Linking Operations, IT Investments, and Firm-level Performance: An Examination of the Acute Care Hospital Supply Chain

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ABSTRACT

The supply chain of acute care hospitals consists of entities that interact to provide the tools, personnel, and information necessary for quality service to patients and seeks to maintain efficient operations. This paper examines the interplay between operational factors such as process coordination activities, IT investments that facilitate these activities, and firm-level financial performance. 800 US hospitals provide data that are analyzed to discern if information technology (IT) investments promote efficiencies in the internal supply chain. The findings suggest that IT investments in back office and clinical applications improve process coordination activities used to measure internal supply chain operations, which in turn contribute to firm-level financial performance. Most telling is that these expenditures in IT and efficiency improvements do not come at the expense of quality.

INTRODUCTION

Acute care hospitals in the United States are under severe financial pressure. A recent study concluded that operating margins dropped 20% from 2003 to 2004 to an average of 4.04% and this trend is expected to continue at least in the near future (Sexton, 2006). Hospital administrators are recognizing that the key to better financial performance is to better coordinate and streamline the hospital supply chain. For the purposes of this paper, the acute care supply chain includes all the entities and activities that come together (often at the hospital) to provide healthcare services. This includes the patients who seek health services; the doctors, nurses, and other clinical staff that provide them; the outpatient clinics, laboratories, pharmacies, and
associated non-clinical staff involved in the service delivery; the suppliers of medical products that support patient care; and finally the billing agencies that oversee financial transactions between these entities.

The US Department of Health and Human Services Secretary Mike Leavitt’s view on healthcare information technology (henceforth “IT”) is that it can provide an interoperable system that protects privacy as it connects patients, providers and payers, resulting in fewer medical mistakes, less hassle, lower costs and better health (Leavitt, 2005). Indeed many of the healthcare administrators we talked to during the course of this study share this view. IT can: (a) streamline purchasing and material management processes through better coordination with suppliers (b) improve efficiencies within the hospital by facilitating communication and standardizing routine processes; (c) reduce errors and improve quality of healthcare by automating manual patient care processes; and finally (d) provide the patients and insurance companies superior billing services.

This study addresses how information technology investments made by acute care hospitals impact their financial performance through improvements in supply chain. Specifically, we proceed in two steps – first, we measure how IT investments impact quality of care and operational efficiencies, and second, how these operational and clinical outcomes affect the financial bottom-line. Our key research question is:

“Do IT investments promote improvements in operations (e.g., quality and process coordination activities) which in turn enhance firm performance?”
As the ensuing review will show, most of the prior studies focus on the advantages of specific technologies; or the collective impact of IT investment on a small set of hospitals or healthcare systems. Our study is unique in two ways: first, this is the first large-scale investigation of the impact of IT investment on financial performance. Our data captures the total IT investment from over 800 acute care hospitals in the USA. Second, it is one of the few studies in the healthcare sector that specifically addresses the impact of IT investment on both supply chain performance and clinical outcomes.

**eCare: An Illustrative IT Investment Initiative**

The hospitals in our data provide total IT investments in dollars of combined expenditures for clinical and back office technologies. To provide an example on the types of IT investments that our study encompasses, we provide a description of eCare™, a $240 million initiative over 10 years (2005 -2015) that is a comprehensive patient information electronic access system under development at major healthcare network in Virginia (Sentara Public Relations, 2005). This healthcare network is a recognized leader in care delivery that embraces technology for many interrelated activities influencing process coordination.

The healthcare network consists of six hospitals for which the eCare™ Health Network will link the electronic medical record (EMR) system with clinical information, scheduling, billing and registration data over a secure network. eCare™ allows the sharing via a web browser of patient information across the acute care supply chain – including the hospitals in the healthcare network; the numerous physician offices and diagnostic centers; and patients’ homes (Sentara Public Relations, 2005).
Patients with Internet connections can log into the system to view results from diagnostics centers and communicate with doctors regarding treatment options. In addition to serving as a repository for their medical history, patients can also schedule appointments, pay bills, and view medication lists from the system (Sentara Public Relations, 2005).

Doctors will use the system to access in real-time a patient’s medical history both online and in the exam room; can retrieve protocols; and can coordinate patient orders for pharmacy, bedside, and diagnostics to reduce prescribing and diagnostic errors. Clinical staff will have fewer manual processes to complete orders/services and now spend more time at the patient’s bedside (Sentara Public Relations, 2005). Diagnostic centers, meanwhile, will use eCare™ to receive physician orders in real time and post test results which is then accessible to authorized persons.

