ESSAYS ON SERVICE DISRUPTIONS AND EFFICIENCY IN ACUTE EPISODES OF CARE

By

David M. Dreyfus

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ABSTRACT

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Waste in healthcare, specifically in acute episodes of care is an important concern in the healthcare industry. It has been estimated that 30% of the $2.6 trillion annual total of all health spending in the U.S. is wasted. This waste epitomizes the level of inefficiencies that are evident within various service encounters in the healthcare sector. Wastes can manifest in the forms of supplies, instruments, and time, yet there is a lack of clarity about the nature of waste, its causes, and ways to manage these inefficiencies within the literature. This dissertation intends to undertake a systematic and in-depth investigation of these issues by means of four essays.

The first essay is a quantitative ethnographic study which analyzes participant observer data collected from over one-hundred surgeries which were performed in the operating theaters of a major teaching hospital. Observational, secondary, and survey data collected as a part of this ethnographic research will be analyzed to understand the nature of waste in the operating theater and the causes for these inefficiencies. The study specifically focuses on the role played by physician preference cards that are widely considered to be foundational for the efficiency of perioperative suites. It also examines the factors that help in keeping these physician preference cards updated.

Building on the first essay and in concert with the observations in the operating theater, the second essay focuses on the issue of service disruptions. A systematic literature review of over 1,300 relevant articles identified in the literature will be undertaken to understand and synthesize

the nature of these disruptions in hospitals. This synthesis provides the basis for essay three in which a more generalizable understanding of service disruptions and operational efficiencies in acute episodes of care will be examined. In particular, the third essay aims at examining the antecedents and consequences of service disruption risk in the context of acute episodes of care by means of primary survey data. Specifically drawing on the current theoretical work of supply chain disruptions, this study examines the antecedent role of system task and operational complexity. The study will further investigate the moderating roles of information exchange among acute care providers and the level of risk management infrastructure within the hospital.

To my wife Natalie Mayfield. My love, we have done it! I cannot thank you enough for helping me pursue this dream. It would not have been possible without your love, support, and encouragement. I only hope that we can spend the rest of our lives together pursuing more dreams.

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CHAPTER 1 – Introduction

1.1 Introduction

For decades' businesses in the United States (U.S.) and around the world have implemented policies and improved processes that have resulted in waste reductions. The benefits of these waste reduction efforts have been higher quality and greater profits, among others. The healthcare industry has not followed this same path. A study conducted by the Institute of Medicine notes that the U.S. wasted $750 billion or about 30% of total health care spending in 2009 (Committee on the Learning Health Care System in America, 2012). This report comes at a time of rising healthcare costs and pressure to reduce this trend (Powell, Savin, & Savva, 2012).

This waste, especially in acute episodes of care, epitomizes the level of inefficiencies that are evident within various service encounters in the healthcare sector. Wastes can manifest in the forms of supplies, instruments, and time, yet there is a lack of clarity about the nature of waste, its causes, and ways to manage these inefficiencies within the literature. The first essay is a quantitative ethnographic study which analyzes participant observer data collected from over one-hundred surgeries which were performed in the operating theaters of a major teaching hospital. Observational, secondary, and survey data collected as a part of this ethnographic research will be analyzed to understand the nature of waste in the operating theater and the causes for these inefficiencies. The study specifically focuses on the role played by physician preference cards that are widely considered to be foundational for the efficiency of perioperative suites. It also examines the factors that help in keeping these physician preference cards updated.

Building on the first essay and in concert with the observations in the operating theater, the second essay focuses on the issue of service disruptions in hospitals. A systematic literature review of over 1,200 relevant articles identified in the literature will be undertaken to understand and synthesize the nature of these disruptions in hospitals. This synthesis provides the basis for essays three and four in which a more generalizable understanding of service disruptions and operational efficiencies in acute episodes of care will be examined. In particular, the third essay aims at examining the antecedents of service disruption risk in the context of acute episodes of care by means of primary and secondary data. Specifically drawing on the current theoretical work of supply chain disruptions, this study examines the antecedent role of system task and operational complexity. The study will further investigate the moderating roles of cohesion among acute care providers and the level of integration within the hospital.

CHAPTER 2 – Ethnographic Study in the Operating Room

2.1 Motivation

"*Proper Planning and Preparation Prevents Piss Poor Performance.*" – 7 P's, military adage

The United States (U.S.) spends more on healthcare than any other nation. On a per capita basis, it spends 2.5 times the average of other industrialized nations ($8745 vs $3484) (Lorenzoni et al., 2014). Health care expenditures, as a percent of gross domestic product (GDP), are expected to rise from 17.4% in 2013 to 19.6% by 2024 (Centers for Medicare & Medicaid Service, 2015). Future expenditures are projected to grow faster for federal, state, and local governments, as well as the portion that private insurers or consumers will need to pick up due to (1) increased economic growth, (2) continued implementation of the Affordable Care Act, and (3) the aging of the population . This cost trend is unsustainable.

