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COMPLEMENTARY RESOURCES AND A MULTI-HOSPITAL EMERGENCY MEDICINE SYSTEM PILOT TEST

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Abstract

This paper reports on an embedded-cases study of three hospitals' participation in a pilot test of an inter-organizational system which gathered data about medication orders (prescriptions), so physicians can discover drugs a patient might be taking (this is a difficult problem in US emergency medicine, since no single data source exists as a master repository of such information, yet a complete list is sometimes of vital importance). The study revealed the relevant institutional, technical, and organizational resources (assets and capabilities) in use, and their complementary (or non-complementary) effects. Our analysis observes that resources can vary in their complementary/non-complementary effects over time and when deployed for different purposes. We conclude with a discussion of how bundles of complementary institutional, technical and organizational resources support informed collaboration in emergency medicine, and are likely to have similar impacts in other contexts that share the characteristics of high data interdependence, high task interdependence, and high time pressure. We offer suggestions for further research in other health care contexts as well as in contexts such as natural disaster first response, and in contexts with different levels of data or task interdependence and time pressure.

Keywords: resource-based view, complementary resources, complements, health care, pilot test, interdependence

1 Introduction

In an ideal scenario a patient's master information (identity, blood type, insurance eligibility) is securely available to any authorized clinician who needs it. Accurate, timely and complete records of medications a patient is currently taking, conditions s/he is currently being treated for, recent procedures performed on the patient, and other relevant data would also be readily available. Much work remains to be done to achieve ideal systems for informed clinical collaboration. Implementation of electronic health records (EHR), computerized provider order entry (CPOE) and other health information systems provide a foundation for collaboration within health care organizations, and passage of the 1996 US Health Insurance Portability and Accountability Act (HIPAA) has led to helpful industry-wide standards for collaboration *across* organizational boundaries.

This paper analyzes an embedded-cases study of three hospitals' participation in a pilot test of "ED-Rx" (disguised), a system with two main functions: a) use of a master patient index, fuzzy logic, and four-factor patient identification, and b) an ability to query multiple organizations' prescription databases to identify medications previously ordered for that patient. The pilot was conducted by a state Consortium (providers, insurers, other stakeholders). A multi-hospital pilot test presents unique challenges (Gogan et al, 2011; Gogan and Rao, 2011). A pilot should reveal necessary complementary resources (singly or bundled) for successful implementation and full-scale rollout. However, the temporary nature of a pilot gives rise to special challenges. For example, participants may not be willing to invest in new resources until they know whether sponsors will approve the system's rollout. Prior studies have not examined IS pilot testing in light of resource theory. Our study sought to learn *how resource bundles support or impede informed collaboration in healthcare*.

2 Literature Review: Resources and Complements

Resources include *tangible assets* (e.g., hardware, networks), *intangible assets* (data, software, specialized medical knowledge), and *capabilities* (e.g., a clinic's ability to quickly perform a CT scan and transmit the scanned data to a consulting neurologist at a tertiary-care center). Penrose (1959) is credited with first viewing the firm as a bundle of resources. Resources can confer strategic advantage (Wernerfelt, 1984), particularly those valuable resources that are rare, difficult to imitate and substitute (Barney 1991). Capabilities ("competencies"), which combine technical, human, and other assets (Prahalad and Hamel 1990), are harder for competitors to imitate than individual assets; they are also more difficult to develop, deploy, and manage. Peteraf (1993) observed that firms vary in how they assemble assets and capabilities (different firms utilize different resource bundles).

To *complement*, per *Random House Dictionary* "...refers to putting together two things, each of which supplies what is lacking in the other to make a complete whole." For example, a glass of milk complements a piece of pie and chalk complements a chalkboard. Teece (1986) defined complementary resources as assets or capabilities that are used in conjunction with one another. A software app is an asset that complements an iPhone. A surgical checklist is an asset that complements a clinical team's capability to safely perform surgery. A hospital patient registration process is intended to complement clinicians' patient care processes; however, this capability might be complementary under conditions of low urgency, but not in urgent situations. To the extent that assembled resources are complementary, they may strengthen a firm's competitive position (Collis and Montgomery, 1995). A key strategic challenge is thus the "continuous development, alignment, and reconfiguration" of complementary assets and capabilities (Augier and Teece 2009, p. 415). Teece further specified three types of complementary resources:

- *Generic* resources do not require any modification in order to be complementary. For example, an operating system would complement a variety of applications without modification.
- *Specialized* resources are tailored to interact with another resource. For example, middleware would connect two otherwise incompatible applications.
- *Co-specialized* resources arise out of a mutual dedication to one another. For example, a desktop docking station or power cord fits a particular laptop model.

