search or wait for patient charts. In addition, lab results and X-rays will be sent electronically to doctors as they are completed, for immediate analysis, diagnosis and treatment. Sutter's sophisticated online system will electronically connect more than 5,000 physicians, 27 hospitals, and millions of patients ([www.sutterhealth.org](http://www.sutterhealth.org)).

According to Gardner [2006], an elderly Pennsylvania woman vacationing in Maine found herself in need of emergency care. When an ER physician sat down to take her complex history and find out what medications she was on, she reportedly offered to log onto the Web and show him the medical record: physicians seen, hospital stays, recent lab results, and so on. The records at myGeisinger.org, the Danville, Pennsylvania, health system, were precisely what he needed [Gardner 2006]. Geisinger, which operates 40 hospitals, clinics and physician



practices in Pennsylvania, has spent \$70 million since 1995 to put an electronic health record system into place at its 40 locations. The project began showing a return on investment after about five years. The physician practices that use the software saw a five to 10 percent reduction in productivity for the first six to eight months but later saw a marked increase in productivity [Havenstein 2006b]. In-patient order entry system for hospitals is envisioned for the future [Sullivan 2006]. Geisinger directors' ultimate goal is to join with other statewide RHIOs to form a larger coalition that will eventually connect into the National Health Information Network (NHIN). This is an example of the gradual evolution of HIT, from electronic health record (direct-low) to a collaborative model (direct-high).

**Table 2. Examples in the Direct-Low Model**

Organization/location	Application, Initiative, Project	Reference
Permanente—Western region	Healthconnect—integrated medical records system	<a href="http://www.eetimes.com">www.eetimes.com</a> clcp.lcp.org
Sutter Health—California	Electronic health record network	<a href="http://www.sutterhealth.org">www.sutterhealth.org</a>
Geisinger, Pennsylvania	Networked electronic health record system—myGeisinger.com	Gardner [2006] Havenstein [2006b] Sullivan [2006]
University of Pittsburgh Medical Center (UPMC)	Integrated E-record system	Landro [2005]
Indiana Heart Hospital	Digital information network	Bowe [2005]
Marriott International	Limited Web-based personal health record system for employees	Mcgee [2008a]
Wal-Mart	E-health records system for employees	Mcgee [2008b]
Intel Corp, British Petroleum	Data warehouse—digital health records	McWilliams [2006]
Aetna	Online access to customers to interact with their health data	Havenstein [2007a]
University of North Carolina	Web-based interoperable health record system	Mcgee [2006b]
Allscripts Healthcare Solutions (vendor)	E-prescription application	Havenstein [2007b]
Kaiser Permanente Veterans Administration	Web-based decision support	Landro [2006]
Montefiore Medical Center, New York	Electronic lab reading & physician order entry system	Whiting [2004]

Over the past decade, the University of Pittsburgh Medical Center (UPMC) has become the largest healthcare provider in Western Pennsylvania, with 19 hospitals, 400 outpatient clinics and doctors' offices and more than a dozen retirement homes and long-term care facilities. The challenge has been to bring those different pieces into the information age, wiring them together into a seamless network. UPMC has committed more than \$500 million to technology that will eventually connect all of its hospitals and offices into the high-tech e-record system. UPMC is presently testing a personal health record system that will allow patients to use a secure Web site to view their test results, interact with their doctors online and help manage chronic conditions such as diabetes and asthma. Integration of the systems at the various hospitals may prove the greater challenge, however. Among the systems being rolled out to UPMC hospitals is an emergency room system called First Net, now used in about 16 percent of emergency department visits to track and triage patients as they enter the ER, expedite their registration and quickly access available medical records. UPMC says the technology has already helped to increase its Medicare reimbursements because of more accurate cost reports and billing. In addition, despite rising drug prices, UPMC has cut pharmacy costs by \$1.5 million at its largest hospital by eliminating duplicated or erroneous prescription orders. UPMC says its IT initiatives have yielded an average annual 10 percent return for the first five years [Landro 2005]. At the Indiana Heart Hospital in Indianapolis, digital information networks are used in admitting and treating patients and maintaining their records. The hospital has become one of the first "true digital hospitals," according to PWG health research by integrating information networks and medical technologies. PWG estimates that the Indiana Heart Hospital experiences 85 percent fewer medication errors; many fewer denials and delays in payment, and 80 percent less than expected in patient chart management costs [Bowe 2005].



