High Performing Hospital Enterprise Architecture: insights from a multi-method exploratory case

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Abstract – The US healthcare system is a critical infrastructure grappling with as much as 16% of the GDP in its expenditures and unsatisfactory outcomes, and undergoing considerable public scrutiny. High ranking officials have both singled out the US healthcare system as the most expensive and among the least effective in the developed world. Hospitals hoping to find "*The Toyota Way*" so as to rid themselves of waste through lean and six sigma improvement initiatives, have mostly focused in applying tools at a process level, rather than adopting an enterprise perspective and understanding the full breadth of their socio-technical complexity. This paper adopts a systems thinking approach in describing a leading Boston hospital's enterprise architecture through a multi-method exploratory case. The initial exploratory question proposed by hospital senior leadership was "*How to speed patient flow in the Emergency Department*?", however as results became available, the scope was expanded to include the whole hospital enterprise. Both qualitative and quantitative data evidence were collected through a variety of methods, namely observation, archival records, documentation, and interviews. Analysis includes techniques consistent with the grounded theory approach, as well as more traditional quantitative data analysis. Hospital enterprise performance is hypothesized to be related to hospital enterprise architecture, and an alternative hospital enterprise architecture is proposed as well as future work.

I - Introduction

The US healthcare system is a critical infrastructure grappling with as much as 16% of the GDP in its expenditures and unsatisfactory outcomes while undergoing considerable public scrutiny [1]. High ranking officials have both singled out the US healthcare system as the most expensive and among the least effective in the developed world [2]. In fact, the president of Johns Hopkins University was quoted: "*Simply stated, the US does not have a health care system*" [3] as he alluded to the highly fragmented nature and variation of billing, care provision, accountability, safety etc inherent in the delivery of care.

The key categories often referred to when assessing the performance of the healthcare system are access, quality, and cost. In terms of access, an estimated 15% of the US

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population is uninsured [4], as much as 75% of care providers practice alone or in groups of five or fewer [5]. As for quality, adults on average are said to only receive as little as 55% of the recommended care for many common conditions [6], and as many as 98,000 annual deaths are attributed to medical errors [7]. Finally, as previously mentioned the US spends 16% of its GDP on healthcare expenditures, including 30 – 40% of US healthcare spending which is believed to be wasteful [8], and the largest source of expenditure, namely over 30%, is hospital expenditures [1]. Consequently, the strategies and operations developed and implemented by hospitals have a significant effect on access, quality, and cost of care [9].

In the 90s, faced with a similarly turbulent environment in the US automotive industry, researchers at the Massachusetts Institute of Technology (MIT) studied at length 52 assembly plants in 14 countries over a five year period to explore the significant performance gap between Japanese and Western automotive organizations [10]. They coined the term *lean* when describing their finding that Japanese companies had a manufacturing system in place that built greater customer loyalty and strived for continuous quality improvement and doing so at a lower cost. Since then several academics and practitioners have studied Japanese companies in detail and developed recipes for lean success, most notably "*The Toyota Way*" [11]. As a result other industries began to take notice and wondered about finding their Toyota way. However, often times the majority of lean and other improvement methodologies are reportedly unsuccessful [12,13,14] and the US healthcare industry in particular was said to have "*No Toyotas*" [15].

This paper builds on a brief review of the literature concerning failed lean implementations, and while adopting an enterprise perspective with a focal point in healthcare's highest source of expenditure (i.e. hospitals), follows a systems thinking approach in studying a leading Boston hospital's enterprise architecture (EA) so as to derive a richer understanding of its underlying socio-technical complexity. The research methodology is informed by Tien's [16] characterization of the services sector from a system's perspective which offers that modern systems-of-systems (SoS) are becoming increasingly more human-centered, and hence more complex, thus requiring a multidisciplinary approach including techniques from the social sciences and management, as well as those of science and engineering. To that effect, enquiry uses traditional analysis tools (e.g. value stream maps, patient flow statistical analysis, etc) as well as techniques from social sciences and management (e.g. grounded theory, case study, etc), while guided by an emerging holistic enterprise architecting framework under development at MIT [17,18]. An effort is made throughout the paper to convey the exploratory nature of the research while describing the expanding scope of analysis and the insights from the use of complementary methods, while managing the research project organizational sponsorship for complex system enquiry.

The paper is composed of six sections. Following this introduction, the second section provides an overview of reported success and failure of lean in healthcare, and refers to the literature for diagnostic insights. In the third section, we make the case for a systems thinking healthcare approach and introduce an emerging holistic EA framework which

helped guide the exploratory case. A description of the hospital sample and research methodology is given, including problem statement, data sources, analysis, and exploratory approach in the fourth section. Section five includes the results of the hospital's "*As Is*" EA characterization, followed by analysis that culminates in a proposed "*To Be*" EA. Finally, section six summarizes findings and offers avenues for future research.

II - Hospitals and the *elusive* Toyota Way

Considering the great visibility that *The Toyota Way* [11] has had in the marketplace, today one would be hard pressed not to find a hospital in the US which isn't aware of lean principles and considering the implementation of some kind of lean program [19]. Different experts vary in their enthusiasm when describing the success hospitals have had so far in their improvement efforts. Table 1 below features some of the experiences most consistently reported.

Table 1: Frequently reported success cases

Reference	Case
[20]	The Virginia Mason Medical Center decreased the number of ventilator-associated pneumonia from 34 cases with 5 deaths in 2002 to 4 cases with 1 death in 2004. They have also made space utilization improvements in their cancer center and are now able to see 57% more of patients in the same original space.
[21]	A cohort of hospitals in Pittsburgh reduced the amount of central line associated blood stream infections by 68% on average
[22]	A pre-surgery nursing unit at Western Pennsylvania Hospital in Pittsburgh reduced the time for registering patients from 12 to 60 minutes to only 3 minutes, and also reduced the number of unnecessary blood bank reports issued from 10 to 11 a day to 0 a day
[20]	The Park Nicollet Health Services (PNHS) in Minneapolis, Minnesota, improved the number of CT and MRI scans performed per day by 2 and 1, as well as reducing the waiting time of urgent care patients from 122 to 52 minutes

Observing the level of the results reported one begins to understand why there are those who go as far as saying that there aren't any Toyotas in healthcare, and that the reported successes have been limited in scope, duration, and impact [15]. Similarly, and in a domain independent fashion, we are reminded that while on one hand the "*number of tools, techniques and technologies available to improve operational performance is growing rapidly, on the other hand, despite dramatic successes in a few companies most efforts to use them fail to produce significant results*" [14].