IS studies have proposed various capabilities that underpin successful IT strategy (Feeny and Wilcocks 1998, Santhanam and Hartono 2003), e-business (Daniel and Wilson 2003) and an IS organization's capacity for strategic adaptation at the enterprise level (Peppard and Ward 2004). Overby et al. (2006) reported a strong association between IT resources and enterprise agility (see also Sambamurthy et al. 2003). Beard and Sumner (2004) observed that ERP systems confer competitive advantage only when coupled with complementary resources. Others proposed more generally that complementary resources help organizations achieve positive returns on their IT investments (Caldeira and Ward 2003, Melville et al. 2004, Wade and Hulland 2004, Nevo and Wade 2010), especially when IT resources support or enhance core competencies (Ravichandran 2005; Rivard et al. 2006). Other researchers called for studies to examine effective resource configuration (Piccoli and

Ives 2005; Mithas et al. 2012). Rai et al. (2006) report that an integrated IT infrastructure (a lower-order capability) is a complementary resource that contributes to supply chain management (a higher-order capability). Tarafdar et al. (2007) report that resources used in deploying computerized provider order entry and an electronic health record system reinforce and strengthen one another. Mani et al. (2010) reported that information capabilities that complement information requirements are associated with effective outsourcing satisfaction. Ray et al. (2005) contend that “tacit, socially complex and firm-specific” IT resources are associated with effective processes (e.g. knowledge shared between IT and a customer service unit is a key resource that facilitates effective customer service). A strong relationship is reported between complementary manufacturing and organizational capabilities and IS investments (Banker et al. 2006), and more generally between IT investments and complementary organizational resources such as redesigned processes, employee training, and organizational reporting structures (McAfee and Brynjolfsson 2008). McAfee (2006) further proposed that while implementation of enterprise software *does* demand concomitant investments in complementary resources, complementary resources are not necessarily needed when implementing functional or collaborative systems. Conversely, studies report that when enterprise or inter-enterprise systems and processes are *not* complementary, outcomes fall short of expectations (Bhatt and Grover 2005; Ray et al. 2005; Karahanna et al. 2006; Karimi et al. 2007). Furthermore, Prieto (2006) found that bundling of valuable resources is not always effective, because their interaction is not always positive (i.e., a *valuable* resource is not necessarily a *complementary* resource). Thus, successful enterprise or inter-enterprise systems implementation requires complementary technical, organizational, and extra-organizational resources (Robey et al. 2008). Research is still needed to investigate the conditions under which different resource bundles contribute to successful implementation of healthcare systems (Bradley et al. 2012). Within-case and cross-cases analysis of a multi-site pilot test can reveal whether and how different bundles of technical, organizational, and institutional resources affect system use and outcomes.

Hereafter we substitute “institutional” for “extra-organizational” resource. Our reasoning is that an organization’s implementation of a new system can be affected by institutions such as national or state laws, professional regulations, and informal professional norms. While our study did not examine institutional *processes* (per institutional theory; Oliver, 1997), we did find evidence of *resources that were produced by institutional processes*, and evidence of how those resources affected the implementation of ED-Rx during its pilot test. Thus, our research questions:

- What relevant institutional, technical, and organizational resources (assets and capabilities) affected the ED-Rx pilot test? To what extent did the pilot test participants believe these resources facilitated ED-Rx adoption, usage and outcomes (that is, were complementary) or impeded them (were non-complementary)?
- What does the ED-Rx embedded-cases study reveal about whether and how complementary institutional, technical, and organizational resources (separately and bundled) facilitate the adoption, usage of and outcomes from inter-organizational systems for informed clinical collaboration?

3 Research Methodology: Embedded Cases Study

ED-Rx was pilot-tested by three participating hospitals. We employed an embedded cases methodology (the Consortium is the focal case; each participating hospital is an embedded case). Data were gathered from public and private sources (presentations, web site, etc.) and field interviews conducted with 12 individuals: the Consortium Executive Director and three Consortium consultants, five clinicians (physicians and nurses) and three IT personnel at the three participating hospitals (Table 1). Most interviews were conducted on-site (one conducted via telephone). Before the pilot test, interviews with the Executive Director and Consortium consultants explored the rationale for developing ED-Rx, challenges in bringing multiple stakeholders (insurers, hospitals, HMOs, pharmacies) to the table, and expectations for the pilot test (what they hoped to learn, post-pilot plans). Interviews one year later were conducted with the consultants and eight other people involved in the pilot test. These 10 interviews explored each hospital’s motivation for participating in the pilot test, how they went about it, challenges that arose during the pilot test and lessons learned. A change in Consortium leadership following the departure of our sponsor (the Executive Director) caused our study to be suspended, so we were not able to conduct as many interviews as were initially planned at the three hospitals (thus, only one interview was conducted at H3. Also, the CIO of H1 was interviewed, but we did not interview a CIO at H2 or H3). Interviews were recorded and professionally transcribed.

Analysis proceeded as follows: Two authors independently assigned codes, using a high-level coding scheme. Each author sought evidence for the existence of, and impact of several categories of resources:

- *institutional assets* (e.g., funding agencies, laws or regulations)
- *institutional capabilities* (e.g., professionally sanctioned methodologies)

- *IT assets* (e.g., hardware, software, data, network)
- *IT capabilities* (e.g., change management, software development)
- *organizational assets* (e.g., reputation, cash resources, patient population)
- *organizational capabilities* (e.g., training, governance, collaboration track record)

We reached consensus on classification of interview segments and other data pertaining to IT, organizational and institutional resources (and other codes). Then we applied a grounded interpretive lens to consider whether each resource complemented or did not complement ED-Rx, and how particular resource bundles contributed to or impeded the adoption of, use of, and outcomes from ED-Rx at each hospital.