Patients have also been negatively affected by rising healthcare costs. The average cost for a family health insurance policy in 2014 was $16 834, which represents a 69% increase from 2004 (Claxton et al., 2014). These higher costs to the consumer have created a growing share of persons whom are under-insured (Schoen et al., 2008). Accordingly, medical bills are the largest reason for bankruptcy in the U.S. (Himmelstein et al., 2009).

A large portion of U.S. healthcare spending is wasted. A study conducted by the Institute of Medicine notes that the U.S. wasted $750 billion or about 30% of total health care spending in 2009 (Committee on the Learning Health Care System in America, 2012). Thus, it is imperative that our understanding of healthcare costs improves, so that we can reign in rising healthcare costs and address the pressure to reduce this upward trend (Powell et al., 2012).

The operating room department (OR) within hospitals is the highest revenue generator in a hospital, accounting for over 40% of all revenues (Cardoen et al., 2010; Healthcare Financial Management Association, 2003; Macario et al., 1995), and the largest expense as well (Denton et al., 2007; Resnick et al., 2005). The waste found within the OR, epitomizes the level of inefficiencies that are evident within various service encounters in the healthcare sector. In the OR, wastes can manifest in the forms of supplies, instruments, and time, yet there is a lack of clarity in the literature concerning the nature of waste, its causes, and ways to manage these inefficiencies. With the passing of the Affordable Care Act, healthcare has been brought into focus by politics, industry, and the desire of those working within healthcare to become better for their customers. Utilizing social network analysis and learning theory, we link the roles of planning experience and ego density to their impact on unplanned costs occurring in the operating room. In addition, we provide further insights into how the rise in unplanned costs influences patients' length of stay and healthcare workers' perception of waste.

In this essay, we aim to better understand how procedure planning practices and the relationships between team members within the OR influence the generation of waste, by answering the following questions: (1) Does a greater number of planning instances reduce the cost of supplies that are used outside of the operating procedure plan? (2) How do team relational dynamics influence the cost of supplies that are used outside of the operating procedure plan? (3) How do unplanned costs within the OR effect the patient and perception of waste?

The rest of this paper is organized as follows. We review the literature, present the hypotheses, describe the data collection and methods used to estimate our model, then the results are shown and discussed before concluding with a summary of our findings, robustness checks, limitations, and suggestions for future research.

2.2 Background

The operations and healthcare literatures have written extensively about various wastes within hospitals (Boyer and Pronovost, 2010, Esaki and Macario, 2009, Froehle and White, 2014, Lingard et al., 2004), but very few studies have presented a detailed understanding of what wastes are occurring, where they are occurring in hospitals, how much is occurring, and why they are occurring. This paper contributes to the literature on healthcare waste in the OR. Going forward, we refer to a surgery or a procedure within the OR as an "episode of care," which takes place from the moment when the surgeon arrives to the room and ends when the surgeon or patient leaves the room.

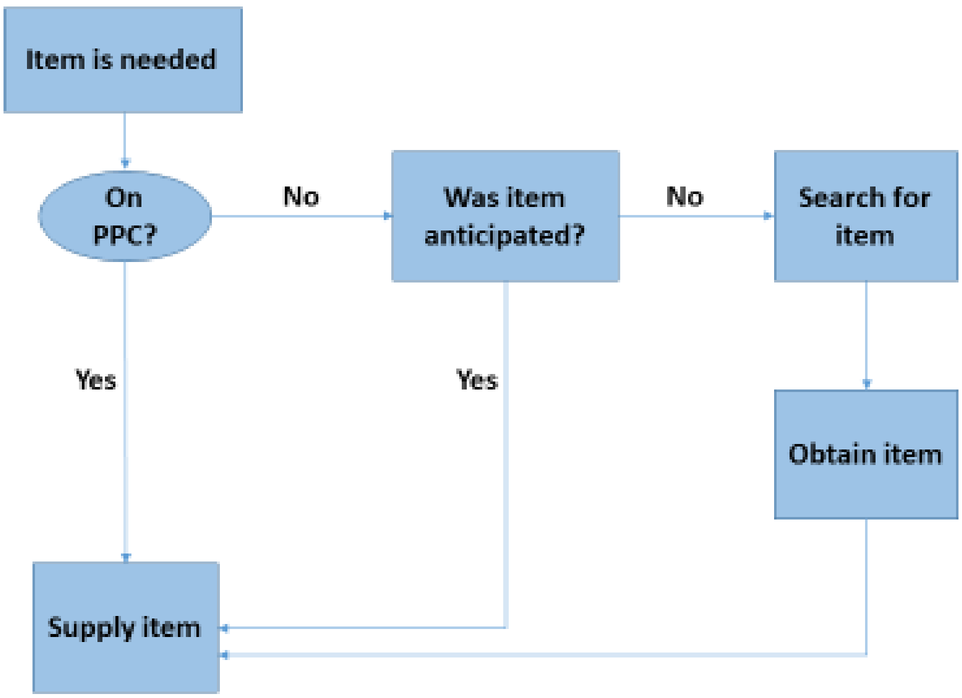
Healthcare research in the supply chain management field has continued to blossom for more than a decade now. With the recent regulatory changes from the Affordable Care Act (ACA), hospitals margins are being squeezed further. Therefore, there is a sense of urgency to understand where waste is occurring within organizations, so that hospitals remain profitable. The OR is the largest revenue maker for most hospitals and may offer the greatest opportunity to increase profits by eliminating some of the waste. However, the supply chain management literature has paid little attention to the largest profit center within most hospitals, the OR (Resnick, et al., 2005).

