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A Systems-of-Systems Perspective on Healthcare:

Insights from two multi-method exploratory cases of leading UK and US hospitals

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I. INTRODUCTION

Several developed nations around the world are grappling with high healthcare expenditures and unsatisfactory outcomes. High level country benchmarks show that there is wide variation in health outcomes for countries with similar levels of income and education [1,2,3], and the US healthcare system in particular is often singled out as the least effective system amongst developed countries [4]. A common US and UK characteristic is that the highest source of healthcare expenditures are hospital services and infrastructure [5,6]. Consequently, the strategies and operations developed and implemented by hospitals have a significant effect on access, quality, and cost of care [7]. This paper's intended contribution is twofold. Firstly, to provide a system's perspective of healthcare beyond traditional high level country benchmarking exercises, and conduct two exploratory cases of leading hospital enterprises, one from the US and another from the UK, so as to further our understanding of hospitals' inherent system complexity, which has remained buried within traditional high level comparative country statistics. Secondly, to address a recent call from the systems engineering community to adopt a multidisciplinary research approach that combines both qualitative and quantitative methods with the goal of further supporting the systems-of-systems (SoS) practice.

II. A SoS PERSPECTIVE ON HEALTHCARE

Commenting on the US healthcare system, the president of Johns Hopkins University said: "Simply stated, the US does not have a health care system" [8]. Contributing to this statement is the fact that the provision of medical care entails a complex and technically sophisticated enterprise that encompasses many different parties [9] which often times are not aligned with one another (Fig. 1). 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 population is uninsured [10], as much as 75% of care providers practice alone or in groups of five or fewer [11]. As for quality, adults on average are said to only receive as little as 55% of the recommended care for many common conditions [12], and as many as 98,000 annual deaths are attributed to medical errors [13]. Finally, the US spends 16% of its GDP on healthcare expenditures, of which 30 – 40% is believed to be wasteful [14]. Furthermore, 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" [15]. 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. An opportunity exists to adopt a systems thinking approach and address this call for an enterprise perspective capable of furthering our understanding of hospitals socio-technical complexity.

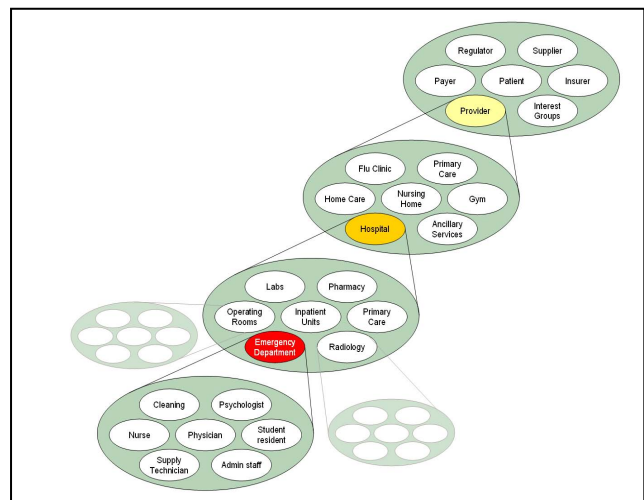


Figure 1. Multilevel stakeholder decomposition of a healthcare system.

III. RESEARCH ROADMAP

The derived research methodology is informed by Tien's [16] characterization of the services sector from a system's perspective which 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. Similarly, Rhodes [17] 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.

A. Exploratory Case Sample

In October 2006, the Engineering Systems Division, at the Massachusetts Institute of Technology, held a workshop charged with the creation of a draft Healthcare Research Agenda. The senior leadership of two leading hospitals (Table I), one in the US and one in the UK, attending the workshop agreed to house empirical exploratory work with the objective of furthering our understanding of the inherent complexity of hospitals, and also of demonstrating the benefits of a systems thinking research approach.

TABLE I. EXPLORATORY CASE SAMPLE CHARACTERISTICS

Characteristic	US Boston Hospital	UK London Hospital
Ownership	Non-profit physician owned group practice	Non-profit National Health System (NHS) Foundation
Type	Multispecialty tertiary urban hospital	Multispecialty tertiary urban hospital
Total Beds	327	872
Total Staff	4263	5534
ED Visits	38,631	141,000
Total Income	\$679,454,000	\$745,316,000
Operating Income	\$50,929,000	\$20,045,600

B. Case Studies Initial Exploratory Questions

Despite being ranked at the top 1% acute hospitals by various third party agencies in their respective countries, both hospitals were facing increasing pressure in specific functional areas. The Boston based hospital was grappling with the US nationwide problem of Emergency Department overcrowding, whereas the London based hospital was readying itself for an increased governmental pressure to shorten elective surgery operating waiting lists. Both burning platforms served as different entry exploratory questions which are consistent with the case study research strategy [18]:

- US Boston Hospital: How to speed patient flow in the Emergency Department (ED)?
- UK London Hospital: How to increase productivity in the Operating Rooms (OR)?

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*” [19]. Data was collected with multiple methods so as to allow for triangulation and theoretical saturation [20]. Exploratory work followed the process prescribed by Eisenhardt [21] in case selection, crafting research instruments and protocols, entering the field, analyzing the data, shaping hypothesis, enfolding literature, and reaching closure.