Various authors have offered different views to explain this lack of generalized significant results. Some argue that one should not draw correlations from the automotive industry to other industries as there are fundamental differences in conditions [23]. Along those lines and in healthcare in particular, others have noted that there isn't any single customer to focus the improvement on and that instead many 'customer' communities exist and present a complex and fragmented scene, thereby hindering improvement initiatives [24]. Others point out that even though organizational officials claim to

implement lean, they are only implementing one or two of the elements [25], while solely focused at the process level [26] and often times within individual silos [27], instead of adopting a broader mindset beyond the 'shop floor' and across the whole enterprise [28].

Admittedly the importance of considering multiple stakeholders as well as adopting a holistic approach that cuts across hospital silos, has began taking hold in the healthcare process improvement literature [29]. However, although the scope of hospital interventions are beginning to be enlarged, they are still insufficient if one wishes to strive for long term sustainability. With that in mind Liker and Morgan [19] argue that one needs "*a true systems approach that effectively integrates people, processes, and technology [and that what makes Toyota work] is that all the pieces fit together and support each other.*" Moreover, Donald Berwick, chief executive officer of the Institute for Healthcare Improvement (IHI), emphasized that the problem of healthcare redesign becomes increasingly "*harder and the evidence weaker as one moves from the microsystem to the organization*" [30][4]. There is thus an opportunity to adopt a systems thinking approach and address this call for an enterprise perspective that is capable of furthering our understanding of the socio-technical complexity of healthcare's critical infrastructure.

III - Systems Thinking, Enterprise Architecture, and Frameworks

The field of engineering systems has evolved over the past decade and embodies an integrated holistic view of large-scale, technologically-enabled complex systems, which have both significant enterprise level interactions as well as socio-technical interactions [31]. Within this field a key area of inquiry has emerged and focuses itself in understanding how to characterize, architect, integrate, manage, and transform large scale enterprises, with careful appreciation for their overall environment [18] which is consistent with open systems thinking [32].

Architecture as defined by the IEEE P1471 Standard is "*the fundamental organization of a system embodied in its components, their relationships to each other and to the environment*". The Systems Architecture Working Group of the International Council on Systems Engineering [33] defines architecture as "*the fundamental and unifying system structure defined in terms of system elements, interfaces, processes, constraints, and behaviors*". Several other definitions exist and there isn't a singular and agreed upon definition of architecture related to enterprises or systems, but they do share a common abstract approach to accommodate different levels of system complexity and represent order, interactions, and relationships amongst system elements.

Enterprise Architecture (EA) similarly shares a breadth of definitions in the literature however these have predominantly been related to the development and implementation of information systems. Two illustrative definitions include: Morganwalp and Sage [34] "*[EA explains] how all the information technology elements in an organization – systems, processes, organizations, and people – work together as a whole*; and. the Systems and

[4] The microsystem refers to the care given at service unit level (e.g. emergency department), whereas the organization is the care provider facility (e.g. hospital) that supports one or more microsystems.

Software Consortium [35] "*EA relates organizational mission, goals, and objectives to work processes and to the technical or IT infrastructure required to execute them.*" However, others take a broader interpretation of EA considering the enterprise in a holistic manner and not just its information technology related infrastructure [36, 37, 38].

Architecture Frameworks are not in themselves an architecture and are used as a plan of how to organize and represent an EA [38]. As such, they are tools for managing complexity by establishing standards for the descriptions of architectures [39]. Furthermore, frameworks facilitate comparative evaluation of alternative architectures for the same enterprise [36,40]. Several EA frameworks have been developed and are different in nature as they reflect the above mentioned EA meaning variation. An understanding of the structure and function of other architecture frameworks is useful and is evident in the varying degrees of analysis of various architecture frameworks that can be found in the literature [39,41,42,43,44]. Ultimately, scholars have conveyed that "*the practice of enterprise architecting and transformation has yet to encompass a more holistic paradigm, largely continuing to be performed from a single 'lense' approach*" [18] and referred specifically to the information technology focus [45], the process re-engineering focus [46], and the organizational transformation focus [47]. These scholars argue that in order to meet the challenges of complex systems-of-systems in the long run, and beyond mere aggregation of multiple lenses, one needs to adopt a holistic architecture approach [18].

To that effect, Nightingale and Rhodes [17] have devised a holistic **EA Framework** that adopts an engineering systems perspective and encourages the study across multiple lens interactions to identify critical relationships that affect the enterprise as a whole. The framework is shown in Figure 1, and having emerged mainly from preliminary generalized results based on several years of empirical studies, it is currently being enriched with both theory and additional exploratory work such as the one presented in this paper. Table 2 below provides a brief summary of each of the views embodied in the framework.

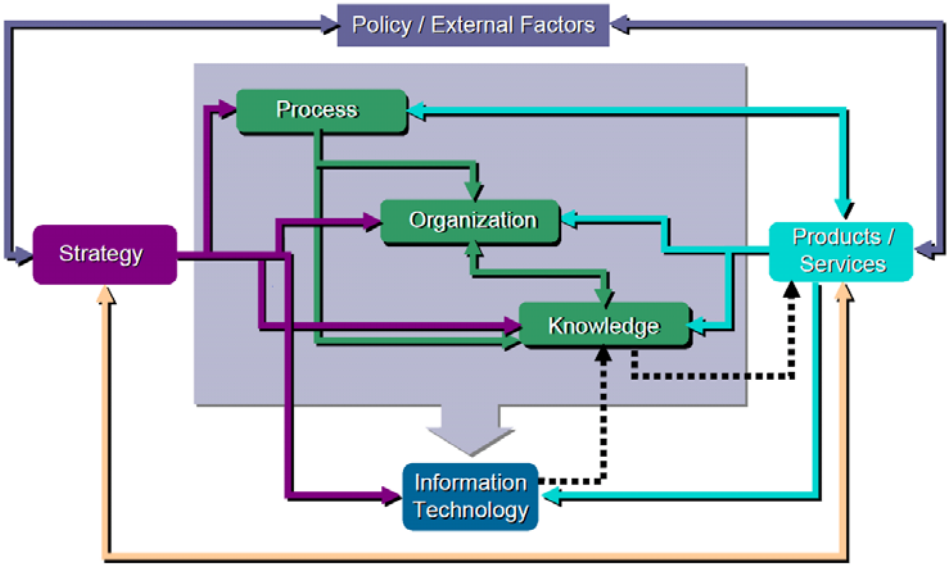

Figure 1: A Holistic EA Framework [17]