Extant literature in organizational design has found that strategic planning helps teams transition from their current state to their future state (Galbraith et al., 2002). The planning of an episode of care is critically important to patient health and safety, as the risks to the patient increase with their length of stay within the hospital (Dindo et al., 2004). Additionally, the planning of an episode of care allows the hospital's fulfillment department to order what is needed. Each episode of care within the OR may be viewed as a project. A project is a network of activities that result in providing value for the customer (Smith and Eppinger, 1997). In episodes of care, an integral piece of the project is the physician preference card (PPC), as it instructs the hospital personnel in various departments what supplies, instruments, and other items are needed for an episode of care. A PPC may be likened to a bill-of-materials, as it lists everything that should be needed to complete an episode of care. The PPC may be different for each physician and for each episode of care that is perform. Typically, once an episode of care is scheduled, a PPC for that episode of care is created (or digitally attached to it) and the needed materials and personnel are provided to the physician so that they have everything they want before the episode of care begins.

Then, before an episode of care begins supplies and instruments are delivered to the OR based on what is listed on the PPC. Once the OR personnel are ready, they will unpack the items according to what the PPC states needs to be done. During this time, it is common for additional items to be brought in to the OR. These items are not listed on the PPC. Instead, they are brought in based on the judgment of those working in the OR. This use of their tacit knowledge may help lower the amount of time that is needed to gather these supplies during an episode of care. However, it would be more advantageous for the hospital and patient if these items were already listed on the PPC and delivered prior to the OR being prepped for an episode of care. For the hospital, it would allow higher paid employees, such as the nurses, to perform work at their intended pay grade. For patients, it would free up the employees' time to concentrate on delivering quality care.

Throughout an episode of care, supplies, instruments, and other items are requested. When this occurs, the item requested will be located, opened, and handed to the appropriate person. If this item is on the PPC, it will be close by and quickly handed over. If the item was not on the PPC, then the OR personnel may have brought in to the room before the start of the episode of care. If they did not, then time will be spent searching and obtaining the item before it is delivered. Figure 1 outlines this process. This process will continue until the episode of care is completed.

Figure 1: Operating Room Item Search Process



2.3 Hypothesis Development

When changes are made to a PPC, often it is updated with additional requirements as a physician is trying to avoid the risk of not having a needed item during an episode of care. This behavior provides additional certainty that all needed items will be available and thus the risk of not having what is needed is lowered. Also this may increase procedural efficiency, as the need for someone to acquire the needed item just before or during the episode of care has been avoided. Conversely, when an item is removed from a PPC, the physician has certainty that this item will not be needed again. One may view this as risk seeking. However, from a lean management perspective waste has been avoided and a more simplified process put in place to further increase procedural efficiency (Womack et al., 2008).

Every surgeon and the other members of an OR team have their own process for completing their tasks (Fredendall et al., 2009). Therefore, changes made to a PPC are based on an individual's intuition, rather than on a systematic analysis of the process such is used in value-stream mapping or service blueprinting. Even when one has a full view of a process, optimizing a complex process, such as is frequently found in the operating rooms across the world, often produces a sub-optimal result (Pich et al., 2002). Additionally, intuition is not inherent. Instead, intuitive schemas are developed over many years (Dane and Pratt, 2007). Thus, when OR team members suggest changes to the PPC, the changes may not lead higher procedural efficiency. Instead as changes to the PPC are made, procedural complexity may increase with the additional requirements added to the PPC.

By regularly updating the PPC, a physician is attempting to provide the maximum value to the patient, by minimizing the risk that they will not have something they need. The intention is good as each time a physician requests an update to the PPC it is to improve the plan for an episode of care. An update to the PPC may include the inclusion or exclusion of supplies, instruments, or other instructions to supporting hospital personnel, such as how to position patients, so that an episode of care is run efficiently.