C. Boston Hospital Case Description

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. 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.

Both qualitative and quantitative data evidence were collected through observation, archival records, documentation, and interviews. 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 interviews revealed perceptual data on the ED’s key limitations. 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 was assisted by two senior nurses who had inconsistent process level mental models that were only clarified through value stream map exercises. All analysis and results were shared and validated with senior leadership.

D. London Hospital Case Description

Senior hospital leaders described that the ORs had to undergo considerable productivity improvement if they were to keep up with the imminent government policy change towards shortening elective surgery waiting lists. Although asked to study the ORs specifically, once again, root cause analyses led the research to gradually progress onto other functional areas and examine multiple organizational levels.

The evidence was collected over a one month onsite study and was mostly qualitative given that available quantitative data would have either entailed a prohibitive coding effort (i.e. paper based) or had considerable integrity issues (i.e. missing data fields). As such, qualitative data collection included multiple types of ORs (Main; Cardio Thoracic; Neurosurgery) allowing to compare and contrast operations and interactions with other service units. A total of 15 semi-structured interviews were conducted and transcribed, as well as six non participatory meetings. Additionally, one of the authors conducted a summer surgery rotation at the hospital, allowing her to explore the ORs, ED, and wards. Only the hospital CEO was aware of her involvement in this study. Finally, other sources of data included documentation and observation. Two initial Main OR walkthroughs were facilitated separately. Interviews were then conducted at both nurse and physician levels which worked in ORs and/or patient wards. Interview transcripts underwent initial and focused coding according to grounded theory while using specialized text analysis software (i.e. MAXQDA), and their contents were systematically compared and contrasted to assess internal validity of findings. The end result of the analysis was shared and validated with senior leadership.

IV. RESULTS

TABLE II. US BOSTON HOSPITAL CASE RESULTS

Characteristic	Description
Lack of strategy alignment	The ED was not mentioned in any of the strategic and operational plans, which probably explained the apparent lack of concern from several inpatient service units towards the ED and fueled the culture of blame and the feeling of neglect from ED staff.
Lack of end-to-end view	Having integrated data from three different hospital information systems we derived an unprecedented end-to-end view of patient flow to inform both the research and decision making. Up until that point senior hospital leaders exhibited quick fix behavior. An example includes the desire to purchase self chek-in kiosks for the ED when such process represented as little as 3% of patient waiting time. Another example was the failed investments in lean consultants who favored local optimization and neglected an end-to-end view.
Fragmented patient experience	During a single hospital stay patients suffering from multiple illnesses would benefit from team based specialized care. However, if a patient visited the hospital in different occasions, he or she would have to repeatedly provide the same information to the medical staff, and often times have difficulty in coordinating their care. The senior leadership preferred metric of total number of annual patient visits obscured patient experience (e.g. 2 patients visiting 3 times each was considered the same as 6 visits by the same patient).
State of the art silos	The information system backbone was said to be state of the art, and indeed it was within each service unit. However, the ED systems were completely independent and thus required medical record printouts to be sent with each admitted patient in order to then manually insert the information in another system.
Probing beyond the ED	Data analysis revealed two distinct patient samples in terms of time spent in the ED (i.e. admitted and non admitted patients). Interestingly the average time spent in the ED by non admitted patients was roughly 4 hours whereas the admitted patients were spending more than 8 hours on average. Having controlled for patient health stabilization we analytically corroborated anecdotal evidence of patient boarding and extended the analysis scope beyond the ED
Multiple internal organizational configurations	Quantitative and qualitative data analysis characterized varying levels of performance in the interaction between different pairs of service units. Informed by an emerging holistic enterprise architecture (EA) framework [22], subsequent exploratory inquiry revealed considerable variation of policies, strategy, process, organization, knowledge, and information technology.

TABLE III. UK LONDON HOSPITAL CASE RESULTS

Characteristic	Description
Unifying external entity	The strong influence of the UK's Department of Health was noted when one of its policies (i.e. maximum waiting time of 18 weeks between primary care referral and specialist treatment) was tracked at multiple levels of the enterprise (e.g. senior leaders, managers, physicians, and nurses). In essence, an external entity (i.e. NHS) was setting a unifying vision for the hospital as a whole.
Misaligned strategy and operations	Senior leaders recited the hospital's value proposition as one spanning the needs of local, national, and international patient populations. However, care providers and managers expressed that such a value proposition induced significant stress in operations as it involved servicing significantly different types of patients. Strategy, process, and organization were misaligned.
Limited incentives	Physicians with US and UK experience noted the highly bureaucratic and stifling career progression in the UK. Furthermore, the existence of national pay scales whereby care givers earn the same baseline salary regardless of where they practice within the NHS, was consistently linked to a lack of motivation towards continuous operational and knowledge improvement.
Organizational divide	Senior leaders were all non clinicians and referred to as "Executive Suits" by the care practitioners (i.e. nurses and physicians). Care practitioners felt controlled by senior leaders via the care group managers and service unit coordinators (both non clinicians), as well as by the internal team of former Airbus expert lean engineers charged with driving process improvement. The divide was also present between service units (e.g. different specialties not talking with one another), and among clinicians (i.e. nurses and physicians).
Silo based management	Senior leaders considered the Main ORs inefficient but ignored external influences (e.g. patient stuck in ward, unavailable patient test results, etc). Similarly, the internal lean team focused at the process level of each service unit and ignored subjective data. Additionally, each service unit had its own procurement, hiring, systems, and scheduling practices, thus rendering any coordination highly complex and error prone. Generally, smaller and independent service units were said to perform better than the larger interconnected ones.
Cross boundary coordination	The ORWIG (OR Ward Integration Group) was a weekly meeting solely attended by nurses from ORs and wards, and was facilitated by a manager. The ORWIG was a tightly knit group that addressed dysfunctionalities and took satisfaction in improvements (e.g. they unanimously cheered "Yes!" when the manager announced an above 90% patient discharge according to plan). A similar group existed amongst physicians, whose leader expressed his frustration given the lack of senior executive leadership support to induce change.