Table 2: Views of an Enterprise [18]

Views	Description
Strategy	Goals, vision and direction of the enterprise, including business model and competitive environment.
Policy/ External Factors	External regulatory, political and societal environments in which the enterprise operates.
Organization	Organizational structure as well as relationships, culture, behaviors, and boundaries between individuals, teams and organizations.
Process	Core processes by which the enterprise creates value for its stakeholders.
Knowledge	Implicit and tacit knowledge, capabilities, and intellectual property resident in the enterprise.
Information	Information needs of the enterprise, including flows of information and systems/technologies for information availability.
Product	Products produced by the enterprise for use by its stakeholders.
Services	Services of the enterprise, including services as a primary objective or in support of product.

When taken together the EA Views allow one to better characterize the context of a particular enterprise. A simple example is given in Table 3 below in relation to a hospital's EA. The remainder of this paper will present an in-depth multi-method exploratory case conducted at a leading Boston hospital while using the above mentioned framework as an exploratory guideline.

Table 3: Hospital EA Overview

EA View	Description
External/ Policy	Some of the major external factors shaping hospital strategy include: economic and demographic trends; regulation; public and private purchaser behavior; plan and hospital market characteristics (i.e., number and type of competitors); payment methods; technology; and labor supply [48]
Strategy	Faced with a turbulent environment hospital administrators need to determine whether to pursue complexity reduction or rather complexity absorption strategies [49] and which strategically important clinical issues to pursue [50].
Process	Hospital operations need to run smoothly and safely whilst supporting a continuous care giving process across and between multiple visits by the same patient (i.e. continuum of care). Interdependences are seldom pooled, and more often sequential and/or reciprocal [51].
Organization	Physicians enjoy significant degree of autonomy and tend to concern themselves with their specialty and focus on their own incentives. Multiple organizational forms are present (service lines, service units, and pathways) thus adding to the complexity in coordinating nurses, physicians, and others.
Knowledge	Over 10,000 randomized controlled trials are published annually [52] making it difficult for care givers to remain up to date [53]. Additionally, significant knowledge about individual patients is captured by different people who need to somehow create a joint patient health profile.
Information	Quality measurement and improvement have been strongly affected by progress in information systems, computer technology, and communication techniques [54], and as organization becomes more complex the greater the information processing requirement [55].
Product/ Service	Provide tertiary level care, invest in medical training, offer competitive prices, and enhance quality of service.

IV - Research Methodology

The study of EA from a holistic standpoint is in a nascent phase, as such Rhodes [56] states that there is an urgent need for empirical studies of an exploratory nature so as to obtain preliminary findings, heuristics, and researchable hypotheses towards attaining more effective systems engineering practices. Concerning healthcare enterprises in particular, Tien's [16] characterization of the services sector from a system's perspective offers that modern SoS are becoming increasingly more human-centered, and hence more complex, thus requiring a multidisciplinary approach including techniques from the social sciences and management, as well as those of science and engineering.

The research methodology derived for this paper is consistent with these recommendations in that an in-depth multi-method exploratory case was conducted at a leading Boston hospital while using the previously mentioned holistic EA Framework to guide our inquiry. We next describe our case sample, followed by the enterprise's problem statement, as well as the quantitative and qualitative methods used, and finally we also give an overview of the case exploration to better situate the analysis and the reader.

A. Exploratory Case Sample

The Greater Boston Hospital (GBH is a disguised name of the studied enterprise) has consistently been ranked by various 3rd parties as a top 1% acute care provider in the US. GBH is a non-profit medical center and teaching hospital with a longstanding culture of specialized teams directly available to individual patients from local community and elsewhere. In 2006 the hospital derived over $600 million in income, which led to an operating income (loss) of nearly $51 million. With over 4000 staff and close to 300 patient beds, they have national and international recognition in particular for their Cerebrovascular Disease Center, Liver Transplantation Team, and Heart & Vascular Center. Furthermore, GBH plays a significant role in clinical trials for new diseases therapies, and hosts residency and fellowship programs.

B. Problem Statement and Initial Exploratory Question

Emergency Department (ED) overcrowding has become a common problem in the US as well as in other developed countries, up to the point where patient safety is considered to be at risk since healthcare systems are unable to provide timely and adequate emergency services. The volume of high acuity patients and the volume of patients that are later admitted to the inpatient units within hospitals are two of the major factors reported as the causes of ED overcrowding [57,58]. The interaction between these two factors is in essence a representation of the healthcare care provider architectural strength. Upon discussions with senior management at GBH, we identified that ED overcrowding was an ongoing platform and we were asked to focus our exploratory work there. Amid an environment where EDs were being closed down elsewhere, GBH was finding itself without capacity to handle the increasing demand which in 2006 alone saw over 38,000 ED patient visits. Visible bottlenecks had begun to arise such as the waiting time for initial diagnosis, and the waiting time to be physically admitted to the inpatient ward. There were multiple causes immediately identified for this situation, and some fell in the realm of internal organization. For instance patients may have been discharged from the

ED and admitted to the hospital, however they remained within the ED because the specific ward within the hospital did not have a bed available for them (also known as patient boarding). Alternatively, patients without a primary care physician, or with difficult access to one, were instead opting to visit the ED, thereby placing additional pressure on GBH's internal system. This patient behavior would be an example of an externality which GBH was unable to directly control.