Nurses, surgeons, or other personnel may update PPCs depending on a hospital's policies. Nurses and scrub techs tend to bear the brunt of additional work required from using a poorly planned PPC, since they will be the ones gathering any additional supplies needed for an episode of care. Additional supplies are gathered before an episode of care often due to the tacit knowledge that the nurses and other personnel have about a patient, the surgeon, and others that will be present in the room. These items are classified as foreseen uncertainty, as it involves anticipating a need (De Meyer et al., 2002). This anticipation of needs takes time away from other duties, but may save procedural time for the patient. Also, nurses are incentivized to gather additional supplies as not having a supply when it is needed may be viewed unfavorably by the surgeon or others in the room, even if it was not on the PPC. Often, surgeons are unaware of the additional supplies gathered for an episode of care, as many of the supplies are gathered prior to their arrival to the OR.

A central tenant in the behavioral theory of the firm is that performance feedback drives learning (Argote and Greve, 2007, Cyert and March, 1963). Thus, using the knowledge gained from experience can improve performance (Carley, 1992, Dunbar and Stumpf, 1989). However, a lack of standardized, routine planning behavior indicates that each individual is using their own process to plan or not plan by relying on workarounds (Fredendall, et al., 2009). When learning occurs and planning follows, this mostly leads to additional supplies being added to the PPC, which is why when a PPC is updated, the updates almost always include additions to the plan rather than subtractions. The logic for this is simple when one understands that physicians do not want to go without an item and nurses and scrub techs do not want to have to gather additional supplies during an episode of care. From everyone’s viewpoint in the OR, more is better. Thus, one should expect that as the PPC is updated, it lowers the number of items needed for an episode of care that is not found on the PPC.

This line of reasoning is in direct contrast to many of the supply chain management principles that are taught throughout business schools all over the world. The lack of experience and knowledge with process improvement ideas may be a significant hindrance to better planning outcomes (Tucker and Edmondson, 2003). Without proper knowledge and training, changes to the plan may be sub-optimal (Rivkin and Siggelkow, 2003). To properly integrate any learning that occurred one may need to verify the additional information and better understand its consequences.

Lack of coordination, information sharing, cooperation, knowledge on how to improve processes and operations in a complex environment are preventing organizational learning from occurring, thus allowing additive behavior to take hold. Without planning routines or standardized planning methods, process variation and process failures will continue to occur and may even do further harm (Fowler et al., 2008). Individual agents may act with good intentions, but their actions have consequences on the greater system that are often unknown. Therefore, even though planning brings about changes, the changes may not lessen the cost of process variation. Furthermore, when non-standardized planning methods are used it may create a situation in which it is more difficult to see future changes that would improve the cost of process variation. Thus, additional supplies on the PPC and in the OR introduce more complexity and uncertainty into the process. This occurs, because the change to the plan was an attempt to optimize the episode of care. However, the complexity of the OR provides an environment where the consequences of the changes are not always readily apparent. Thus, the change results in a sub-optimal solution. Instead of optimizing with additive behaviors, one should be trying to use the new knowledge gained to discern patterns over time that refine their schema and lead to PPC changes that optimize the PPC such that future uncertainty is avoided. This is likened to learning, where policies are changed according to observed patterns (Fowler, et al., 2008, Pich, et al., 2002).

When nurses and surgeons encounter uncertainty, they do whatever it takes to resolve the issue at hand so that patient safety is ensured and good outcomes are achieved. This behavior is typically performed by using first-order problem solving (Tucker et al., 2002), when someone takes the initiative to do it themselves. This happens frequently when bringing in foreseen uncertainty products and variation products (Pich, et al., 2002). For second-order problem solving to occur, someone must ask for help from another individual. This may occur when someone is preoccupied or the best solution is unknown. Unfortunately, the individual asked may not be the best person to ask (Tucker, et al., 2002). Furthermore, second-order problem solving does not lead to a permanent solution, as the time constraints and culture are not conducive to going beyond solving the immediate problem (Tucker, et al., 2002). Thus, learning may occur but it is localized to the individuals involved and often is not translated into further action (Pich, et al., 2002).

Due to localized knowledge, when a PPC is updated the OR team will need to re-execute the plan to notice any differences in efficiency. This learning may result in further planning instances. For example, when process improvements are made in manufacturing or other service settings, the improvements may bring to light other inefficiencies that were not readily apparent previously. These new inefficiencies require further planning instances to overcome them.