Automation also promotes fewer errors during “hand-offs” between shifts and reduces mis-communication among shift personnel. Just five years ago, the Institute of Medicine (IOM) reported that nearly 98,000 people die each year due to medical errors in hospitals, which is more than car accidents and AIDS combined – many of which could have been averted by systems such as eCare™ that automates laborious documentation and facilitates efficient information management (Institute of Medicine, 2001).

Finally, the hospital management will use the eCare™ system to streamline medical care management workflow; improve referrals/authorization processes; and enhance the claims management processes. The system will also improve capture of Health Plan Employer Data and
Information Set (HEDIS) data (i.e., standardized patient satisfaction, purchaser, and consumer data measuring performance of managed health care plans) (Sentara Public Relations, 2005).

Faced with high volume and complex patient care, this healthcare network will be able to use eCare™ to streamline processes by reducing burdensome paperwork; reduce errors by real-time information sharing; and standardize best practices by improving workplace efficiency and patient management (Sentara Public Relations, 2005).

While eCare™ is just one example of the sort of IT investments represented in our data, we note that most healthcare systems use a portfolio of investments to streamline their supply chains. Typical investments include EMR technologies such as eCare™, Material Management Information Systems (MMIS) or ERP to standardize processes, data warehouses that acquire and maintain data, Decision Support Systems (DSS) that help the entities in the acute care supply chain better decisions, and Financial Management Systems (FIS) that manage the business and financial aspect of the hospital (Sentara Public Relations, 2005).

Our intent in this study to investigate the aggregate impact of technology on financial performance and as such we do not distinguish between specific technology investments by hospitals. As with any investment, IT implementations have associated costs (e.g., implementation expenses, maintenance, outsourced data processing services captured in accounts payable, etc.) before any observed benefits (e.g., lower full time employee needs, lower operational expenses, increased rates of service resulting in cash increases etc.). In this cost conscious industry, hospitals have therefore historically been slow to adopt new technology for
clinical or back office systems or technologies to improve connectivity between all entities involved in the patient care process. Our study is directed not only at researchers, but stakeholders in the healthcare system looking to potential benefits from employing IT.

The rest of the paper is organized as follows: (a) we review relevant literature and formally state the hypothesis we test, (b) we describe our data and methods, (c) present our results, and (d) discuss our findings and conclude.

LITERATURE REVIEW

Quality, Information Technology and Performance

Researchers in healthcare systems have generally divided quality into two primary constructs – clinical quality and process quality. Clinical quality refers generally to the technical outcomes of medical processes. Process quality indicates the quality of the delivery of the medical services. Others have parsed out customer satisfaction as a measure of quality (Li & Benton, 2003). We focus on the extent to which clinical quality is affected by firm IT investments, and in turn supports firm performance.

A number of researchers have examined the relationship between customer satisfaction, clinical quality, process quality and performance. They generally support the association between health care quality and performance (Frost & Sullivan, 2006; Marley et al., 2004)

Further, the association between IT investments and clinical and process quality is established by previous research (Devaraj & Kohli, 2003).
Through a survey of managers in 142 hospitals, Li and Collier (2000) concluded that information technology investments should be considered independently from clinical technology because they impact processes differently. They found that information technology investments are better suited to predict process quality which in turn influences hospital financial performance. They propose that future research should examine how clinical and process quality affects hospital performance.

Li and Benton (2006) also found a significant relationship between information technology adoption and hospital cost performance. Their results also indicated a direct, causal relationship between information technology adoption and lower operating costs. They conclude that information technology’s impact upon hospitals’ cost performance is mediated by better decisions made by clinical staff ostensibly through improved processes.

Consistent with Li and Collier’s suggestion and Li and Benton’s conclusions, we test the proposition that IT investments lead to greater process coordination and clinical quality which in turn result in higher hospital financial performance. Our examination of clinical quality also serves as a control measure to ensure that hospital performance, if improved, did not occur at the expense of clinical quality. This leads to the following two propositions:

Proposition 1: Greater IT investments lead to higher quality

Proposition 2: Improvements in quality, partially attributed to greater IT investments, lead to improvements in firm performance
Process coordination, IT and Performance

Process coordination comprises a range of cross-functional activities that create a firm’s capabilities for efficiently integrating and streamlining transactions with partners, exchanging information and monitoring performance (Kim et al., 2006; Stank et al., 1999a) (Clemons et al., 1993). The goal of process coordination activities is to achieve a seamless and timely flow of information, materials, money and product among the core firm, and its suppliers and partners. Our study focuses on the extent to which process coordinating activities lead to improved hospital performance, as well as the degree to which they are supported by IT investments.