Consortium	Hospital 1 (H1)	Hospital 2 (H2)	Hospital 3 (H3)
Before Ed-Rx Pilot: Executive Director Consultants A, B, C	After ED-Rx Pilot: H1 CIO H1 Analyst/Project mgr	After ED-Rx Pilot: H2 Nurse Educator H2 ED MD-1 H2 ED MD-2	After ED-Rx Pilot: H3 Analyst/Project Mgr
After ED-Rx Pilot: Consultants A and B	H1 Nurse Manager H1 ED MD		

Table 1. *ED-Rx Study Interviews*

4 Findings

4.1 The State consortium and ED-Rx

The Consortium served as a forum for hospital and health plan CIO’s and other health care leaders in the state to discuss opportunities and priorities for technology-enabled information sharing. It sponsored pilot tests of applications (such as Ed-Rx) that were felt to offer promise for improving health care and/or reducing costs.

ED-Rx was designed to quickly search databases maintained by several health plans/insurers, pharmacy benefit management (PBM) companies, and other external sources, and return results for specific patients. Before the pilot-test began, physicians at each hospital’s emergency department decided on the circumstances when ED-Rx searches should be conducted. For example, a search could be run for every patient who came into the ED, or just for those patients who could not speak for themselves (e.g., unconscious or otherwise incapacitated), or just for those patients for whom medications were likely to be ordered due to their presenting condition. Each hospital ED’s normal triage process would thus be slightly modified in order to conform to criteria set by the ED physicians. The process for using ED-Rx to learn about a patient’s prescription history was as follows: Once a patient was selected (and if he or she was conscious), a clinician would describe the ED-Rx functionality and explain how patient confidentiality would be assured, then ask for the patient’s verbal consent to conduct a query. If a patient was unconscious, the clinician was allowed to run the query but required to inform the patient once he or she regained consciousness. Once consent was obtained, an authorized user would log on to ED-Rx, type the patient’s first and last name and three other identifiers (gender, date of birth, zip code). The system would match the patient with a record in the Master Patient Index, then ping each of several medication orders databases to determine whether records for that patient were stored therein. Those databases that did have data for that patient would return prescription history results to a web-based presentation layer, which would display on the user’s screen and could be printed out.

A key function, the Record Locator service, relied on a Master Patient Index relational database that referenced between various individual databases, and filtered out non-allowed “sensitive” data (described below). This was essential to verifying patient eligibility (currently covered by a particular insurer) despite variation in data formats and identification numbers used in the several source databases. Each data source had a different method of storing and allowing access to their data, even though they conformed to existing health-care data format standards. To account for these differences as well as for human keying errors, fuzzy logic coded into the software recognized the likelihood that an individual listed under various forms or with minor misspellings (e.g., Mary Q. Jones, Mary Jones, MQ Jones, Mary Jone) might be the same individual. A four-factor identification scheme (name, date of birth, zip code, gender) provided strong assurance that the right patient was located in the databases.

In its native form, the ED-Rx software required a unique logon and password for each authorized user (except at H2; there, user credentials for the emergency department workflow software were integrated with ED-Rx). Security and controls were provided through authentication and audit modules and use of encryption as required by HIPAA. A software filter blocked “sensitive drug” information that pointed to substance abuse, mental health conditions, or HIV treatment. This state imposed greater privacy restrictions on these medical conditions than

were imposed by HIPAA. If a patient had been treated for any of these three conditions, such data would not be revealed in the query. Other relevant data were not presented because the data sources were not participating in this pilot test. For example, most Medicaid records originating in this state were included in ED-Rx, but data from Medicare, the Veterans Administration, and several other parties were not yet included. Also, some large employers mandated “carve-out” provisions in their health plans: these employers would provide their own drug benefit or obtain it from a less expensive provider. Thus, a particular patient’s drug history might not be completely revealed via an insurance company system. Information about over-the-counter medications was also not included, nor were drugs that patients obtained in Canada (an issue since ED-Rx was tested in a northern state not far from Canada). Uninsured patients were not covered, and data about patients who spent months out of state (e.g., retirees who wintered in Florida) and/or otherwise had access to doctors out of state might also be incomplete.

5 Three Participating Hospitals

Hospital 1 (H1) served an affluent suburban area with an aging population. H1 treated about 34,000 patients per year; its emergency department employed 14 full-time and 4 part-time physicians. The Consortium executive director asked Hospital 1’s CIO to consider participating in the ED-Rx Pilot. After consulting with ED physicians, the CIO agreed that the hospital would participate, provided that this would have no impact on H1’s IT budget and only a minimal impact on participants’ time. So, H1 did not do any custom programming to integrate ED-Rx with their existing clinical systems – other than to place a link to the ED-Rx website on ED computers. A planning team comprised of clinicians and staff ensured that H1’s ED chief announced the start of the pilot and encouraged use. Signs were posted, other aspects of a communication plan were implemented, and “super users” received thorough training and were given responsibility to train and assist others. At first, nurses ran ED-Rx queries. The rationale was that since nurses normally participate in a manual medication reconciliation process and administer meds, they were the natural choice. One nurse explained that ED physicians would have been just “too busy” seeing many patients to pause and run queries on the system. An interviewee stated, “We thought ... doctors would only do it when they had an obvious need” for medication use information, and thus might not seek to learn about it.