Judgmental forecasting has long been argued against (Armstrong and Forecasting, 1985). However, this type of forecasting is exactly what is used for PPCs. Hogarth and Makridakis (1981) recognize the benefits and need for judgmental forecasting, while acknowledging the numerous biases and errors that are likely to occur when using this method. To date, research on judgmental forecasting has focused on recurring sales forecasts, while we are evaluating forecasts of procedural plans which do not greatly differ from one procedure to the next. Additionally, most judgmental forecasting is performed through adjustments after a statistical forecast has been created (Sanders and Manrodt, 1994), which further differentiates the PPC forecasting process, as this latter step is not done. Additionally, no formal forecasting training is provided to OR personnel, meaning that learning may be diminished since personnel do not know to or how to look for opportunities to improve the forecast (Klassen and Flores, 2001, Nikolopoulos et al., 2006).

The literature is divided on the merits of judgmental forecasting. (Goodwin and Wright, 1993) highlight several studies which found that judgmental adjustments to statistical forecasts provided benefits. However, Syntetos et al. (2009) find that no learning occurs with the use of judgmental forecasting, so while some benefits may occur, the overall benefit does not get larger over time. (Lawrence and O'Connor, 1992) differentiated forecasting between stable and unstable series and found that stable series were best performed by statistical techniques and not judgments. PPCs are most likened to a stable series, as procedure processes do not change often.

While there are many hindrances to proper planning (Hogarth and Makridakis, 1981), planning based on schemas and non-formalized processes regularly occurs (Bunn and Wright, 1991, Lee, 1996). Specifically, Pich, et al. (2002) refers to this as opportunistic learning. Once these opportunistic learning opportunities are incorporated into the PPC, the plan is retested when a patient needs that type of episode of care. This feedback loop is what makes forecasting a PPC unique. Unlike a traditional sales forecast which has many environmental influences that subject it to changes and outcomes are not immediately known, a procedural process in the OR is stable and outcomes are typically known rather quickly. This creates an ideal environment for obtaining improvements in judgmental forecasting (Goodwin and Wright, 1993). Thus, with the same procedural process being performed each time a PPC is used, the PPC may become fine-tuned enough to result in procedural efficiency gains. Specifically, once a PPC is created one can expect refinements that include adding items to the plan. However, these additions are not necessarily correct, as one’s intuition has not developed good schemas yet. Therefore, procedural efficiency may not improve and instead complexity may have increased, such as can happen when one provides a forecast at the item-level, when the parent-level has not been stabilized. Over time, as the episode of care is performed many times and additional planning instances occur, one's intuition and schemas become more refined (Pich, et al., 2002). Thus, we can expect increases in procedural efficiency due to refinements in one's schemas.

Finally, literature is unclear as the advantages of planning more frequently. Planning frequently may be disruptive and make it harder to understand the underlying process (Amburgey et al., 1993, Barringer and Bluedorn, 1999). Other literature agrees that taking more opportunities to review a plan will lead to better performance (LaPorte and Consolini, 1991, Miller and Cardinal, 1994). A PPC is most likely to be updated between the time an episode of care is scheduled until just after the episode of care. Thus, surgeons who have updated their PPCs more, have had the opportunities to gather the necessary information to refine their schemas and improve their judgments as to what is needed, which will result in higher procedural efficiency via reduced variance from the plan. Thus, it is hypothesized that:

Hypothesis 1: The number of planning instances has an inverted U-shape, such that as the planning instances increases the cost initially increases and then decreases.

The value of teams and their impact on performance has been researched heavily (Bell, 2007, De Dreu and Weingart, 2003, Evans and Dion, 1991, Gully et al., 2002, Mesmer-Magnus and DeChurch, 2009). Literature shows that more integrated teams perform better (Lichtenstein et al., 1997), but the literature is lacking in its understanding of how team members within the OR communicate and its effect on performance (Bartunek, 2011). Cross disciplinary communication can be difficult, but is important, as it is shown to increase conformance and experiential quality metrics (Senot et al.). Interest in collaboration amongst nurses and physicians has been heightened within hospitals as their Medicare and Medicaid services reimbursement has become linked to their conformance and experiential quality metrics.

OR teams have a natural hierarchical nature to them since the surgeon is ultimately responsible for the results of the episode of care. However, the surgeon needs the support of the team to complete the episode of care in an efficient and safe manner. When OR teams come together for an episode of care, the team members may or may not know each other well. If the team members are unfamiliar to each other, then 'swift trust' is formed to complete the episode of care (Meyerson et al., 1996). For example, a new hire or transfer may be new to the department or profession or a visiting doctor may be performing an episode of care with others whom they have never worked with previously. Thus, often there is only one person who is unknown to the team. The ability to accept swift trust in these cases is important, so that everyone can do their tasks without worry. However, when new team members arrive, communication and performance may suffer until new routines and expectations are accepted amongst team members (Edmondson et al., 2001).