In an extensive review of literature examining the role of information technology in supply chain coordination, Sahin and Robinson (2002) concluded that an incomplete understanding of information sharing and physical flow coordination could limit gains from supply chain initiatives. Similarly, surveys of the literature and provides a taxonomy of supply chain coordination (Whang, 1995). The surveys found that information sharing and process coordination is associated with improved overall supply chain performance, most frequently due to reduced costs. However, most of the studies included in both surveys focused on manufacturing systems, with a particular focus on the effect of increased coordination on inventory levels. Although the results of studies of manufacturing systems can provide general guidelines and insights to health-care supply chains, they do not capture the unique characteristics of this service system.
Furthermore, an essential assumption in this literature is that increased information sharing will lead to increased process coordination among supply chain partners. Information sharing – and hence process coordination, exists on a continuum which includes internal as well as external partners. Along these lines, studies in manufacturing and healthcare have examined the effect of varying levels of information sharing and process coordination on the firm’s financial performance. For instance, process management activities which support internal and external process integration in manufacturing firms are found to be a significant mediator in the information technology-performance relationship (Ward & Zhou, 2006). Albino et al. (2002) suggest that by assessing the process coordination load, i.e. the effort required for resources to address coordination problems, managers can enhance coordination, improve processes, and select coordination technologies that best meet their information requirements. In healthcare, the need for understanding the healthcare process flow has been suggested as “…a means to define and manage the events, roles, and information integral to health-care delivery…”(Buffone et al., 1996) to deal with increasing pressures to reduce costs and improve quality. Marrin et al. (1997) argue that finding cheaper supplies and reducing patient length of stay (LOS) can serve short term cost control, but the long term success depends upon the reduction of costs by understanding process dependencies and reengineering the processes of care.

Information technology investments and their eventual adoption have shown to support coordination by reducing costs, improving information quality, increasing the speed of information sharing and improving cooperation among buyers and suppliers (Bakos, 1991; Clemons & Row, 1993; Stank et al., 1999b). Similarly, in healthcare organizations data
warehouses serve as a critical resource for analyzing large volumes of patient data to identify areas of cost reduction and process improvement (Wisniewski et al., 2003; Zhan & Miller, 2003).

As noted above, process coordination and its impact on firm performance has been widely studied in manufacturing organizations and one would expect these relationships to hold true; this study aims to validate the positive association between process coordination, IT investments and firm performance. This leads us to the following propositions:

P3: Greater IT investments lead to improvements in process coordination activities

P4. Improvements in process coordination activities, partially attributed to greater IT investments, lead to improvements in hospital performance.

METHODS

We use five years of data from a commercial database that is maintained by Solucient Inc., a leading information products company serving the healthcare industry. Solucient Inc. maintains the data via extractions from Medicare Cost Reports for nearly every U.S. acute care facility (the database has over 7000 hospitals, 800 of which reported values for their IT investments). The database provides performance data for peer hospitals, market share and competitive data, trend data enabling industry analysis, and the ability to examine lag effects associated with realizing the impact of IT while controlling for other factors such as size of the hospital. We supplemented the Solucient data with longitudinal mortality and complications based quality data from The Delta Group, a commercial provider of quality indicators of hospital performance (DesHarnais et
al., 2000). The Delta Group’s database compromises of all Medicare cases discharged from all
general, acute, non-federal U.S. hospitals and is adjusted for differences in patient severity,
intensity, complexity, and risk.

Studies examining IT investment indicated that influence of IT investments are not realized
immediately but rather after a period of time (Brynjolfsson & Hitt, 1998; Mahmood & Mann,
2000). Brynjolfsson and Hitt (1998) suggest that, “if there is some lag or adjustment time
required to match organizational factors and IT investments, we would expect to see more
benefits over longer time periods.” Also, Mahmood and Mann (1997) note that “attempts should
be made to use a time-lagged regression analysis to allow for the fact that benefits derived in a
given year may be due to IT investments made in previous years.”