After using the system for two and a half months, nurses became “discouraged,” as one nurse put it, because many ED-Rx queries either failed to find the patient or did not reveal any ordered medications. Since nurses were also busy with their normal care duties, they expressed concern that the benefit of ED-Rx use in the rare moments when it returned useful information did not compensate for the time they needed to expend to use it, which some felt was distracting. So, a decision was made to have emergency department registration clerks check Ed-Rx as part of their existing workflow. A checklist was modified to alert clerks to run a query if a patient met certain eligibility requirements and had provided consent. Clerks were instructed to print the result and insert it in the patient’s chart. An ED Nurse Educator trained the registration staff, and ED-Rx was integrated into their process. Some planners feared the clerks would resist this addition to their workload; instead, they “took to it with total enthusiasm,” stated one informant. Soon, clerks noted a “glitch” in the ED-Rx system. As described above, fuzzy logic and four-factor identification (matching on name, gender, birth date, and zip code) enabled the system to home in on a patient despite misspellings and other minor errors. When there was a close but not exact match to a user’s query, ED-Rx returned patient information without alerting the user to these slight differences. This led some users to question its reliability. When a name was slightly different from what they typed in (missing a middle initial, or “Diane” instead of “Diana”), these users wanted to use their own judgment to decide whether the computer had returned a correct match. In response to these concerns, the pilot was temporarily halted. Analysis revealed that the system had never returned an incorrect match, but some users persisted in their belief that ED-Rx was unreliable. Use of ED-Rx declined over time, and among the explanations was the lingering distrust due to the “glitch.” Furthermore, in an apparent oversight, summer interns and some registration clerks who were hired midway through the pilot test did not get ED-Rx training. Doctors and nurses were disappointed that ED-Rx did not reveal “sensitive” data which would have helped doctors prescribe medications that would not interact badly with other drugs a patient was taking (or would be given). Clinicians commented that ED-Rx was poorly designed for the many elderly patients that H1 served (ED-Rx did not have access to Medicare records).

Hospital 2 (H2) was a 600-bed urban teaching hospital affiliated with a medical school; the CIO of its parent organization had achieved national prominence for several innovative initiatives. About 35 H2 emergency physicians treated more than 50,000 patients per year. Several physicians had extensive IT training and experience, and now specialized in clinical informatics. One designed and coded a “smart” whiteboard that tracked the ED’s workflow and was used by most ED doctors. H2 chose to make ED-Rx available through the smart whiteboard application and to do the necessary coding for a single sign-on, single password capability. Use of ED-Rx was initially optional; each doctor and nurse could decide to use it whenever they saw fit. On further consideration the Chief of emergency medicine became concerned about national and state patient

privacy regulations which he felt gave rise to a strict due diligence requirement. He required that until a doctor or nurse was trained regarding privacy issues, they would not be permitted to use ED-Rx. The doctors were trained quickly; H2 had low physician turnover, and physicians were already in the habit of meeting as a group two or more times per month. Also, these doctors were comfortable using the smart whiteboard, so they saw ED-Rx as just one more whiteboard function. Nurses took longer to train, in part because H2 used many traveling or rotating nurses. Also, since nurses were somewhat less likely to use H2's smart whiteboard, they faced a steeper learning curve.

Hospital 3 (H3) was a 500-bed urban teaching hospital affiliated with a medical school. Its emergency department treated approximately 130,000 patients a year, including many impoverished patients who lacked insurance and many whose primary language was not English. About 30 emergency medicine faculty and 50 residents staffed the ED, which was sub-divided into multiple units in two separate city locations. The CIO committed H3 to participate in the ED-Rx pilot test before vetting the idea with the faculty leaders of the emergency department. At first, nurses were expected to run ED-Rx queries, but subsequently it was decided that registration clerks would run and print ED-Rx queries. For several months, the H3 workflow specified that a clerk would run an ED-Rx query for every conscious, English-speaking patient who gave consent (English speaking patients constituted about 65% of the total seen at H3). Clerks reported that the time they took to log in to ED-Rx and run queries added to their workload, with few discernible benefits. An interviewee stated, "Buy-in decreased as we went along, because we weren't getting results ... it just kind of fizzled." Many H3 patients could not afford insurance coverage, so many ED-Rx queries did not return any information on a patient. Other queries returned some information, but clinicians deemed it of limited value because medications prescribed for "sensitive" conditions (HIV, substance abuse, psychiatric care) were not revealed, nor were over-the-counter drug purchases. An interviewee recalled that clerks "...kept printing [the ED-Rx results] to the printer, but then they weren't ending up in the clinician's hands. They just ended up being thrown out." Apparently, when a query did not reveal any ordered drugs, a clerk would discard the printout. However, clinicians still wanted to know if a query had been run for each patient. So, after a few months' use, the registration checklist was modified; it now instructed clerks to conduct an ED-Rx search "and print the results to the appropriate ED area for it to be collated with the chart ... regardless if medication history is found or if no history was found (to inform clinician the search was conducted)."