In another example of direct-low, Marriott International is setting up a system for its 50,000 U.S. workers that is expected to send alerts to an employee's physician in case there is a potential drug interaction or an important test was missed [McGee 2008a]. It is a limited Web-based personal health record system from ActiveHealth Management, owned by Aetna. Members are expected to complete a health-risk assessment questionnaire in addition to a medical history form.

In yet another example of limited interoperability, direct-low model, Wal-Mart Stores Inc., is installing an e-health records system for tens of thousands of its employees and their dependents in conjunction with Dossia, a consortium of eight large employers including Intel and AT&T [McGee 2008b]. Intel Corp. and British Petroleum have also planned to store the digital health records in a data warehouse that would link hospitals, doctors and pharmacies [McWilliams 2006]. The strategy calls for each company to construct a data warehouse to store and update the e-records. Employees could potentially order prescriptions and computer their out-of-pocket costs utilizing software that recognized their particular health plan.

Aetna too had planned to launch a system to provide its 15 million customers with online access to their health data. The system was expected to let customers' access health data gathered from claims and other sources as well as enable them to update their own records with data for vital signs [Havenstein 2007a].

In another example of direct-low, University of North Carolina Healthcare System has deployed a Web-based health record system that lets 7,000 caregivers across several hospital inpatient units and dozens of outpatient clinics and other settings access medical data for more than 1 million patient visits annually. Using Web-based secure single sign-on, UNC Health Care's 2,000 physicians have off-site access to patient data including lab reports, medical imaging, scheduling, disease prevention applications, and patients' hospital progress notes. UNC uses the IBM Health Information Framework, a standards-based SOA that allows connectivity between disparate systems. Improved patient safety and cost savings have been key benefits since UNC Health Care deployed its electronic clinical systems. Automated drug ordering for inpatients has decreased potential drug errors by 70 percent. Meanwhile, a transition away from written notes and dictation to online physician notes and voice-recognition applications has saved the provider about \$4.5 million over the last two and a half years [McGee 2006b].

It is reported that a consortium of technology companies, healthcare providers and insurance companies have developed a multimillion dollar program via which all physicians in the U.S. will be offered free access to software to automate the medication prescription process [Havenstein 2007b]. The software from Allscripts Healthcare Solutions, Inc, Chicago automatically verifies a prescription for patient allergies or potential interactions with other drugs prior to prescription being sent to a pharmacy.

Kaiser Permanente and the Veterans Administration have initiated enterprise wide efforts to implement Web-based "decision support" programs to assist physicians with the diagnostic process including ordering tests, developing follow up plans and performing appropriate physical exams [Landro 2006]. Montefiore Medical Center in New York City was an early implementer of electronic laboratory recording and physician order entry systems. Additionally, physicians there utilized wireless laptops and handhelds to prescribe medications and verify test results [Whiting 2004]. However, the system was designed for internal operations and did not access external pharmacies or laboratories. The next section gives examples of applications in the indirect-mediation/high-collaboration model ("indirect-high").

### **Indirect-Mediation/High-Collaboration Model**

Examples of the indirect-high model are summarized in Table 3. Blue Cross Blue Shield of Massachusetts has budgeted \$50 million for a regional pilot for an e-health records program that could serve as a model for the rest of the state [Mcgee 2004c]. The project entailed peer-to-peer communication in which patient data such as laboratory results could be shared among various providers without changing the ownership of source data.

In a generic example, COVISINT, the Compuware Corporation Subsidiary, plans to launch a portal to serve Michigan's healthcare industry, signing Blue Cross Blue Shield of Michigan (BCBSM) as the first licensee. The portal aims to let healthcare professionals, hospital networks, insurers, and companies that use those insurers automate business transactions and share information via the Internet. Conveniences include real-time claims processing and insurance-eligibility authorization, as well as access to healthcare and benefits programs research data and electronic medical records. The COVISINT portal is part of BCBSM's plan to invest between \$200 million and \$300 million to modernize its IT infrastructure. When the nonprofit company adds electronic prescriptions to the platform in 2007, it will reduce errors and improve safety for patients [Sullivan 2005]. McGee [2008c] also reports on the setting up of a hosted infrastructure in Tennessee by Covisint and AT&T to enable healthcare providers and payers to "securely" share patients' clinical and administrative data. It allows for broadband access to the Covisint OnDemand platform, a hosted service that is expected to use a VPN-based portal. Called the "eHealth Exchange Zone" it is

expected to enable Tennessee's six regional health information organizations and other physicians and hospitals to access telemedicine services and share digital patient data including prescriptions and lab records [McGee 2008c].