**Research Design**

We applied a longitudinal design to determine the effects of total IT investments on selected
process coordination and quality of services variables. We then assess the impact of these
process coordination and quality-of-service variables on firm performance. Our premise is that
IT investments influence firm performance via mediating conditions. Investments in IT promotes
improvements or efficiencies in work processes that allow for better coordination of processes
that impact the quality of healthcare delivery, and indeed the quality of care itself. We posit that
this in turn improves the financial performance of the organization. We identify IT investments,
process coordination, quality, and financial performance as constructs from prior literature that
are commonly available across all hospitals and captured in routine reporting (Devaraj & Kohli,
2003). Herein we propose the relationships between these constructs.
**Proposed Relationships**

The propositions test that, all else being equal, IT investments will lead to improvements in quality and process outcomes (P1 and P2), which in turn will lead to improvements in firm performance (P3 and P4). Figure 1 represents our initial process-based approach to examining IT investment impacts in the hospitals, which is followed by a description of the selected variables. A positive notation (+) reflects the expected parallel relationship. A negative notation (-) would represent an inverse relationship. It is imperative to note that we have coded a positive relationship between IT Investments and Quality (i.e., as IT investments increase, quality does also). However, indexes used to measure this Quality indicate complication and mortality values for which lower complications and mortalities indicate higher quality. Thus, the indexes that measure quality have an inverse relationship with IT investments.

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**Insert Figure 1 Here**

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Figure 1 Representation of our Initial Process-Based Approach to Examining IT Investment Impacts

**Criterion Variables**

IT Investment

In our study, IT Investment represents data processing expenditures i.e. the sum of capital expenses consisting of both clinical and back office types of information systems and technologies, salaries of the IT personnel who service the information systems and technologies or support the various clinical and administrative and other expenses associated with the
implementation. Hospitals that reported their IT investments represent approximately 12% of US acute care hospitals.

Quality

Quality is a success measure indicating how well the hospital meets the requirements of its service to patients in terms of not inducing more harm or injury and prolonging life due to effective treatment and care. Quality is assessed by examining the actual outcomes with expected outcomes. The expected outcomes are based upon national benchmarks modeled by The Delta Group after examining all US discharges (DesHarnais et al., 2000). The relationship between IT Investment and Quality is positive, indicating that as IT investments increase, which promote efficiencies in the internal supply chain and suggesting improvements in quality (indicated by decreases in complication and mortality indices). The variables are as follows:

- Risk Adjusted Complication Index (RACI) represents the number of actual complications divided by number of expected complications. An index value below 1 indicates that the hospital is successful in not inducing more harm or injury to patients in its care. Thus, a decrease in RACI indicates an increase in quality.

- Risk Adjusted Mortality Index (RAMI) represents the number of actual deaths divided by number of expected deaths. An index value below 1 indicates that the hospital is successful in its attempts to prolong life of patients in its care. Thus, a decrease in RAMI indicates an increase in quality.
Process Coordination

Process coordination variables measure the productivity of the internal services that impact various components of the supply chain such as patient care services, liquidity and revenue, and operational expenses. Various studies examining efficiencies of internal activities of hospitals have used a number of the following variables:

- **Average Length of Stay (ALOS)** is the total number of inpatient days in a hospital's inpatient acute care or sub-provider units divided by the total number of admissions to these units. It is a widely used variable that measures the productivity of the patient care services to not prolong the hospitalization of a patient (Devaraj & Kohli, 2003; Devaraj & Kohli, 2000).

- **Accounts Payable (AP)** is the value of the debts resulting from purchasing supplies and services. It reflects the level of activities between supply chain partners and the hospital (Briggs, 2006).

- **Cash to debt ratio (CASHDB)** is the sum of net income and current depreciation divided by total liabilities, this ratio measures the proportion of a hospitals total debt obligations that could be met if demanded by creditors. It is one measure of debt repayment ability or creditworthiness and hence the financial performance (Friedman & Wong, 1995).
• Cash per bed (CSHBD) measures a facility's ability to generate earnings (before interest, taxes, depreciation, and amortization) calculated as the net available for debt service divided the beds in service for the total facility (Melzer et al., 2001).

• Full time employees adjusted (FTEADJ) is the number of full time equivalent employees divided by total acute care admissions adjusted by casemix. The number of full time equivalent personnel per 100 adjusted admissions is a measure of the staffing level of a hospital and a measure of efficiency (Devaraj & Kohli, 2003; Devaraj & Kohli, 2000).

• Occupancy Rate (OCCRT) is the average daily census of inpatients of a hospital's inpatient acute care or sub-provider units multiplied by 100 then divided by the number of beds in service for the total facility. Higher occupancy rates indicate efficient use of hospital resources (Harrison & McLane, 2005).

• Plant Operational Expenses (PLNTOP) are the expenses associated with plant operations, expressed as a percentage of the hospital's total operating expense (Woolhandler et al., 1993).