H3 served an area that included a large number of Hispanic patients, so to remove a language barrier, another change was made after a few months' use of ED-Rx: the handout supporting patient informed consent was translated to Spanish, and a checklist informed registration clerks that "A search of a patient's medication history will be conducted for all English and/or Spanish speaking/understanding patients who present to the Emergency Department, provided they have given verbal consent." Despite these changes, most queries did not reveal useful information, and clerks continued to complain that ED-Rx use was time-consuming and offered little benefit. So, a new set of patient-inclusion criteria were set, along with a new workflow. Now, the checklist indicated that ED-Rx should be used only if the patient came in by ambulance. Physicians were to run a query if they had reason to believe the patient would need to be treated with medications that could be affected by other drugs the patient could be taking. Unfortunately, changing the workflow and responsibility for ED-Rx queries did not lead to an upsurge in usage. One explanation was that neither physicians nor nurses wanted to pause to log into a separate system (how ED-Rx worked at H3). Some physicians were not properly registered to use ED-Rx, so they could not log in to it. Some personal computers in the emergency department may not have had the ED-Rx client software properly loaded. The IT project manager who served as a coordinator for this pilot test was also working on a challenging implementation of a packaged emergency department information system across H3's multiple ED locations. Several aspects of that rollout were problematic and as a result, "our focus has kind of come off <ED-Rx>..."

6 The Consortium's Evaluation of the ED-Rx Pilot Test

At each participating hospital ED-Rx usage tapered down to very few queries in the last weeks of the pilot. As the pilot test reached its scheduled end, the Consortium conducted an evaluation and concluded that concerns expressed by clinicians about the patient consent procedure and data gaps were sufficient reasons to decide not to roll out ED-Rx in its current form. Instead, the Consortium authorized further work on a new health exchange utility that would incorporate some features from ED-Rx (such as its master patient index) and new functionality that would increase the likelihood that relevant clinical data could be provided as a financially sustainable shared utility. Because the Consortium's evaluation revealed that each hospital's CIO and clinical leadership team believed much had been learned about informed clinical collaboration through their participation in the pilot test, and because Consortium leadership similarly felt they learned much about hosting a health information exchange utility, the pilot test was publicly declared a "success," even though ED-Rx did not survive in its tested form. One interviewee, who coordinated the pilot test for the Consortium, graded different aspects of the pilot test differently:

“This had to be done; we had to find out what we found out, whether it was good news or bad news. The value of that information is an A <grade> across the board. Has it changed the quality of information in the emergency room for treating a patient? It probably hasn’t really made a blip on any radar screen. It’s just sort of an introductory change to clinical data exchange. So, that’s probably a C. ... We learned that privacy and security could be done. ... It’s a big deal <and> it can be done.”

Another participant, referring to the incomplete set of data sources, stated, “... the market is going to be very picky about the quality and completeness of the solutions. ... We learned that the market is going to set a very high bar on this.” This individual also reflected on lessons learned from a workflow perspective: “We learned that information <needs> to be fully integrated in the work flow ... The requirement to toggle out of one system into a freestanding web lookup application creates a barrier to adoption.”

7 Findings: Institutional, Technical, and Organizational Resources

We discuss institutional, IT and organizational resources used in the ED-Rx pilot. Some affected all hospitals similarly; others were unique to one or more hospitals in existence or impact. Some resources had both complementary and non-complementary impacts. Each hospital was uniquely affected by its particular resource bundle.

7.1 Institutional Resources

The State Consortium was an institutional resource that affected all participating hospitals, since it brought together IT and clinical leaders in the state to oversee the design of ED-Rx, obtained funding to build and pilot-test it, and conducted an evaluation of the pilot test.

HIPAA (Health Insurance Portability and Accountability Act) went partially into effect in 1996; other provisions of this national law went into effect over time, providing needed clarity regarding privacy and security requirements for individually-identifiable patient data (see <http://www.hhs.gov/ocr/privacy/index.html>).

Local Health Informatics Community: This region has many well regarded universities and medical schools that produce cutting edge research and treatment, and the region was also a hub of activity in health informatics. The Consortium arose in part because the area included a number of MD’s with strong IT skills. For example, several emergency physicians at H2 were active in the health informatics community, and one wrote the software for H2’s emergency department smart whiteboard system.

Teaching Hospital Two ED-Rx pilot test sites were teaching hospitals associated with prominent medical schools – an environment characterized by a constant stream of clinical and technical innovation, and presumably a higher likelihood that advances in technology will be understood and accepted by clinical teams.

State Privacy Provisions: State laws/regulations regarding patient data were demanded by some constituents (who presumably saw them as necessary and valuable). However, these were ambiguous and open to interpretation, per several interviewees. One regulation prevented the exchange of information about “sensitive” conditions (substance abuse, mental health, HIV/AIDS), so drug orders related to these conditions were not reportable via ED-Rx. Several interviewees felt this impeded their ability to give good care (e.g., if a patient was taking psychotropic medicines, physicians wanted to know, since these could interact with other drugs). An H2 emergency MD stated: “Some key medications we’d really need to know about are blocked. ... HIV medications are known to have major interactions with other medications and you’d really need to know about that – what if the patient was unconscious?” An H1 emergency physician similarly described the system as “unreliable” because of this restriction.