Meanwhile, GBH had been trying to cope by applying different tactics such as the usage of patient bed buffers in locations nearby the ED such as the Cath Lab. They had also contracted the services of a lean consulting company to help them improve flow in the ED, however they found their results to be disappointing. All in all, GBH wanted to address the problems faced by its ED, and thus offered as an initial exploratory question: "*How to speed patient flow in the Emergency Department (ED)?*"

C. Quantitative and Qualitative Methods

The exploratory case had a multi-method approach both in the collection of data as well as in the subsequent analysis. Data evidence was collected through walkthroughs, observation, archival records (i.e. electronic medical records), internal documentation, and interviews. Traditional analysis tools such as Value Stream Maps (VSM) and patient flow statistical analysis were used to build iterative rich descriptions and identify data trends such as patient arrival and departure patterns, average waiting times, average patients without being seen, financial charge capture, etc. As a research strategy, "*the distinguishing characteristic of the case study is that it attempts to examine (a) a contemporary phenomenon in its real-life context, especially when (b) the boundaries between phenomenon and context are not clearly evident*" [58]. Data was collected with multiple methods so as to allow for triangulation [59] and theoretical saturation [60]. Exploratory work followed the process prescribed by Eisenhardt [61] in case selection, crafting research instruments and protocols, entering the field, analyzing the data, shaping hypothesis, enfolding literature, and reaching closure.

D. Exploratory Case Overview

Senior hospital leaders described the ED as a loss leader, that patients consistently filled up the waiting room, that staff were churning at a high rate, and that considerable tension existed between the ED and other parts of the hospital as they blamed each other for the overcrowding in the ED. Over time root cause analysis led the research to gradually progress from the ED onto other areas of the hospital, thereby examining multiple levels of the organization (i.e. senior leadership, departments, teams, individuals). An initial patient flow walkthrough was hosted by a senior nurse praised as the "*bed czar*". Over a period of four months several site visits were made at different times, and a non-participatory research role was taken in observing operations in the ED and specific inpatient units. Initial analysis revealed tension felt at the ED interfaces, mostly stemming from its interactions with inpatient hospital operations, thus prompting targeted semi structured interviews with management level staff from the pharmacy, imaging, and a random selection of inpatient units. The targeted interviews revealed perceptual data on the ED's key limitations, as well as early signs of different interpretations of processes and responsibilities. End-to-end patient flow objective data was made possible after

integrating fragmented electronic medical records available in the inpatient and outpatient settings. A one year longitudinal data sample was collected clearly demonstrating the patient flow from the ED onto the inpatient hospital side and finally onto discharge. The data integration exercise itself proved to be valuable as two contributing senior nurses, one from the ED, and another from the inpatient side, helped determine what each element of the database schemas could say about a patient's experience during his or her hospital stay. Several process level inconsistencies were identified and clarified through value stream map exercises. The end result of all analysis was shared and validated with senior leadership in the form of a deliverable and also a presentation.

V- Results and Analysis

As previously noted the exploratory case followed a multi-method approach which informed our analysis of both the "*As Is*" and "*To Be*" enterprise architectures of the hospital under study. We firstly describe our results using traditional tools and then proceed to explore GBH's socio-technical complexity while using the holistic EA Framework described in section III. Having derived the "*As Is*" EA we present our recommended "*To Be*" EA for GBH.

A. Results from traditional analysis tools

The first step in our analysis was to draw a VSM of the ED in order to identify the key processes, the informational and patient flows, the key supporting technical infrastructure, the different types of patients, and begin to understand the existing coordination and integration of the ED with its input and output sources as well as the remainder of the hospital. A simplified version of the VSM is provided in Figure 2 (next page). Next we focused on gathering data that would allow us to build an end-to-end detailed analysis of all patients who were checked in the ED and later either discharged immediately or admitted to the hospital and finally discharged from the inpatient units. To do this we had to integrate data from three separate systems, namely the in-house developed ED system, the inpatient side electronic medical record, and the bed tracking system for the whole hospital. With this data we were able to determine the average patient arrival and departure patterns on any given month (Figure 3), as well as the time spent in each step within the ED (Figure 4).