Firm Performance

Firm performance measures the collective financial stance of the hospitals. Net income and return on assets are commonly used variables in studies examining the financial performance of healthcare organizations (Nelson et al., 1992; Ozcan & McCue, 1996). We chose net income and return on assets as variables because we believe these variables are indicative of the financial
benefits derived indirectly from investments in technology that can spur improvements the ability of the organization to provide quality patient care services and efficiencies in the processes involved in coordinating internal activities. The variables are as follows:

- Net income (NETINC) is the sum of net patient revenue and total other revenue minus the sum of total operating expenses and total other expenses. Net income is a measure of a hospital’s surplus of revenues over expenses.

- Return on assets (ROA) is Net income divided by total assets, return on assets is another measure of profitability. It measures the size of the surplus generated in relation to the amount of assets needed to achieve the surplus.

**Control/ Instrumental Variables**

We used control/instrumental variables from past studies in hospital performance research (Devaraj & Kohli, 2003; Gapenski et al., 1993). The chosen variables are common across all hospitals and captured for routine regulatory reporting (Devaraj & Kohli, 2003). These variables are as follows:

- Beds in service (BEDS) the total number of beds in service in the inpatient acute care and sub-provider units of a hospital. It is a measure of the capacity or size of a facility.

- Case Mix Index (CMI) is a measure of the range of services offered by the hospital based on Medicare categories of care. It is a measure of the complexity of the Medicare cases
treated by a hospital relative to the complexity of the national average of all Medicare hospital cases. The Medicare Case Mix Index approximates the complexity of the hospital’s entire patient mix. The higher this measure, the more complex the services rendered by the hospital. Revenue and reimbursement are affected by higher casemix due to higher resource consumption generally expected for such services.

- Revenue per admission (REVADM) is the total charges for patient care services. Gross patient revenue does not represent the revenue actually collected, since it does not reflect deductions for contractual allowances and discounts, charity care, and similar uncollectibles.

**Data Analysis**

We apply a two step procedure using hierarchical multiple regression (HMR). HMR requires entering the independent variables into the equation in the order specified by the researcher. HMR enters variables in steps or blocks with each independent variable being assessed in terms of what it adds to the prediction of the dependent variable (i.e., the amount of variance explained by the independent variable) after the previous variables have been controlled for (Pallant, 2005).

Once all variables are entered for the controls, independent, and dependent, “the overall model is assessed in terms of its ability to predict the dependent measure (Pallant, 2005, p.141).”

We initiated our analysis by examining correlations, for the five year period, between the total IT investments and quality and process coordination variables that were selected based on the aforementioned literature supporting our claims about interplay between the constructs.
Consistent with previous studies examining the impact of lagged IT investment on performance, we found that a lag of two years explained the impact of IT investment on quality and process variables (Devaraj & Kohli, 2003). Next, we applied HMR to determine the impact of IT investments on each of the quality and process coordination variables; and their ensuing impact on firm performance. We controlled for the size of the hospital, case mix, and revenues per admission. These controls were entered into regression equation based on the significance of their correlation coefficient.

We applied diagnostics analysis, typically assessed in regression analysis, to determine multicollinearity. The tolerance values were above .10, the VIF values were less than 10 for all variables, and the Durbin-Watson statistic for variables less than 2.0, which indicates that multicollinearity was not an issue. Also, a normal probability plot of the regression standardized residuals suggests that there are no major deviations from normality.

From the initial descriptive statistics analysis performed on the data, we determined a number of hospitals with reported values for the various variables that were well above or below calculated mean values. We also examined scatter and box plots and casewise diagnostics and excluded hospitals that had reported values for each variable of interest that were greater than three standard deviations from the norm. Tabachnick and Fidell (2001), renown statisticians, suggest removing data points that are outliers (i.e., values greater than three standard deviations from the norm to allay skewing of the data) (Tabachnick & Fidell, 2001).
RESULTS

Correlations

Tables 1, 2 and 3 are correlation matrices that reveal relationship worth exploring between model constructs based on Pearson coefficients for each variable ranging from small (i.e., .10 to .29 or -.10 to -.29), medium (i.e., .30 to .49 or -.30 to .49), and large (i.e., .50 to 1.0 or -.50 to 1.0). In conjunction with the Pearson coefficients we assessed the t-statistic and indicate the significance levels at the .01, .05, and .10 levels. In Table 1 we find significant correlations between IT investments and specific Process Coordination variables (i.e., ALOS, AP, CSHBD, FTEADJ, and OCCRT). Thus, we expect to see some significant influence of IT investment on these Process Coordination variables in our regression analysis. In Table 2 IT investments are only significantly correlated with RACI (i.e., just the complications incurred in patient care and not the mortalities). Therefore, we expect to observe significant influence of IT investment on RACI in our analysis. In Table 2 we see that, RACI and RAMI are not significantly correlated with Firm Performance; thus we do not expect to reveal a significant relationship between Quality and Firm Performance. Additionally, Table 3 shows that all of the Process Coordination variables are significantly correlated with NETINC. Only ALOS, CASHDB, CSHBD, FTEADJ, and OCCRT are significantly correlated with ROA. This indicates a significant relationship between Process Coordination and Firm Performance.