Patient Consent Restriction: The ED-Rx designers would have liked a process whereby patients in each health plan would provide a one-time consent for their data to be shared among qualified clinicians at other health plans. For reasons related to their own prior history of patient liability issues, one health plan’s senior management team insisted that a verbal patient consent should be obtained whenever a query was to be made in the ED-Rx system (if the patient was unconscious, he or she would be notified about the ED-Rx query once conscious). This created a major constraint for the three hospitals, which had to integrate this requirement into their existing processes. Some interviewees mentioned that this negatively impacted ED-Rx usage by clinicians.

7.2 IT Resources

Secure Internet Connectivity: Because of HIPAA requirements, all three hospitals had already made investments in network hardware and software to protect patient data confidentiality. Had these investments not already been made, hospital leaders indicated that they would have been reluctant to participate in the ED-Rx pilot test.

Integrated Clinical Technology: The added step of integrating ED-Rx into the smart whiteboard with a common logon/password (see Application Access Control, above) facilitated usage at H2. H2 had previously implemented the ED smart whiteboard, and physicians and some nurses were already very comfortable using it. Those who were already comfortable with the whiteboard found it easy to use ED-Rx.

Data Set: ED-Rx was designed to access various medication order data sets for a patient (Note: our analysis treats the data sources as separate IT resources. An alternative view would see them as central system elements, where a “system” consists of hardware, software, web interface, network, and data). Although ED-Rx was designed to increase the likelihood that emergency clinicians would discover drugs a patient was taking, and thus make better treatment and prescribing decisions, ED-Rx filtered out sensitive drugs and prescription data in “carved-out” portions of a health plan as implemented by some large corporations. It lacked access to Medicare, over-the-counter drug purchases, prescriptions filled in Canada, and other sources. Clinicians viewed this resource “glass” as either “half full” (ED-Rx provided more information than they previously had access to) or “half empty” (they could not rely on the query results). Clinicians who saw the glass as “half empty” used ED-Rx infrequently or not at all.

Fuzzy Logic/imprecise queries: ED-Rx was designed to support searches based on four-factor identification (name, gender, date of birth, zip code), with near-matches on names permissible. In other contexts this complex search algorithm is highly prized, but H1 clinicians saw this feature as a “glitch” (because inexact matches did not return error messages). They worried that there could be moments when they would assume ED-Rx had found an exact match, but since it was not in fact 100% accurate it might return a medication history for the wrong patient.

Application Access Control: At all three hospitals, staff used a specific logon and password to access ED-Rx. H2’s smart whiteboard was modified to incorporate a single-sign on; H2 staff clicked on an ED-Rx button on the white-board application, which triggered a security access control (access limited to those staff who had completed the ED-Rx training and were authorized to use it). At H1 and H3 users had to sign on to ED-Rx for each separate query.

7.3 Organizational Resources

Senior Leader Sponsorship: The H1 CIO consulted with H1 ED clinical leaders before committing to participate in the ED-Rx pilot test, which contributed to system acceptance. However, the budgetary constraint this CIO imposed suggested the project was not a high priority. Also, the CIO described the pilot test as a small initiative that did not warrant board-level attention. H2 had very strong leadership. Its parent-organization CIO is a nationally recognized health IT leader, and its ED included well respected clinicians with strong IT skills. Its ED Chief grappled carefully with complex patient privacy issues. H3’s CIO quickly committed H3 to participate in the pilot test, but without seeking consensus with the clinical leaders in emergency medicine. H3’s project management was also weak (poor consideration of workflow issues, little follow-up to determine why usage was low).

IT Savvy MD: An H2 emergency physician with demonstrably strong IT skills and a strong reputation as a clinician programmed the smart whiteboard and understood how various clinical systems interacted with it. His advocacy of the ED-Rx system carried significant weight within the Emergency Department hierarchy. Other doctors in the department who had IT expertise reinforced acceptance.

ED Clinical Workflow: First, H1 chose to insert ED-Rx into the nurses’ clinical workflow. This choice was seen as problematic because it slowed the nurses down. So, they assigned ED-Rx to the registration clerks’ workflow and supported it with appropriate training and changes to their workflow checklist, with positive initial results. H2, with liability concerns, first incorporated ED-Rx into physicians’ workflow and already-routine use of the smart whiteboard system. Later they permitted use by nurses, which necessitated further training aimed at routinizing nurses’ use of both the smart whiteboard and ED-Rx. H3 assigned registration clerks to do the ED-Rx queries, but did not carefully consider the workflow, user acceptance, and training implications. A subsequent decision to narrow the target patient criteria and assign responsibility to emergency physicians also fell flat.