More commonly, the team members know each other and have experience working together. In these instances, trust and psychological safety are desired for the best outcomes (Edmondson et al., 2004). Psychological safety is an enabler to learning (Edmondson, et al., 2004) and is built upon the formation of relationships formed through shared goals, knowledge, and respect (Carmeli and Gittell, 2009). Fulmer and Gelfand (2012) highlight the need for interpersonal trust in teams to achieve high performance and implement organizational change. One way that trust is built is through communication of information and frequent contact (Gong et al., 2012, Wong and Boh, 2010).

Since it is the sum of everyone's collaborative interactions which produces the procedural outcomes, surgeons and other team members need to remain connected to each other, so that everyone is on the same page at all times. To remain connected to one another, team members must communicate with each other so that collaboration occurs (Lewis, 2006). Collaborative interactions have been explored in the healthcare domain (DiMatteo et al., 1994, Ellingson and Buzzanell, 1999, Medved et al., 2001, Young and Flower, 2002). By achieving greater levels of equality and avoiding status and power differences, collaborative interactions can increase (Barron, 2000).

The degree to which team members trust each other effects the amount of resource sharing and knowledge sharing that will occur. As OR team members trust more, willingness to communicate and share knowledge increases. As the amount of knowledge sharing increases between the team members, anticipation of needs and wants of others in the OR become clearer, such that efficiency increases. For example, when communication is occurring during an episode of care, familiarity amongst the team is increasing and the energy in the room increases, such that everyone is able to work efficiently while building increasing levels of comfort amongst each other. This comfort is seen through the anticipation of needs, psychological safety of speaking up, and trusting that everyone will do what needs to be done to treat the patient effectively.

By exploring the network communication structure within OR teams, we expect that greater communication will lead to higher levels of efficiency due to the intensity of resource dependency and knowledge spillover (Hillman et al., 2009, Inkpen and Currall, 2004, Pfeffer and Nowak, 1976). This increase in knowledge sharing is facilitated by trust built between team members. We hypothesize the following:

Hypothesis 2: Operating room teams that are more densely connected are associated with lower unplanned episode of care costs.

Lower unplanned costs are associated with having a better planned PPC, which may be likened to using lean practices in manufacturing, such that all that is available is what is needed. Nothing more and nothing less. The Taguchi view of quality implies that anything outside of perfect specification has a cost (Taguchi, 1986). In healthcare it is commonly believed that revenue and profits may be impacted by unplanned costs, but quality may remain or be indiscernible depending on the customer expectations. In the OR, specifications are set by the PPC and deviations from the PPC increase costs, but it is unclear if unplanned costs have any effect on patient outcomes.

When an episode of care deviates from the PPC, it often means that time is needed to gather and provide additional supplies, instruments, or information for the OR team. A deviation from the PPC implies that something unforeseen has occurred and added complexity to the process. When these situations occur, additional time is taken to provide what is needed. This additional time may be spent before or during an episode of care. For example, before some episode of care team members may spend time gathering additional supplies that are not on the PPC just in case the surgeon may need them. A trade-off occurs here as those additional items may not be needed and the extra time spent gathering could have been used for more value-added activities. While having these items on-hand may make the OR more crowded, if needed, they may save time and prevent frustration. However, if these items are actually needed, shouldn't they be on the PPC?

The duration of an episode of care is known to influence the outcome of surgery and recovery (Cook et al., 1997, Kessler et al., 2003, Neuman et al., 2014). Episode of cares are extended when team members leave the room to search for and obtain additional supplies, instruments, or information. It is known that the risk of infection increases each time a door is during an episode of care (Lynch et al., 2009) and may cause distractions that lead to errors or additional unplanned costs (Young and O'Regan, 2010). Compounding risks may occur when a needed instrument is not immediately available, as a non-sterilized instrument will be quickly cleaned and rapidly sterilized using flash sterilization methods, which are associated with higher rates of infection compared to traditional steam cleaning sterilization episode of care (Leonard et al., 2006).

As surgeons are able to reduce their unplanned episode of care costs through better planning and team communication, the patient will benefit. Currently, as the unplanned costs of an episode of care increase, it is associated with events that add time to the length of the episode of care, complexity to the situation, and ultimately increase risks to the patient. Specifically, lower unplanned costs represent quality planning, which leads to quality outcomes. Therefore, we hypothesize that:

Hypothesis 3: Greater unplanned episode of care costs are associated with longer length of stay for patients.