V. DISCUSSION AND CONCLUSIONS

In general, despite the significant regulatory and payment differences between the US and UK healthcare systems, it was surprising to see the similarity of issues at hospital operational and strategic levels. Nonetheless, it is important to note the clear difference of having an external entity set a unifying goal (i.e. 18 Weeks) which becomes present at all levels of the hospital enterprise. Similarly, an important distinguishing factor was the much more pronounced Organizational Divide observed at the London Hospital. Notably, healthcare systems are said to be fragmented and multispecialty hospitals are the preferred model to follow, however both of the leading hospitals studied also revealed a considerable degree of internal fragmentation.

Over the years organizational theorists have studied organizational behavior and attempted to explain it with a minimum set of organizational types (e.g. bureaucracy, adhocracy, simple, etc) while positing that only one such type dominates in each organization. For instance, the organic type describes complex environments characterized by high levels of uncertainty and argues for the predominance of non-standardized processes and high levels of mutual adjustment. However, the London Hospital had such an environment but mostly exhibited a silo behavior amongst different medical specialties and across enterprise levels, and relied in a few dedicated, skilled, and overburdened boundary spanning employees (i.e. organic) which were a minority rather than the majority.

The emergent hypothesis of this research is that multiple internal organizational design configurations exist within a single hospital enterprise and vary in their capability of supporting the performance of different service units in the context of the overall hospital enterprise. In light of that, several different aspects of organizational design were considered (e.g. incentives, strategic alignment, leadership support, information systems, cross boundary coordination, holistic process, etc) and offered as potential contributing factors for the observed behavior. When comparing both hospitals, the importance of studying different internal configurations is reinforced. For instance, the London Hospital compensated for its weak information systems with routine cross boundary meetings, continuous improvement culture amongst nurses, and heroic staff efforts. In a way, the strength/weakness of an organizational aspect translated into potential slack/stress upon the other remaining aspects depending on the service unit under consideration.

Finally, the multi-method exploratory cases, informed by the emerging holistic EA framework [22] were essential. The following are some of our key insights into this research strategy:

1) *Narrow thinking to begin with*: senior leaders at both hospitals suggested that the research focus at an underperforming segment which was supposedly solvable in isolation. In both cases the exploratory research found reason to expand the analysis scope and in doing so identified similar types of issues, and potentially transferrable best practices and best principles. Similarly, both hospitals used the services of expert lean engineers, either hired internally or externally, and both experienced difficulty in attaining measurable results in areas that required boundary interfacing. Instead, our SoS exploratory approach was both holistic and beyond process and yielded further insight into dysfunctionalities and underlying hospital complexity.

2) *Organizational support*: senior leadership support is an essential ingredient to allow for research breadth and depth. The ability to share intermediate results, directly linked to chief concerns, and to elaborate on potential avenues for further data collection and analysis, allowed us to nourish the necessary credibility for the organization to gradually provide access to sensitive and sparse resources.

3) *Grounded theory isn't soft research*: a grounded theory approach values the exploration of a given context in order to observe, identify, and eventually measure a given phenomena of interest. It does not concern itself solely with the coding and visualization of qualitative data. It allows for both qualitative and quantitative data, and unlike a pure case study research strategy, it encourages the continuous refinement of the supporting literature included in the study.

4) *Research design refinement*: exploratory research may require significant research design refinement. The objective data driven analysis followed in the Boston Hospital Case was not transferable to the second case given the limited electronic medical record capability. Also, informed by our first case we realized the importance of recruiting a clinician (second author) in order to better explore the management and clinical enterprise dimensions in the second case.

A research project is underway to further explore the hypothesized relationship between hospital EA and hospital enterprise performance, stemming from the characterized variable internal organizational configurations which exhibited different performance. The two exploratory cases described in this paper are examples of the important contribution that SoS research can provide to the ongoing healthcare debate, whereby the conveyed understanding of hospital inherent system complexity allows to reach beyond high level comparative statistics and move towards rigorous studies that enable and recommend best practice sharing.

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