Table 1: Correlations between IT Investment and Process Coordination

Insert Table 1 Here

Table 2: Correlations between IT Investments and Quality
Table 3: Correlations between Process Coordination, Quality, and Firm Performance

HMR Results

Figure 2 represents the results of the HMR analysis. The variables are entered into regression equation based on the significance of their correlation coefficient (i.e., from the most correlated with IT investment control variable to the lowest).

Figure 2: HRM Results

IT Investment to Quality

The negative betas for RAM I and RAMI (-.009 and -.106) indicate an inverse relationship in that increases in IT investments suggests increases in quality (i.e., decreases in complication and mortalities). However, since the p-values are not significant at any level we can only assert that increases in IT investments do not come at the expense of quality. Thus, the following:

Proposition 1: Greater IT investments lead to higher quality is not supported.
**Quality to Firm Performance**

As expected from assessing the non-significant correlations, the quality variables contribute to a non-significant (.906) and extremely low beta (.008) when regressed onto firm performance. However, the negative beta for quality indicates an inverse relationship between the RACI and RAMI variables with the firm performance variables, which suggest that as quality improves, noted by decreases in RACI and RAMI, firm performance increases. Therefore, we ascertain the following:

Proposition 2: Improvements in quality, partially attributed to greater IT investments, lead to improvements in firm performance is supported.

**IT Investment to Process Coordination**

- Accounts Payable (AP) has a positive beta (.407) significant at the .01 level, which means that increases in IT investment promotes increases in accounts payable. This can be rationalized as IT investments in activities such as outsourcing for data processing or purchases of information systems related services like consulting that provides a greater network of entities interacting at various touch points of the internal supply chain in the organization. The expenses for these services are accounted for in accounts payable. In turn services like outsourcing that can produce greater efficiencies making increases in net income and return on assets possible.

- Occupancy Rate (OCCRT) has a positive beta (.221) significant at the p <.01 level, which indicates that increases in IT investment promotes increases in occupancy rates, which
suggests benefits from increased efficiencies in the internal activities to enable greater utilization of services.

- Cash per bed (CSHBD) indicates a positive beta (.189) significant at the p < .05 level, which suggests that increases in IT Investments promote increases in cash per bed, which suggests benefits from increase efficiencies in the internal activities to promote utilization of services.

- Full-time employees adjusted (FTEADJ) has a negative beta (-.021), which indicates an inverse relationship suggesting that increases in IT Investments promotes decreases in full time employees. However, this relationship is not significant; yet the negative sign suggests that there may be need for fewer more employees because IT investment automates manual processes.

- Average length of stay (ALOS) has a negative sign (-.218) significant at the p < .05 level, indicates that increases in IT Investment promotes efficiencies in the internal activities to service patients.

- Plant Operating Expenses (PLNTOP) has a negative beta (-.020) and non-significant; yet, the sign suggests cost savings due to efficiencies in the internal activities of the operation.
• Cash to debt ratio (CASHDB) has a non-significant negative beta (-.160); yet, the sign indicates that increases in IT investments cause decreases in cash due to increases in debts associated with purchasing goods and services such as outsourcing data processing.

Regarding Process Coordination, we assert the following:

P3: Greater IT investments lead to improvements in process coordination activities is supported.

**Process Coordination Impact on Firm Performance**

A positive and significant beta (.639 at the p < .05 level) for process coordination variables regressed on to firm performance variables indicates that as process coordination activities improve so does firm performance. Therefore, we proclaim the following:

Proposition 4: Improvements in process coordination activities, partially attributed to greater IT investments, lead to improvements in hospital performance is supported.

**DISCUSSION AND CONTRIBUTION**

The explanation for the mechanisms of how total IT investments lead to firm performance has been somewhat elusive. The results of this study provide general support that IT investments promote efficiencies in the acute care supply chain as represented by process coordination activities, which in turn increases financial performance. Contrary to expectation, we do not find evidence that hospitals’ IT investment and financial performance are mediated by higher quality
of patient care. However, as consumers of healthcare, it is encouraging that the improved process efficiency and financial improvement are not at the expense of quality of patient services.