**Table 3. Examples in the Indirect-High Model**

Organization/location	Application, Initiative, Project	Reference
Blue Cross Blue Shield—Massachusetts	E-health records program with peer-to-peer communication	Mcgee [2004c]
COVISINT—portal Blue Cross Blue Shield of Michigan	Electronic medical records	Sullivan [2005]
Tennessee eHealth Exchange Zone - COVISINT	Securely share patients' clinical and administrative data	Mcgee [2008c]
RelayHealthCorp Platform (vendor)	Secure Web site & messaging platform for electronic exchange – E-visits	Mcgee [2004b]
iHealth Alliance	Online network for e-mail alerts to physicians on drug warnings	Rubenstein [2008]
Surescripts Messenger Services (vendor)	Online network for electronic prescriptions	Ferguson [2003]
Baylor Healthcare System—Dallas	Integrated view of patient data	Havenstein [2007c]
NewYork Presbyterian Health Care System	Collaborative network	Havenstein [2005]
Chicago Dept. of Public Health	Java-based system for infectious disease monitoring	Havenstein [2005]
New York City	Software to allow physicians to track patients' medical records; also aggregate data for city use	Santora [2008]
Google	Online repository of consumer health data	Lawton & Worthen [2008]
Google and Cleveland Clinic, Ohio	Secure sharing of medical information between Cleveland Clinic system and Google health profile online system	Lawton [2008]
Health Banking Record System Proposal		Gold & Ball [2007]
Microsoft	Healthvault—storage and sharing system for individuals	<a href="http://www.healthvault.com">www.healthvault.com</a>

Many physicians are also using e-visit capabilities since insurance companies such as Blue Cross Blue Shield of Massachusetts, Blue Cross Blue Shield of Tennessee and Group Health in New York have started to reimburse for e-visits [McGee 2004b]. A secure Web site and messaging platform that supports electronic exchange among physicians and patients hosted by RelayHealth Corp. allows verification of patient insurance eligibility and electronic payments. Participating physicians pay RelayHealth per month for the service.

In another example of indirect-high, a nonprofit group called the iHealth Alliance is reported to have started an online network that would send email alerts to physicians who sign up regarding notices from pharmaceutical companies about drug warnings and label changes [Rubenstein 2008]. The physicians can get updates by accessing a Web site called the "Health Care Notification Network." An option for patients too is to set up an online personal health record at [www.ihealthrecord.org](http://www.ihealthrecord.org). Patients can receive updates on drugs they are taking.

An additional example of an indirect-high model is an online network that supports an electronic prescription system. The platform, SureScripts Messenger Services can be accessed by pharmacies [Ferguson 2003]. The goal is to facilitate "accurate drug interaction checking," "error-free prescription filling," and the "adoption of clinical data standards."

A recent report announced that Baylor Healthcare System had completed the initial phase of an initiative to connect "fragmented" data from its "disparate" systems to establish a "360-degree" of its patients [Havenstein 2007c]. Their objective was to develop an "enterprise" view of data for its patients at the 12 hospitals in the Dallas area. According

to Baylor, the long-term goal is to link data from multiple sources in the healthcare network forming the foundation for a comprehensive medical record.

Havenstein [2005] reports on two large-scale efforts to implement automated systems for data exchange: the first is New York Presbyterian Healthcare System, a federation of hospitals and nursing homes which is constructing a “collaborative network” to allow five of its acute-care hospitals to “share” quality-of-care information with each other; the second is the Chicago Department of Public Health’s plan for a Java-based system designed to spot and respond to infectious diseases’ outbreaks.

In a recent announcement, New York City mayor Michael Bloomberg said that the city would promote software that would allow physicians to track patients’ medical records for more effective preventive care [Santora 2008]. The system is expected to integrate a patient’s medical history, laboratory results and current medications into a single interface. More importantly, the system is expected to allow physicians to share data and also enable the health department to obtain “general data from healthcare providers on, say, how well patients are controlling their blood pressure [Santora 2008].”

Recently Google announced an online repository wherein consumers could store their health data [Lawton and Worthen 2008]. In this service, consumers can enter their own health data and also “invite” their physicians to electronically transmit information to the repository. It is also reported that Google and the Cleveland Clinic have formed a partnership to give patients the ability to securely share medical information including “prescriptions, conditions and allergies” between the Cleveland Clinic system and the Google health-profile online [Lawton 2008].