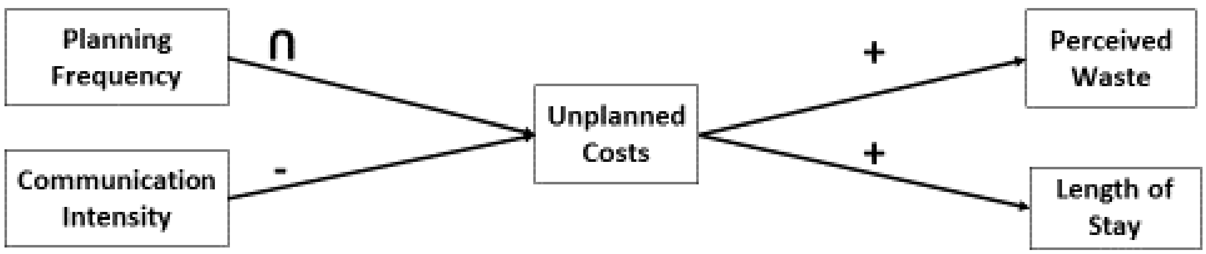
To curb unplanned costs, one must be aware that unplanned costs are occurring. Surgeons, in particular, play an important role in controlling costs, as they choose which items are placed on a PPC. However, there is evidence that surgeons and other healthcare professionals working within operating rooms are unaware of the costs of the supplies and instruments (Jackson et al., 2016, Okike et al., 2014, Parnes et al., 2015). This may stem from a lack of transparency and accessibility to cost data (Tabib et al., 2015). There are indications this is changing, such as the recent reporting by CMS of hospital charge data for the 100 most common Medicare stays (Centers for Medicare & Medicaid Service, 2015). This type of change makes it more important that surgeons and others within hospitals understand the costs of their services, supplies, and instruments.

Little has been written about healthcare workers abilities to recognize process waste. Most healthcare workers are disconnected from what an item or service costs (Jackson, et al., 2016). Additionally, surgeons, nurses, and others within an OR typically are not trained in supply chain methods. Thus, their ability to recognize wastes and inefficiencies is not part of their formal training. However, this does not mean that waste goes unnoticed. The media and most healthcare organizations discuss waste in healthcare in a negative context, such that personnel are aware that waste in healthcare exists.

One way in which OR personnel may notice waste is from the supplies and instruments that are opened and displayed for all to see in the OR. This transparency provides opportunities for OR personnel to notice what is present, but not always usually there. OR personnel are trained to be vigilant and aware of the patient and the environment within the room at all times. It is likely that additional supplies and instruments are noticed by OR personnel, since they would most likely be present when these items are opened or accessed. Additionally, the use of additional supplies and instruments may be noticed when people are leaving the room to obtain items or when people are coming into the room to deliver items. Another opportunity to notice waste is during the end of the episode of care when the trash is taken out. The amount of trash can be easily seen by the size and number of bags that must be carted away. Therefore, we expect there to be an understanding of the waste occurring within the OR, as this awareness may be the impetus for future planning instances. Thus, to better understand how the unplanned costs of surgery are noticed by those in the OR we hypothesize that:

Hypothesis 4: Greater unplanned episode of care costs are associated with greater perceived waste.

Figure 2: Conceptual Model



Controls: Patient severity, length of episode of care, location, number of staff, tenure of staff, scheduled, and number of supplies.

2.4 Research Design

2.4.1 Operationalization of Variables

2.4.1.1 Planning Instances

Physician preference cards (PPCs) contain the instructions for what is needed before and during an episode of care. This includes all of the supplies and instruments requested for an episode of care. It includes information about which supplies and instruments should be opened prior to the start of the episode of care. It also holds information concerning the positioning of a patient within the OR and other pertinent information that OR personnel may need to provide quality care to the patient.

A *planning instance* occurs when a change is made to the PPC. This change could involve adding and/or removing supplies, instruments, or relevant patient information. The number of planning instances for two years prior to the episode of care were obtained and averaged by dividing by two.

2.4.1.2 Communication Intensity

Communication intensity is measured by calculating the ego network density. Density helps describe the general level of linkages among all the actors in a network; allowing us to better understand how everyone within the OR is connected to one another. An OR team's ego network density can give us a sense of the collaborative interaction taking place within the OR by measuring its connectedness (Tichy et al., 1979). More communication is linked to decentralized communication, while less communication intensity will insinuate a more hierarchical, centralized structure (Tushman, 1979). Densely connected networks have higher performance (Carnovale & Yeniyurt, 2014; Clifford Defee & Stank, 2005), as well as a positive association with learning (McFadyen et al., 2009).

A matrix was created at each episode of care to capture the communication intensity between all actors present. Each communication from one actor to another was recorded so that directionality and amount could be determined. When using social network analysis, density is calculated by dividing the number of observed ties by the number of possible ties (or pairs), so one knows the percentage of all possible ties that are present in each ego network. The ties are equal to the number of connections among all the nodes in an ego network. The pairs are the number of possible ties in each ego network. UCINET 6 is used to calculate the ego network density using directed data for each episode of care.