Overall IT investments allow for efficiency gains in internal processes that enable the coordination of activities for servicing patients. Examples of such IT investments are (a) processing clinical and administrative data into information, (b) building the internal and external technological infrastructure to support communication across supply chain stakeholders (i.e., physicians, staff, patients, and suppliers, etc.), and (c) acquiring professional information systems consulting services to automate business processes to streamline workflow. Our captured data fields are consistent with IT investments that contain costs and are likely to increase supplier interaction as manifested in the amount of accounts payable, which is inherent when acquiring products and services to promote efficiencies via outsourcing and subcontracting arrangements. Hospitals make IT investments to broaden the network of partners such as vendors via outsourcing and even patients themselves by allowing them access to their own patient information via web-based applications. Thus, an increase in accounts payables is not unexpected and can be reflection of the effort put forth by the hospitals to improve their abilities to service patients and attain internal efficiencies. In a recent outsourcing survey, acute care facilities outsourcing activities for information systems development, on-line applications to ensure access to real-time data for physicians and clinical staff rose 10.1% from the year prior (Kirchheimer, 2006). The author concludes that the survey shows an increase in clientele as companies seek to expand the array of services offered to hospitals (Kirchheimer, 2006). Further, the survey remarked that hospital IT departments are acquiring more sophisticated systems via custom development and/or outsourcing, contracts for increased response time the vendor can
provide to end users in the hospital, and skilled IT employees to whom outsourcing firms afford great access (Kirchheimer, 2006). US healthcare legislation such as the Health Insurance Portability and Accountability Act of 1996 requires hospitals to employ methods for safeguarding patient information and accounting procedures via IT and has also pushed hospitals to attain technologies or external support from vendors to enable their compliance (104th Congress, 1996).

Our findings also shed light on how hospitals’ occupancy rate mediates their IT investments and performance. As is the case in the airlines and hotel industry, achieving higher occupancy rates has a direct impact on efficiency by dispersing fixed costs to a greater number of patients. Empirical evidence of IT’s influence on occupancy rate and eventual impact on hospital financial performance offers valuable guidelines for hospital management, planners, and regulators in decisions pertaining to location and size of hospitals, and service level capabilities corresponding with the patients need for care (Phillip et al., 1984). As expected, the goal of hospitals is to optimize resources through occupancy rates, stay financially sound by generating revenue while maintaining or improving quality of care. Our results indicate that increases in IT investments are a mechanism for doing so and are indicative of how efficient hospitals service patients.

Our finding that cash generated per bed, as a measure of efficient acute care supply chain operations, has a significant relationship with IT investments. This suggests that investments in IT to support activities (e.g., point-of-care electronic documentation as opposed to error prone manual charting, real time review of labs that streamlines the medical intervention and decreases wait times in servicing a patient, and electronic capture of charges for services, medications, or
dispensable items at the point-of-care) better enable a complete record of the billable activities. The care provider is less likely to forget or mistakenly document erroneously when using a sufficiently designed information systems as opposed to relying on memory or manual notes to enter into the manual record sometime after performing the service (Abraham et al., 2004). Thus, IT aids in ensuring revenue generation from the actual activities performed in patient care. This is consistent with previous findings that improvements in charge captures occurred when nurses were required to document their patient care activities via mobile information communication systems at the point-of-care as opposed to relying on memory or notes to update the manual record or electronic record in a computer (Abraham et al., 2004).

Despite a statistically non-significant relationship, full-time employees decreased with increases in IT investments. This suggests that individuals who perform clinical care or administrative duties such as data entry, data processing, or transcription clerks were more efficient requiring need for fewer full-time employees dedicated to the aforesaid tasks. Technological capabilities, which allow the physician, clinical staff, or administrative staff to directly input or retrieve needed data via an application accessible on an intranet, reduce the need for additional employees. Additionally, outsourcing of activities such as billing or item procurement executed via an extranet requires fewer internal personnel to perform these functions. Consistent with our above explanation, greater coordination with partners is likely to manifest in not only a decrease in dedicated internal staff or full-time employees but also in an increase in accounts payable attributed to outsourcing costs and maintenance expenses associated with the communication infrastructure.
Given the prospective payment system (PPS) under which insurers reimburse a fixed amount for hospital’s services, average length of stay is of a telling value in that hospitals do not generate income on protracted patient lengths of stay. Typically, hospitals encourage physicians to be cognizant of the PPS guidelines when deciding treatment plans (Gracey, 2002). Patient care is a complex workflow that is a major component of the internal supply chain of acute care hospitals in which the efficiency of internal activities such as the time required for lab processing, records updates, etc. affects how, when, and what the care givers can perform for the patients. The premise here is that IT investments enable automation of internal processes for which derived efficiencies manifest as decreases in average lengths of stay. In turn these efficiency gains contribute to a positive impact on hospital performance.