Another example is the proposal by Gold and Ball [2007] to develop the Health Banking Record system whose “objectives include uninterrupted access to patient records, maintenance of the rights of the consumer to control his or her personal health data, and provision of a means for storing all electronic health records and data in fail-safe, readily accessible, secure, and restricted repositories.” This is similar to the HealthVault initiative by Microsoft, which is a “storage and sharing system that uses privacy and security, enhanced measures, and through which people can interact with health-related services and devices.” The objective is to bring the “health and technology industries together to place people in control of their healthcare while enabling seamless exchange of information among hundreds of health services and devices (<http://www.healthvault.com>).” According to Microsoft the Health Vault would enable individuals to “collect their health information from many sources, store it in one place, and share it with whomever they choose, designed to greatly reduce unnecessary confusion, paperwork and delays.” Overall, these are very large scale projects aimed at the universe of healthcare. The following section provides examples of initiatives in the direct-mediation/high-collaboration model (“direct-high”).

### Direct-Mediation/High-Collaboration Model

The examples of the direct-high model are summarized in Table 4. An example of an integrated project is the MedsInfo-ED, “a proof-of-concept clinical data exchange project that uses prescription claims data to deliver patient medication history to emergency department clinicians at the point of care [Gottlieb et al. 2005].” According to the authors the goal of the project was to act as a prototype application for the “building and testing a community clinical data exchange model that uses available technology and operational solutions for improved quality and patient safety outcomes.” The large-scale nature of this project is evidenced by the fact it was sponsored by the Alliance for Health Care Improvement, a consortium of six Massachusetts-based health plans. The payers’ data sources accessed MedsInfo-ED either via a direct connection using a Web service query to the payer’s prescription claims database or a pharmacy benefit manager (PBM) consolidator model with Rx Hub (consolidated access to two that represented three of the participating health plans [Gottlieb et al. 2005]. Another example is a syndromic and disease surveillance system called “The Snow Agent System.” It is a distributed system for monitoring the status of a population’s health by distributing a process to, and extracting epidemiological data directly from, the electronic health record system in a geographic area [Bellika et al. 2007].

An example of a regional network moving toward full interoperability is the MHDC (Massachusetts Health Data Consortium) whose objective was to “develop a system for collecting, organizing and disseminating data on all hospital care in the state [Halamka et al. 2005a].” The expectation was for various “competing hospitals” in Massachusetts to “share their deidentified discharge data with a third-party organization that would normalize and redistribute the data for aggregate analysis,” with the result that standards were enforced for data collection and hospitals collaborate with each other. Another project in this regional initiative was NEHEN (New England Healthcare Electronic Data Interchange Network) involved three provider entities (Partners Healthcare, CareGroup and Lifespan), two payer entities (Tufts Health Plan and Harvard Pilgrim Health Care) with Boston Medical Center, University of Massachusetts Memorial and Boston Children’s Hospital joining later. Millions of administrative transactions were exchanged for 25 cents per transaction. Additionally, the MA-SHARE was initiated to promote “improvement in community clinical connectivity, enabling appropriate sharing of interorganizational healthcare data

among the various participants in the healthcare system, including patients, clinicians, hospitals, government, and payers.” The overall goal was to support secure clinical data exchange. The last project in the regional initiative was MAeHC (Massachusetts eHealth Collaborative) whose objective was to “ensure wiring to the last mile of the provider office.” This was in recognition of the fact that only 15 percent of the providers in Massachusetts used electronic health records [Halamka et al. 2005a].

**Table 4, Examples in the Direct-High Model**

Organization/location	Application, Initiative, Project	Reference
MedsInfo-ED	Community clinical data exchange project	Gottlieb et al [2005]
The Snow Agent System	Syndromic diseases and surveillance	Bellika et al [2007]
MHDC NEHEN MA-SHARE MAeHC	Massachusetts Health Data Consortium New England Healthcare Electronic Data Interchange Clinical connectivity Massachusetts eHealth Collaborative	Halamka et al [2005a]
Centers for Disease Control and Prevention	System to send real-time data feeds from emergency rooms to the CDC	Havenstein [2006a]
GPHIN - Canada	Global Public Health Intelligence Network	Songini [2006]
Foundation for E-health Initiative	Community Learning Network—framework for sharing clinical and health related financial data	Mcgee [2004a]
Santa Barbara County Care Data Exchange Taconic IPA—comprehensive practice-oriented health information infrastructure Indiana Health Information Exchange (IHIE) Mid-South eHealth Alliance—Tennessee	Regional health information networks	Frisse [2005]
PHIN	Public Health Information Network	Loonsk et al [2006]
Denmark	Danish National e-Health Portal	Pratt [2007]
National Cancer Institute (NCI)	caGrid 1.0—NCI Cancer Biomedical Informatics Grid (caBIG)	Oster et al [2008] Pratt [2006b]