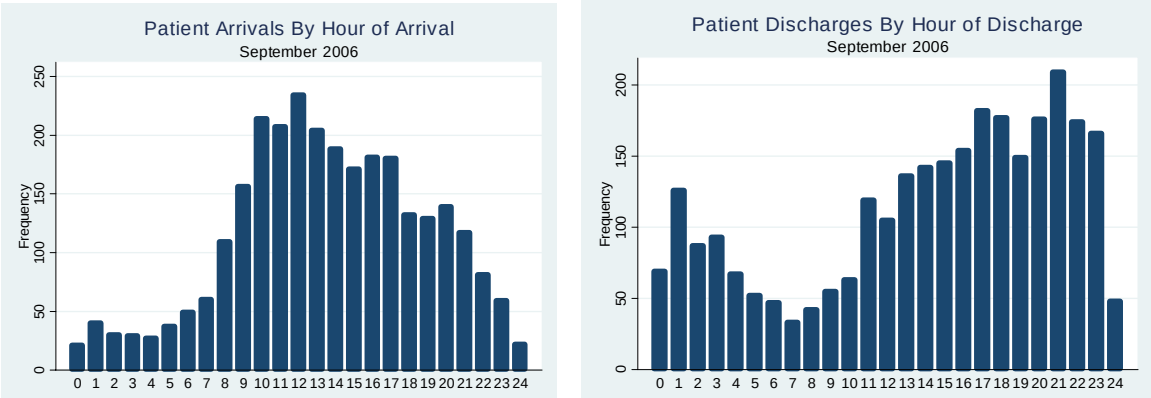

Figure 3: Patient arrivals and discharges by hour

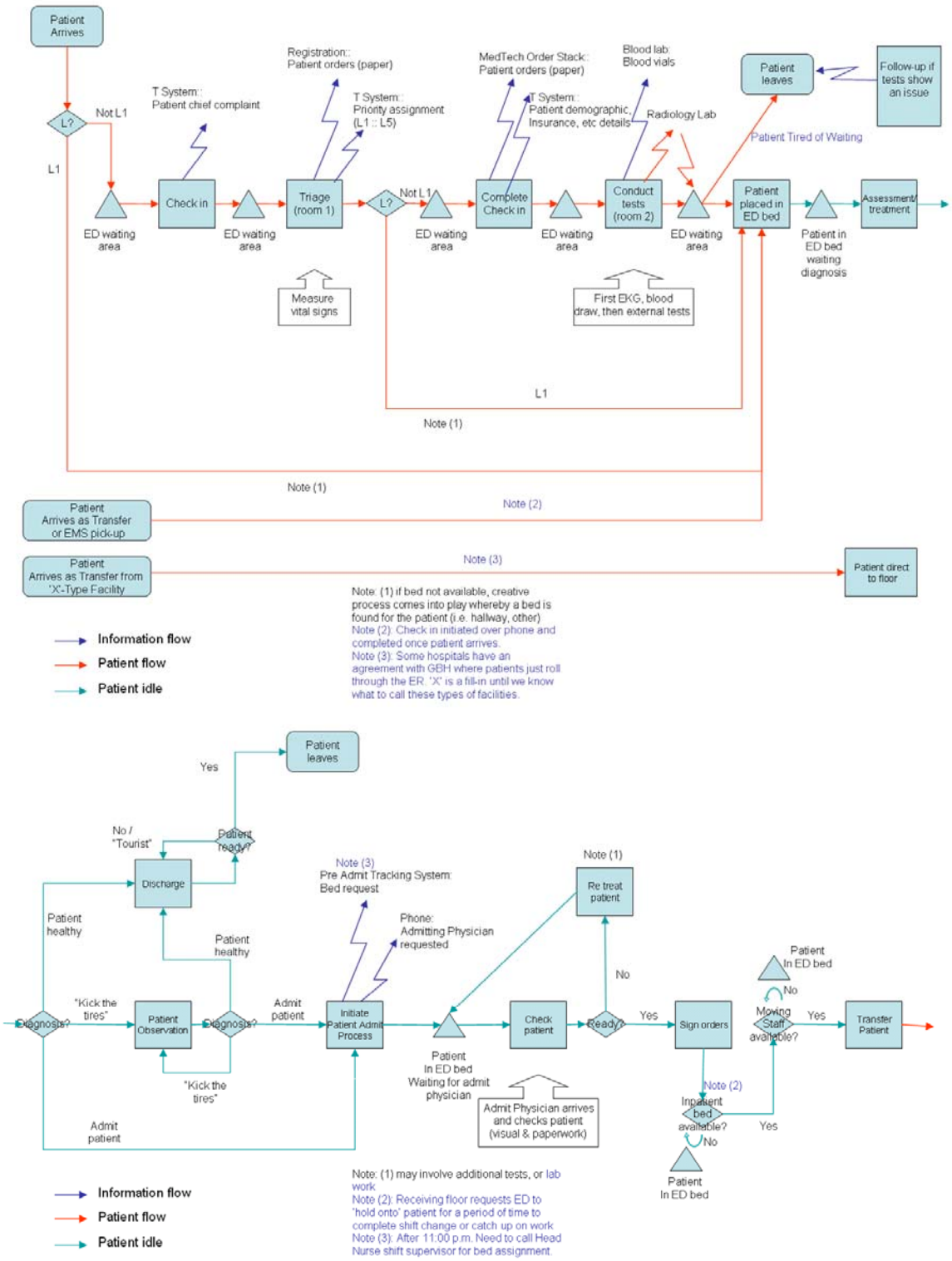

Figure 2: GBH Emergency Department Value Stream Map

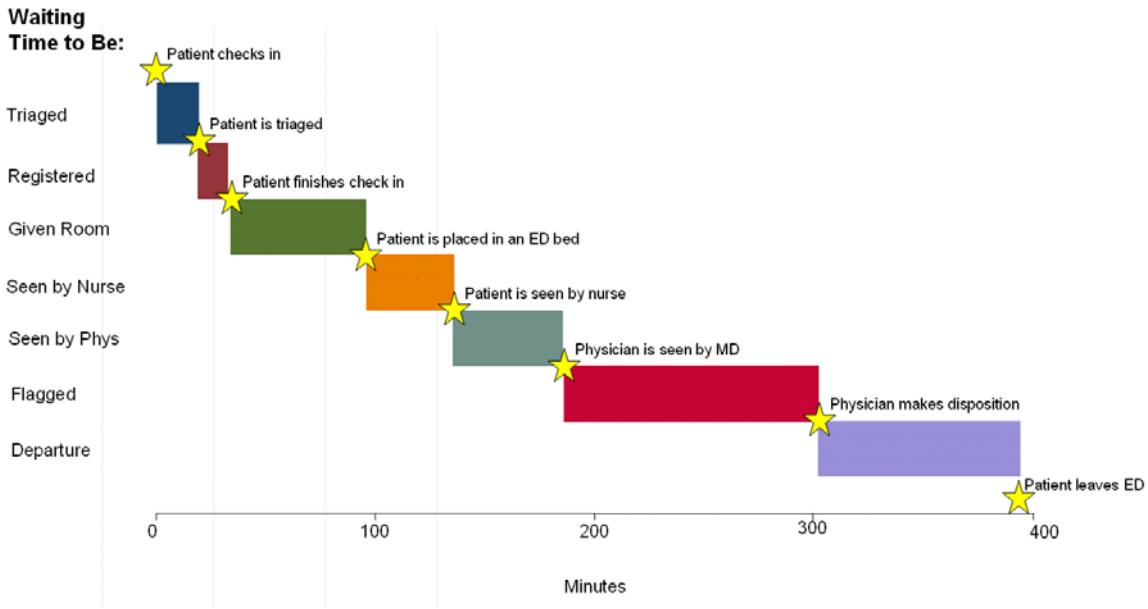

Figure 4: Average time for each step of the ED patient process

This was the first time that senior hospital leadership was able to see their patient flow in an end-to-end fashion. There were immediate benefits from sharing this information with the enterprise. Firstly, they decided to cancel their investment in expensive self check-in kiosks for the ED as they realized that patients spent as little as 3% of their time waiting to be checked in. Secondly, we were able to corroborate anecdotal data that the ED was consistently struggling with overcrowding as demonstrated by Figure 5 which depicts the number of patients in the ED (be they in a bed or in the waiting room) and the number of available rooms (please note that the number varies as it reflects the 12 hour shift of a subset of rooms).