Plant operation expenses are not significantly related to IT investments; yet, the data suggests that increases in IT investments may promote decreases in plant operating expenses for the facility. Although we do not have unequivocal evidence to support this claim, it is intuitive that technologies supporting the automation of plant activities could produce efficiencies recognized in cost savings or gain in revenue. One example is the automation of the food administration inventory and general medical item supply inventories that presumably reduce incidents of spoilage, loss, and under or over stock.

Overall the process coordination variables contribute to the ability of the firm to improve performance (mainly through returns on assets) by most significantly improving efficiencies that enable greater utilization of services and decrease waste of resources internally. We conclude that making IT investments does not come at the expense of quality (i.e., actual vs. expected
complications and actual vs. expected mortality did not increase with increases in supply chain efficiency) the statistically not significant IT investments to quality relationship notwithstanding. Essentially, we have opened the “black box” to show how IT investments, mediated through components of process coordination, increase firm performance but most importantly do not diminish the quality of patient care services.

CONCLUSION

This work describes a large scale empirical study to examine the influence of IT investments on clinical quality, process coordination activities and performance. It indicates that IT investments do impact the ability to coordinate processes among a hospital’s supply network, with process coordination mediating the performance-IT investment link. This contributes to our discernment of the IT productivity paradox (Brynjolfsson & Hitt, 1998). The study also supports the anecdotal evidence presented earlier which suggests that IT is an essential tool for linking the acute care supply chain and consequently reducing the “hassle” of coordinating many processes.

One limitation of this study, indeed due to our expansive dataset, is that we are unable to associate the IT investments with specific types of technology. It is possible that some technologies provide better support for process coordination and therefore hospital performance than others. This is an outcome that hospital managers would be interested in knowing as it would help them better focus their IT investments. Future studies may gather such detailed data, perhaps with fewer hospitals, and examine if different type of IT lead to differences in performance.
Another limitation is that we consider only process coordination and clinical quality as mediators in the IT investment-performance link. There are a variety of other factors that potentially play a significant role in this relationship. Other researchers have identified factors such as lean/JIT practices and organizational culture albeit in manufacturing systems (Ward & Zhou, 2006). Furthermore, earlier studies have shown process quality to be significantly influenced by IT investments, and there are potential interactions between process quality and process coordination (Devaraj & Kohli, 2003). This is outside the scope of the current study, but does pose a question for future research. Additionally, in future studies our model could be extended to incorporate additional performance metrics, such as customer satisfaction.

Acute care provided in hospitals is one of the largest components of the health services and supplies sector representing 15% of the Gross Domestic Product (GDP) with a measure of economic output of nearly $1.8 trillion (American Healthcare Association, 2004). This massive contribution to our economy undoubtedly requires immense coordination of activities to promote value added efficiencies in its services to its internal as well as external stakeholders. Sixty-two percent of respondents from a survey of 100 US healthcare IT decision makers cited increased IT investments for both clinical and administrative processes as a top priority between 2004 and 2006 (Datamonitor, 2004). Hospitals face business imperatives to improve patient safety often prompted by federal regulations, which is prompting healthcare to embark on a new era of development. This new environment provokes healthcare providers to increasingly view IT as a way to address several ongoing challenges and facilitate a means to pursue opportunities that connects stakeholders (i.e., patients, providers, suppliers) in the quest to achieve their mission-critical endeavor -- quality patient care (IDC, 2002).
REFERENCES


Table 1: Correlations between IT Investments and Process Coordination

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### Table 2: Correlations between IT Investments and Quality

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Figure 1: Hypothesized Relationship between IT Investment and Firm Performance mediated by Process and Quality variables
Notes:

a. The value in parenthesis is the p value. Significance is indicated by ***p<.01; **p<=.05; *p<=.10, n.s. = not significant.

b. The negative sign for RACI and RAMI actually indicates a positive or parallel relationship between Quality and IT Investment, which is consistent with the labeling for the proposed relationship in Figure 1.

Figure 2: Hierarchical Regression Model Results for IT Investment and Firm Performance mediated by Process and Quality variables