In the public sector, the Centers for Disease Control and Prevention has begun work with 31 hospitals in 10 large cities to create a system that can send real-time data feeds from emergency rooms to the CDC. The hospitals send data including patient symptoms, diagnoses and geographic information over the Internet as Web services messages using the ebXML standard [Havenstein 2006a].

The nonprofit Connecting for Health launched a prototype project to demonstrate how regional health information networks (RHINs) in individual states or cities potentially can interconnect into a national highway of health information exchanges via the Internet. The prototype exchange does not create a centralized repository of clinical information but rather allows authorized clinicians access to patient information wherever it resides [Mcgee 2005b]. For example, a hospital on the outskirts of Boston will electronically share data on a patient’s medication history, while a facility in Indiana provides lab results with a hospital in rural Mendocino County in California.

In the wake of recent pandemics, the Public Health Agency of Canada has established the Global Public Health Intelligence Network (GPHIN) which functions as a secure, Internet-based early warning system. The Java-based software has a search engine that continuously searches for news reports of significance to public health. The data is automatically filtered for relevance, analyzed by GPHIN officials and made available via reports and other mechanisms to interested parties including World Health Organization (WHO) personnel. In the future, more sophisticated systems will help assess and cross-reference each patient, track the length of time spent in the



hospital or in quarantine and give an end-to end picture of the operations of a pandemic over various regions [Songini 2006].

The Foundation for E-health Initiative has launched a site, called the Community Learning Network, for health communities building infrastructures that exchange health information electronically. Much of the technical, clinical, financial, and legal information on the site comes from community healthcare providers and organizations that have built frameworks for sharing clinical and health-related financial data. Contributors include the Regenstrief Institute, which several years ago created an electronic exchange through which Indiana physicians share clinical information, and the New England HealthCare EDI Network, a consortium of 20 health companies and payers that have built an infrastructure for electronic administrative process. The resource center additionally includes a forum for physicians, hospitals, policy members, and researchers to exchange ideas [Mcgee 2004a].

Frisse [2005] describes several HIT initiatives involved in interoperability. For example, the Santa Barbara County Care Data Exchange was among the first community-based approach to connectivity. The initiative was funded by the California Health Care Foundation (CHCF) and started in 1998. The overall goal was to coordinate the care of county residents across a broad range of care settings. The model was “based on a distributed point-to-point transaction system supporting individual and community health needs.” In New York, the Taconic IPA (independent practice association) utilized its “physician base as a core for a comprehensive, practice-oriented health information infrastructure” that included clinical information systems and secure networks. In addition, hospitals, clinical laboratories, health plans, and pharmacies subscribed to the network for more effective communication with practitioners. It is reported that IPAs in Colorado, Oregon, and other states have started to implement similar models. The Indianapolis Health Information Exchange (IHIE) initially used its central database at the Regenstrief Institute to increase the value of clinical communication to a limited number of practitioners, public health agencies, and hospitals. The IHIE is now used by several thousand physicians and staff. In Tennessee, the Mid-South eHealth Alliance is a comprehensive health information initiative that serves three counties in southwest Tennessee. It evolved from an initiative to achieve interoperability among information systems used by the state’s largest public hospital and more than a dozen of the region’s ambulatory care facilities. It could be integrated with a wide range of clinical data repositories and provider chosen ambulatory care practice systems [Frisse 2005].

.Another example of a public health initiative with direct-high features is the Public Health Information Network (PHIN), a national multi-organizational business and technical architecture for public health information systems [Loonsk et al. 2006]. The goal of this project is to “elevate the capabilities of public health information systems and integrate them across the variety of organizations that participate in public health and the wide variety of public health functional needs.” This would ultimately result in “a consistent national network of preparedness systems.”

Another example of a large-scale initiative in this quadrant is the Danish National e-Health Portal, a national initiative that enables approximately 150,000 “healthcare professionals” and all Danish residents to access the general and detailed personal healthcare information online [Pratt 2007]. The project is believed to have “increased communication among doctors and between doctors and patients; it has also increased collaboration among healthcare providers, boosted efficiencies and even improved the quality of care.” The key to its success is the phased approach that was adopted. The information portal was launched in 2003; this was extended to collaboration finally resulting in complete communication. This included the feature to monitor and share the patients’ health records online.