Patient Consent Process: H1 found that competing claims on nurses’ attention made it difficult for them to take time to obtain consent from patients. Once they switched responsibility to the registration clerks, this difficulty was resolved. H2 interviewees did not mention whether there were patient consent issues when physicians or nurses were involved. H3 registration clerks complained that ED-Rx use was time-consuming. Also, at first H3 leaders failed to recognize the implications of having a large population of patients who spoke Spanish. They later produce a translated consent explanation to give to Spanish-speaking patients, but never fully overcame clerk resistance.

Training: H1 used a train-the-trainer process (and “super users”) when nurses were charged with doing the ED-Rx queries. When responsibility for ED-Rx queries shifted to clerks, H1 used a similar approach to train them. Over time, with addition of summer interns and with staff turnover, newcomers’ training did not occur and usage declined. H2 trained all the ED doctors, but put nurse training on hold until liability issues were better understood. No doctors or nurses were permitted to use ED-Rx until trained and certified to use it (a slow process, because of H2’s use of temporary and “traveling” nurses). Interviews indicated that training at H3 was minimal.

Institutional Resources	Technical Resources	Organizational Resources
The Consortium	Secure Internet Connectivity	(Senior Leader Sponsorship)
HIPAA	(Application Access Control)	IT Savvy MD
Health Informatics Community	(Data Set)	(ED Clinical Workflow)
Teaching Hospital	(Fuzzy Logic/imprecise queries)	(Patient Consent Process)
(State Privacy Restrictions)	Integrated Clinical Technology	(Training)
(Patient Consent Restriction)		

Table 2 *Summary of Relevant Resources (fully or partially non-complementary effects in parentheses)*

8 Analysis: Complementary Resources

Four institutional resources helped participating hospitals derive value from ED-Rx during its pilot test (these resources thus complemented ED-Rx): The Consortium, which spearheaded the development and pilot-testing of ED-Rx; HIPAA regulations, which specified how to protect patient privacy and confidentiality; the thriving local health informatics community of scholar/ practitioners, which contributed helpful expertise and increased the likelihood of system acceptance by clinicians at H2 and H3; and the teaching hospital environment, with its culture of scholarship and experimentation. As a suburban community hospital, H1 probably did not directly benefit from those latter two institutional complements. Our analysis also revealed that two institutional resources, seen as valuable in other contexts, were non-complementary in some impacts. State patient privacy regulations provided useful structure (complementary), but also mandated important restrictions, such as the requirement that important “sensitive” data be filtered out. And, a participating health plan’s unique patient privacy issues affected all three hospitals, due to their insistence on a verbal patient consent every time an ED-Rx query was run.

Two IT resources had complementary effects at all three hospitals: Ed-Rx access controls, and secure Internet connectivity, both of which helped ensure HIPAA compliance.

The availability of multiple data sources increased clinicians’ access to relevant information about a patient’s medication history. However, the incompleteness of the medication orders data sets was a show-stopper for full-scale rollout (even those clinicians who felt they derived some value from ED-Rx believed that state-mandated data restrictions would need to be overcome before ED-Rx would provide optimal value). Thus, the data set was a resource that had complementary and non-complementary impacts. The combined incorporation of fuzzy logic and four-factor identification (ability to support imprecise queries) was an IT resource that also had both complementary and non-complementary impacts. H1 Clinicians distrusted Ed-Rx, believing that it could return results for the wrong patient without warning. Clinicians at H2 and H3 did not view Ed-Rx this way; this feature was a complementary resource at these hospitals. H2 benefited from the integration of ED-Rx with their smart whiteboard workflow application. This particular complementary resource was unique to H2 and not available to H1 and H3.

Our analysis revealed that some organizational resources also had both complementary and non-complementary effects. No hospital’s leaders made perfect choices about complementary organizational resources, although clinical and administrative leaders at all three hospitals did exhibit an ability to learn and adjust during the Ed-Rx pilot test. H1’s CIO demonstrated effective senior sponsorship (a complementary resource) by achieving a consensus with the emergency department’s clinical leaders before proceeding with the pilot test. However, this CIO demonstrated less effective sponsorship (non-complementary) by imposing budgetary constraints and by remarking that the test was a low priority. H2’s CIO was a strong and supportive leader (complementary), while H3’s CIO did not demonstrate strong leadership vis a vis the pilot test. H2 uniquely benefited from the presence on staff of an IT-savvy physician who both coded the whiteboard system to include ED-Rx, and served as a strong and influential advocate for its use.

Many participants felt the strictly mandated patient consent procedure did not fit their workflow well. H1 tried but failed to incorporate ED-Rx into nurses' workflow. H1 then introduced it into the registration clerks' workflow, which was successful for a time. H2 chose to introduce it to well-prepared physicians and subsequently to nurses. H3 encountered obstacles in registration clerks' use of ED-Rx and later attempted to motivate physicians to use it. H3 was uniquely affected by language issues (they later translated the consent form into Spanish). Training was only sometimes complementary. H1 did thorough initial training (complementary) but did not anticipate turnover and train new hires (non-complementary). H2 committed to well thought-out training to support system use, but did not have a solid plan for training part-time and/or traveling nurses. H3 did not allocate sufficient resources to training.