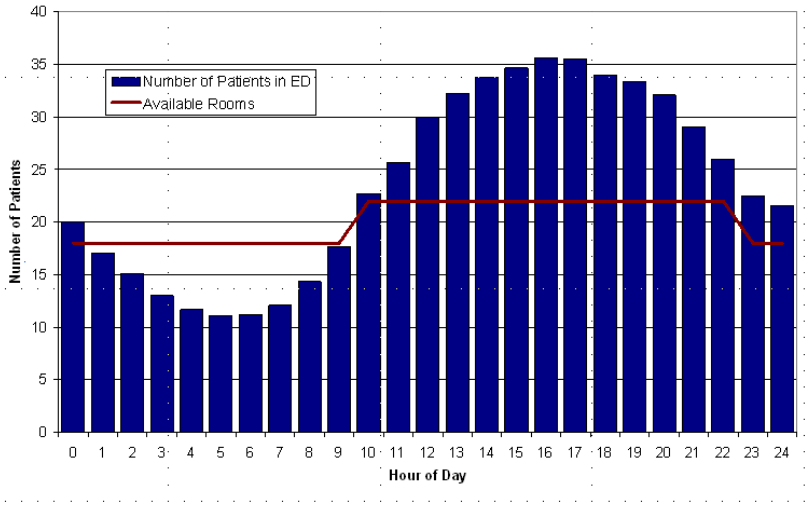

Figure 5: Cumulative number of patients in ED

Thirdly, it became clear that the ED exhibited very different levels of performance depending on whether a patient was immediately discharged or later admitted to the

inpatient side of the hospital. Essentially, non-admitted patients were treated on average in 4.14 hours, whereas the admitted patients remained in the ED for as many as 7.85 hours on average. At first we thought the disparity was mainly due to admitted patients naturally requiring a longer time to stabilize in the ED before they could be moved elsewhere. However, the detailed integrated dataset allowed us to determine that on average a patient remained 3.45 hours beyond the point where a physician had made a decision to admit the patient. Closer inspection revealed that there were significant time lags to attain an available inpatient bed, or to clean a recently vacated bed, or to occupy a bed once the inpatient bed was both available and clean. This last item, namely the clean to occupy time, was particularly striking as it represented an average bed time loss of 2.55 hours with a median of 2.12 hours per admitted patient, and with a monthly average of 630 admitted patients, this represented as many as 693 patient bed days being lost per year (i.e. the equivalent of the hospital being completely empty for more than two days).

Finally, these results, among others, allowed us to start building a trust based relationship with the enterprise, which would prove vital to support the decision to explore beyond the ED and also to grant access to sensitive data (e.g. financial, quality, strategic documents, etc). For instance, having enlarged the scope of our analysis we identified varying performance levels in the admittance practices depending on the particular admission location. As a result, we began hypothesizing that hospital enterprise performance was related to hospital EA.

B. GBH "As Is" Enterprise Architecture

Having conducted our analysis of the ED (and beyond) using traditional analysis tools, we turned our attention towards characterizing GBH's socio-technical complexity, while using the holistic EA Framework described in section III, so as to better understand the root causes of our results and attempt to unlock potential enterprise level recommendations.

While leveraging the full breadth of our data evidence (i.e. walkthroughs, observation, archival records, internal documentation, and interviews) we characterized GBH's "*As Is*" Enterprise Architecture (Figure 6). In essence, the architecture is organization centered which at times obscures the overall enterprise strategy. The 'As Is' EA emphasizes functional silos over process. The architecture shows an IT view that is tangential to the enterprise and, hence, not fully leveraged. There is an overlap between IT and policy due to regulations, such as the Health Insurance Portability and Accountability Act (HIPAA) and Electronic Medical Records (EMR). IT systems are not interconnected and a human is required to serve as a bridge between the systems. Independent IT systems do connect to specific departments but aren't interconnected. Knowledge is shown to reside in each function, rather than being commonly shared. This is widely recognized and a source of friction and inefficiency. The process and service views are one in the same. They are shown as multiple flows to symbolize their discontinuous nature – a flow with multiple starts and stops. Policy is the underlying basis of the hospital enterprise given the highly regulated nature of the business. A more thorough review of the 'As Is' EA through each view is provided in Table 4.