An interesting infrastructure that belongs in this quadrant is the caGrid 1.0, which underlies the service-based Grid infrastructure for the National Cancer Institute (NCI) Cancer Biomedical Informatics Grid (caBIG) program [Oster et al. 2008; Pratt 2006b]. The caBIG program was set up to “implement the enabling information technologies so that researchers can more efficiently share, discover, integrate, and process disparate clinical and research data resources with the overarching goal of accelerating cancer research.” This was imperative because there is a large number of “cooperative groups” and “large scale collaborative projects” such as the Integrative Cancer Biology Program (ICBP) and data resides at these multiple entities. Interoperability, then being a key challenge, the caGrid infrastructure was designed to enable interoperability between “disparate and geographically distributed data and analytical resources, support secure electronic data interchange, and enable information discovery in a distributed environment.”

One of the biggest initiatives of the direct-high model is the U.K. National Health Service project, a multi-billion dollar effort to provide electronic patient records, e-booking, e-prescribing and electronic ordering of tests in what is perceived to be the world’s largest single-payer government sponsored project. It is expected to cover all 50 million patients and the one million staff. Additionally, the project is expected to replace X-ray films with digital images, making possible remote consultations [Clark 2004].



## Summary

Our content analysis of the numerous applications, initiative and projects show that healthcare delivery organizations are implementing HIT on a continuum from indirect-mediation/low-collaboration to direct-mediation/high-collaboration. The indirect-low model is characterized by ad-hoc applications or applications interfacing with manual systems; these are mostly internal to the organization with negligible interaction with the outside. The direct-low model, a progression over the indirect-low comprises of applications that are more interactive and focused on healthcare delivery (in contrast to administrative applications); additionally, applications in this quadrant interact with other applications, both within and outside the enterprise with limited interoperability. The third quadrant, namely, indirect-high, while still consisting of activities in the processes contributing indirectly to a healthcare process, shows more interoperability evidenced by interactions with numerous outside providers and participants. The most desirable model is direct-high—while most providers would ultimately link into various networks, presently, projects in this model are mainly large-scale efforts initiated at the state or country level. Organizations would, therefore, progress from an indirect-low model to a direct-high model over time.

## VI. SCOPE AND LIMITATIONS

Our study is not without limitations. First, our research is qualitative and was not subjected to empirical testing. Content analysis was performed on a large number of HIT implementation reports that were publicly available but are secondary sources of data. Second, the authors drew on their background and expertise in HIT to classify the various projects into the strategic framework. Some projects may have been misclassified or the characteristics were not delineated clearly enough to put them into the most appropriate quadrant. Third, the study is limited to the development of the strategic framework. We do not address peripheral issues, such as development mode, organizational issues, and impact on medical practice, security, privacy or the risk of undertaking large-scale implementations [e.g. Kaiser E-health System; Rosencrance, 2006], which are beyond the scope of this study. Nevertheless, the study is sufficiently extensive so as to draw important conclusions. Future research can focus on surveys, case studies and other empirical studies for additional validation.

## VII. CONCLUSIONS

While HIT has the potential to deliver high quality care at lower costs, healthcare delivery organizations face several hurdles. The complexity of the healthcare process is just one of them. There is also the high cost of implementation as well as the limited availability of time to build this technology. Additional challenges include the need for development of open standards and the management of security and privacy. The average time for implementation of HIT ranges from two to 10 years. Further, one can assume a faster migration pathway of HIT into hospitals than into small clinics or nursing homes, given that many hospitals have some EHR system capabilities already in place, while most small clinics and nursing homes do not. Also, hospitals generally have greater access to technical expertise and financial resources [IOM 2003].

Development tools such as agile methodologies and service-oriented architectures are used more and more frequently, but there still is a need for a strategic framework that will provide healthcare executives and systems developers a high-level view of what constitutes strategic HIT applications and that will show them a path to full functionality and interoperability and participation in healthcare delivery. The charting of the strategic path described here will help evolve and manage the development process. The framework provides a basis for positioning an organization's HIT infrastructure. The evolution of the HIT infrastructure can be tracked in the organization. For example, organizations may evolve from an electronic medical record to a longitudinal electronic health record over time. Simultaneously the framework can help identify the potential changes to the workflow and the appropriate level of desired interoperability in the organization.

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