9 Discussion and Suggestions for Further Research

This study contributes to understanding how resources – singly and in bundles -- affect information systems acceptance and use. Our study fills a gap by offering a rich description of a new system (ED-Rx) and related institutional, technical, and organizational resources in practice, over time, and in three settings with three different resource endowments. We examined technical, organizational and institutional resources, which have received little attention in the IS literature. Our analysis revealed that a non-complementary institutional resource – a well-intended state regulation designed to protect the privacy of patients suffering from so-called “sensitive” conditions – was a “showstopper” for the ED-Rx system, since physicians felt it impeded their ability to identify drugs a patient might be taking that could interact adversely with medications for emergency treatment. In contrast, a complementary institutional resource – HIPAA – helped set the stage for more effective inter-organizational sharing of clinical data.

McAfee (2006) proposed that complementary organizational resources are necessary for successful implementation of enterprise software, but not when implementing functional or network IT. Other IS researchers assert that *any* IT is strengthened with appropriate complements (c.f. Melville et al. 2004, Wade and Hulland 2004; Nevo and Wade 2010). Our study points to *interdependence* as one driver of a need for complementary organizational resources. We observed two kinds of interdependence in this embedded-cases study. Data interdependence refers to the fact that the ED-Rx system relied on data produced by other systems, and that clinicians relied on data delivered via Ed-Rx. Task interdependence refers to the interconnected work of clinicians: doctors depend on nurses and intake personnel, and nurses and patients depend on doctors and intake personnel. Both data and task interdependence are affected by the presence or absence of complementary resources. Doctors at H1 and H3 complained that an important complementary asset – data about “sensitive” drugs that may have been prescribed for a patient – was not included in ED-Rx. Other potentially complementary assets were also not included – Medicare data, records of over-the-counter drug purchases, and so on. At H3 some PCs in the emergency department did not have ED-Rx installed on them. At H2, a complementary technical capability was not in place: nurses lacked smart whiteboard expertise, and this affected their use of ED-RX. At H3 an organizational complement was missing: doctors were not strong advocates for using ED-Rx, because the CIO decided to participate in the pilot test, without consulting with them. Also, at first the prescribed intake process did not specify that clerks should include negative ED-Rx query results in the patient charts. This missing data put a spotlight on the extent to which clinicians depended on the intake clerks. Our findings thus suggest that data and/or task interdependence create a need for complementary technical, organizational and/or institutional resources. We thus propose that *task interdependence and data interdependence give rise to a need for technical and/or organizational and/or institutional resources that complement an information system*. Future studies can closely examine resource needs under differing interdependence conditions.

Our analysis revealed that a resource should not be characterized merely by its presence or absence (this is how most prior IS research has treated this variable); the same resource can have complementary and non-complementary effects at different times. By conducting interviews at the start of the ED-Rx pilot test and again near its conclusion one year later, we were able to learn of resources that had different effects at different times. Yet, managers need not be paralyzed by their resource bundles; the hospitals we studied adjusted their resource configurations in order to improve user acceptance and/or system effectiveness. However, our findings, within and across cases, underscore the managerial complexity of assembling appropriate and cost-effective bundles of complementary resources

Several study limitations must be acknowledged, most important being that ED-Rx was being pilot-tested. A pilot is a somewhat artificial context, since participants may deliberately choose to limit various system features and data sources (as occurred in the ED-Rx test), and these choices can influence usage amount and outcomes. Also, based on this one study we cannot readily generalize beyond the state in which ED-Rx was tested or beyond the United States. Given that our embedded-cases methodology did reveal a rich picture of institutional, IT, and organizational resources that affected system acceptance (positively and negatively), we infer that

additional embedded-cases studies would be helpful. To probe deeper into the effects of data or task interdependence on complementary resources (and vice versa), other studies could be designed in similar health care contexts or in other contexts that share similar characteristics. ED-Rx was tested in the context of emergency medicine, with high data and task interdependence and high time pressure. Telemedicine for acute stroke diagnosis and treatment is another health care context with high task and data interdependence and time pressure. Beyond health care, studies of responder teams during natural disasters or other episodes would also entail high data and task interdependence and time pressure, but likely different resource configurations. Further studies could also inquire into the hierarchy of IT capabilities proposed by Raj et al. (2006). For example, our findings suggests that HIPAA was a foundational institutional resource, yet we cannot prove that hospitals were better prepared to use ED-Rx because of this foundation. Further research into different varieties of complementarity (generic, specialized, or co-specialized) would also be fruitful. The link to the ED-Rx website was a generic complementary resource. Signs posted to remind people to use ED-Rx, super-user training, and H3's Spanish checklist were specialized complementary resources, and development of a single sign-on capability to the H2 smart whiteboard is a co-specialized resource. Beyond this description, we have not yet derived meaningful insights from observing this variation in this study.

We conclude that bundled complementary resources contribute to the effective implementation of systems for informed clinical collaboration in health care, and likely in other contexts characterized by high data and task interdependence and time pressure. Because our study reveals that some resources had both complementary and non-complementary impacts in different contexts and at different times, many questions remain regarding how to best design systems for informed collaboration and how to support them with appropriate resource bundles.

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