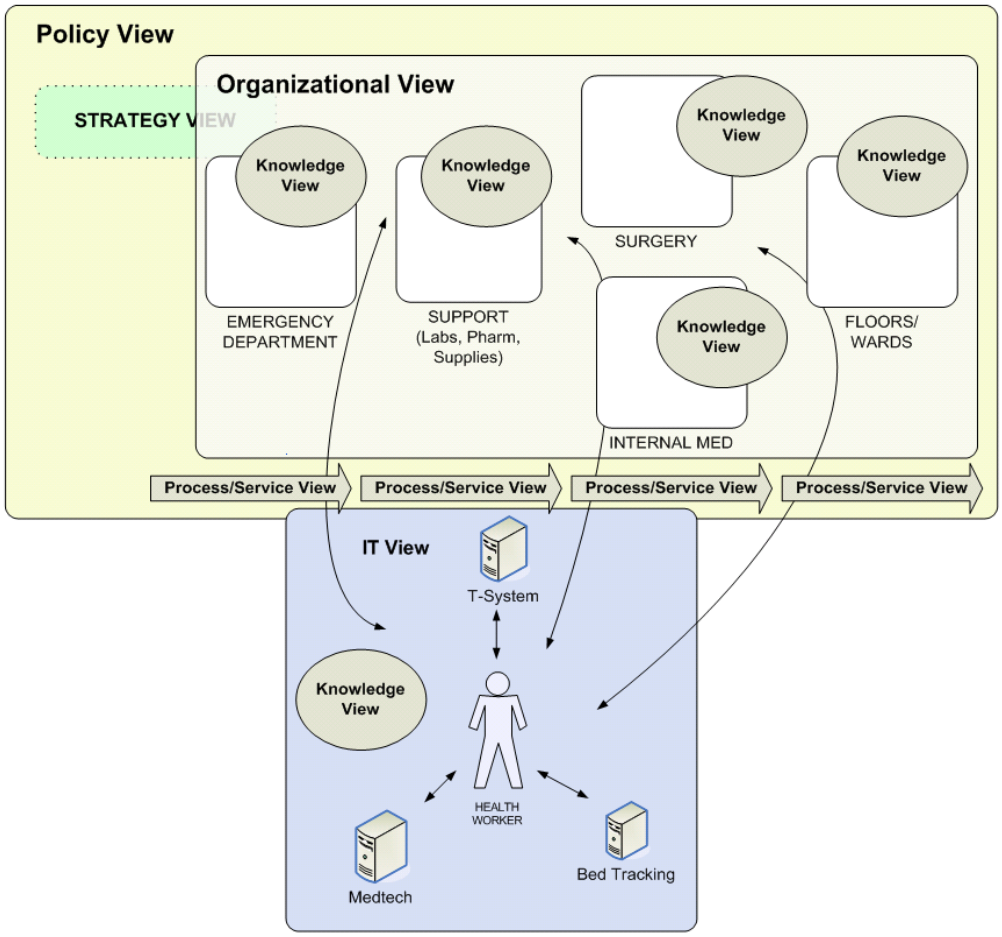

Figure 6: GBH "*As Is*" Enterprise Architecture

Table 4: GBH EA Overview

EA View	Description
External/ Policy	From a policy perspective it is clear that our healthcare enterprise is influenced from a regulatory point of view by organizations such as the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) and the Centers for Medicare and Medicaid Services (CMS). In addition to regulatory and administrative oversight our enterprise also serves as a teaching hospital for medical schools. This program, which makes a small contribution in terms of revenues, means that physicians spend some portion of their time instructing and assisting medical students. An additional external factor which impacts GBH is the closure of small community hospitals within its service area. These closures have increased the service area of GBH so that it now regularly sees patients from greater distances. Finally, from an external point of view, GBH serves as a safety net for the community. Its emergency room, specifically, interfaces with local residents on a continual basis. The local community has representation on GBH's board of directors and impacts GBH's future expansion by controlling building permits.

Strategy	From a strategic view, our healthcare enterprise sometimes obscures the importance of strategy by focusing on the wants and needs of the multiple organizations. This can most simply be observed by a review of GBH Operating Plan which establishes no less than sixteen objectives. With so many objectives, conflicts are easy to find, priorities become difficult to establish and our healthcare enterprise focuses on local and not global optimization. At the same time, some issues of utmost concern to the enterprise do not show up in their strategic objectives. For example, the Emergency Department, which is a focus of our team's interaction with GBH is notably not discussed in the GBH Operating Plan.
Process	From a process view, the GBH enterprise has basic, established processes for diagnosing and admitting patients. These processes have not been analyzed to determine where value resides and as such are optimized based on tribal knowledge. Individuals who carry out the processes make improvements and changes as they see fit. Each individual believes that their optimizations benefit the entire process and the patient when, in reality, they are unaware of the unintended consequences. Additionally, there is anecdotal evidence that nurses on admitting floors will intentionally not file bed cleaning requests so that they may keep rooms dirty longer to delay the time until a new patient arrives. These individuals are focused on their work, but are unaware of the consequences of their actions on upstream operations such as the Emergency Department. These unintentional "*optimizations*" cause the bed assignment process to shift from being largely automated (by individuals carrying out supporting processes) to one in which a person is required to push the process forward.
Organization	From an organization view, the enterprise operates as a number of functional silos. Within each silo there are three separate reporting structures for physicians, nurses and administrators. Each reporting structure spans the entire organization and cuts across the functional organizations. As discussed in the process view section, there are observable instances where the organization seeks to optimize processes based on a local view. This is counter to the notion that optimization should be done a system-level. Local optimization often lengthens time spent in other "*localities*" which can lead to much longer overall system time. There are communication issues that emerge due to the number of different functions represented in our multidisciplinary enterprise.
Knowledge	The knowledge view shows that knowledge largely resides in each function and is not commonly shared. GBH promotes team-based medicine where physicians from many disciplines converge to diagnose problems of a complex nature. In practice, though, team-based medicine is heavily dependent on the relationships between physicians. GBH also promotes an EMR as a means of sharing patient medical information among departments. Interviewees indicate that there has been some success with EMRs but there is also evidence that patients get frustrated with the lack of shared information in the EMRs.
Information	The architecture shows an IT view that is tangential to the enterprise and, hence, not fully leveraged. IT systems are not interconnected and human input is required to bridge between systems. For example, in order to effectively analyze patient flow through the ED it was necessary to pull discrete data from no less than three IT systems. This data required one of the authors to write server query language (SQL) code to interface with each system, extract the necessary data and then translate the data into a usable format. No flexibility was built into the

	IT architecture to allow for the generation of custom reports. Nor was an export capability established to allow for integration between the multiple IT systems. The IT system captures a tremendous amount of data, most of which is known only to individuals who readily use the data. There is a lack of shared knowledge about IT data and as such strategic decision and process improvement projects which could leverage already captured data do not. Multiple IT systems do exist. Some of these are dedicated to specific functions such as the one only used by the ED. Other IT systems may interface with the ED system, as the one from the lab that communicates when lab results are available.
Product/ Service	From the perspective of the service view, GBH is home to numerous specialty Centers of Excellence. For example, when famous individuals review national hospitals for prostate surgery, GBH is always considered. GBH has emphasized a Physician-Patient Partnership as a means of improving the delivery of service to patients. The idea behind the partnership is the physician and patient act as a single customer in the eyes of the enterprise. The Team based medicine practice includes elements of the service view since the team approach is aimed at solving patient problems that a traditional single disciplinary approach could not solve.

C. GBH "To Be" Enterprise Architecture

Clearly the ED at GBH does not function in a vacuum, as its performance and resource usage affect the remainder of the hospital and vice versa. If the inpatient units are overcrowded, the ED will serve as a safety net and keep its admitted patients inside the ED, although their disposition technically ascertains that they should be moved to the inpatient side of the hospital. Furthermore, other services such as the Operating Rooms, compete with the ED for resources such as lab work and radiology, and it is not always clear how priority is awarded to each case. Any future vision of GBH should not be solely centered on the ED, and on the same note, nor should it be neglected. The ED not only serves as the safety net for the remainder of the hospital, but it also provides the infrastructure that allows for the hospital to pursue its growth strategy in sub specialty services. If the ED were not able to accommodate the growing number of patients seeking such services, then the hospital would not be able to guarantee the adequate level of emergency services to cope with the multiple complications that accrue from the sub specialty expertise offered. Furthermore, GBH as a whole does not operate in a vacuum either, and much of the recommended vision is related to the nature of relationships kept by the hospital with external stakeholders.

Considering our recommended "*To Be*" EA (Figure 7) the following observations can be made:

- As before, the Policy View operates in the background as an underlying influence for the whole enterprise. However, unlike before, the Strategy View is now designated as an arrow at the top to show a driving influence on the Organization as well as on Policy. This representation of Strategy addresses the key weaknesses previously identified.
- The "*To Be*" EA provides for an enterprise abstraction that places the patient at the center of the enterprise, and thus represents a significant departure from the existing EA. Specifically, the Service View surrounds the Patient as hospital services solely exist to serve the patient.

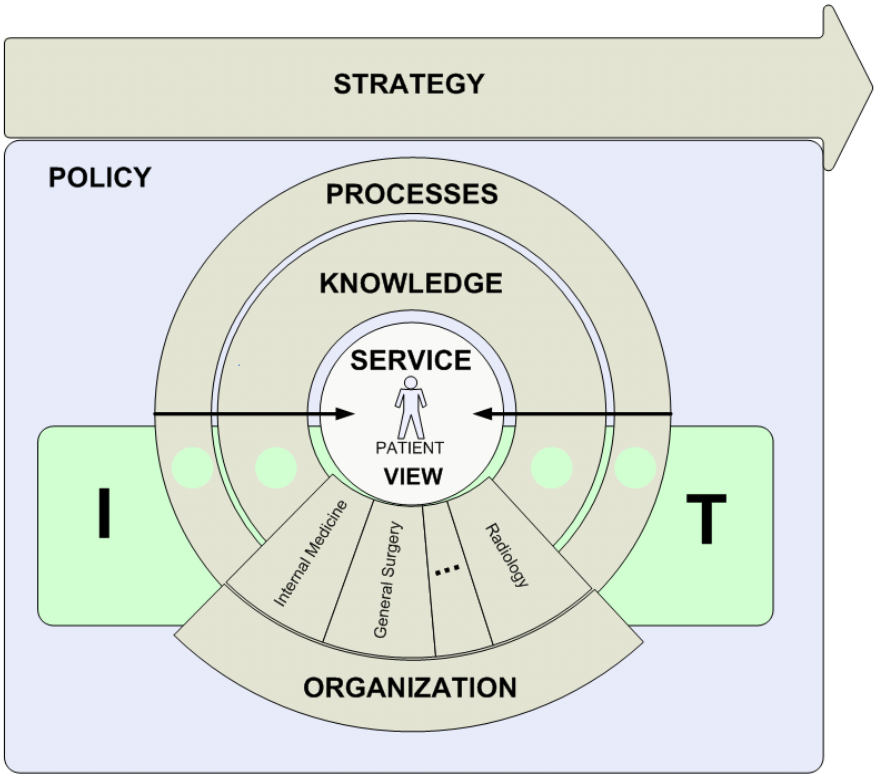

Figure 7: GBH recommended "*To Be*" Enterprise Architecture

- In turn, the enterprise builds Knowledge around the Patient to satisfy his or her specialized care treatment and information needs. Similarly the Process View encircles the patient. This new orientation emphasizes process efficiency from the perspective of the patient, a shift from batch-and-queue thinking (e.g. only admit patients when a minimum threshold is reached) to one-piece flow (e.g. patients are immediately considered).
- The Organization View is shown as supporting the Service View. Each competency required for patient care is detailed, but with all functions coming together into one Organization View. This single Organization View is deliberately created to break down silos.
- The IT View is shown as supporting the organization, process, knowledge, and service, to not only assure that information is transferred between all actors involved in patient care but also enable information sharing and knowledge diffusion across the organization as well as to drive process monitoring, control and improvement.

Conclusions and Future Work

Competitiveness in any industry drives organizations to improve what they are currently doing in terms of cost, quality, speed and efficiency. Companies or industries are also driven to be innovative in the processes they use for the manufacturing of their product or the generation of their service. A core value in the industrial world is to develop more efficient ways to produce a product or service with the result of improved quality. To be

competitive, it is required to search for improved processes to produce a product or service. Paradoxically a knowledge intensive industry such as healthcare is traditionally accompanied by poor information management practices where handwritten notes, prescriptions and orders are still the norm in place at hospitals. Understandably mere "*tune ups*" are inadequate to address the needs of closer informational and human relationships, therefore requiring hospital leadership to embrace paradigmatic change amid their existing financially strained context. However, deciding to undergo significant change is but the first phase of a long and intricate process during which many leaders are tempted to return to the path of least resistance upon clashing with rooted cultures that favor task over process. Any attempt to remedy the situation will necessarily have to understand the inherent difficulties of what can be regarded as the healthcare complex system and will need to characterize socio-technical complexity at the enterprise level. Otherwise, "*The Toyota Way*" will remain elusive for hospitals in general.

In line with recent methodological recommendations, this paper conducted a multi-method exploratory case study of a leading Boston hospital, and applied a guiding emergent holistic EA Framework, so as to explore enterprise behaviors beyond the results rendered by traditional analysis tools. We find that this complementary approach yields further insights towards understanding the socio-technical complexity of healthcare's critical infrastructure.

We specifically offer two avenues for future research. Firstly, to robustly characterize the complexity of service units (e.g. ED, inpatient units, operating rooms, etc) and having measured the performance of their interactions, explore the relationship between their supporting EA Views (e.g. via process standardization, incentives, IT systems, etc) and identify phenomena of interest. Secondly, considering the emerging holistic EA Framework, an opportunity exists to theoretically enrich it with clear constructs and guidelines to allow for subsequent empirical validation in a more systematic and robust manner.

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