2.4.1.3 Unplanned Episode of Care Costs

This variable captures the cost of the supplies that were opened and used which were not part of the PPC, as well as the supplies that were open and unused which were part of the PPC. When supplies are needed beyond the PPC, often the episode of care is delayed. As more items are opened which are not on the PPC, it provides an indicator to the amount of time spent gathering these additional supplies before and during an episode of care. Higher levels of efficiency are associated with lower costs of supplies beyond the plan.

This data was collected by recording the supplies that were opened and comparing them against the PPC for the episode of care. A supply was considered unplanned, when the packaging was counted, but the item did not exist on the PPC and when the item existed on the PPC but was discarded without ever being used. During an episode of care, any packaging discarded was collected. Also, careful attention was paid to any item that was discarded without ever being used by the observer sitting by the trash bag. After the episode of care, each piece of packaging was catalogued and matched with its price paid by the hospital. During the cataloguing process, great care was taken to protect the observer by always wearing protective gloves and outfitting the computer with a keyboard protector to minimize any transference of possible contaminants.

2.4.1.4 Length of Stay

The number of days a patient stays at the hospital is a common measure of performance. Hospitals are rewarded for treating patients quickly, so long as they do not return within 30 days of being discharged. This secondary data was collected months after the episode of care to ensure that the patient's care had ended.

2.4.1.5 Perceived Waste

Immediately after each episode of care, a survey was handed to the surgeon, scrub tech, and circulator nurse present. A one-item measure to assess their perception of waste was obtained by measuring the extent to which the surgeon had to wait for a needed item during the episode of care and the extent to which the scrub tech and circulating nurse struggled to find a needed item during the surgery. This concrete measure provides an indication to the extent that items not on the PPC were needed, as an increase in the number of items not on the PPC creates additional waiting by the surgeon and searching by the other personnel. A one-item measure was used to ensure that personnel in the episode of care would take the time to complete a survey. Measures that are clearly understood by those completing the survey are said to be ‘concrete’ and have the same predictive validity as a multi-item measure (Nair, A et al., 2016). A composite score of the three responses was calculated.

2.4.2 Control Variables

2.4.2.1 Patient Severity

Uncertainty inserts variability into a process. Uncertainty can influence efficiency and the subsequent waste created. The American Society of Anesthesiologists (ASA) developed a physical status classification system which is commonly used to assess the severity of a patient’s condition (American Society of Anesthesiologists, 2014.). This ASA classification ranges from 1 to 5. ASA 1 is for a healthy person, ASA 2 is for a patient with mild systemic disease (i.e. social smokers, social alcohol drinkers, pregnancy, obesity, etc…), ASA 3 is for patients with severe systemic disease that substantially limit normal functions (i.e. morbid obesity, alcohol dependence, pacemaker, renal disease, etc…), ASA 4 is for patients with severe systemic disease that is a constant threat to life, and ASA 5 is for patients who are not expected to survive the episode of care. As a patient's ASA classification increases, increases in uncertainty are inserted into the episode of care process, which may influence the number of supplies that are needed to complete an episode of care. Therefore, we control for this.

2.4.2.2 Length of Episode of care

The amount of time within the OR is critical for the patient's health and safety. The most critical time for the patient is when they are under anesthesia, as it is well known that many complications can occur the longer one is under the influence of anesthesia (Yoho et al., 2015).

In addition to patient safety, the caregivers in the OR must be paid. While the surgeons are the highest paid individuals in the OR, the others in the room are not inexpensive for a hospital. Thus, as the turnover of patients within the OR increase, the revenue of the hospital will increase as it can serve more patients or send personnel home (if no more patients are scheduled for the day). The observer recorded this data by noting the time at which the surgeon entered the room and the time at which the surgeon left. For the rare occasion that a surgeon arrived before the patient, the time was not started until the patient arrived.

2.4.2.3 Location of Episode of care

The location of the episode of care may influence performance due to the amount of space available to those in the OR. At this hospital, inpatient rooms are about twice the size of outpatient rooms. Using a binary variable, we control for the size of the OR. The observer recorded this data.

2.4.2.4 Patient Weight

A person's weight is known to have a direct correlation with their level of health. We control for patient characteristics by including the number of pounds that they weigh. This secondary data was provided by the hospital.

2.4.2.5 Episode of Care Type

Several types of episodes of care were sat in on. They included Ears, Nose, and Throat (ENT), Emergency, General, Gynecology, Neurosurgery, Orthopedics, Podiatry, Urology, and Vascular. As the majority of episodes of care were considered General, a binary measure was created with general episode of cares listed as one and all others as zero to control for the type of episode of care being performed.

2.4.2.6 Number of Staff

The number of staff within the OR is controlled for as it is expected to affect the amount of communication, interaction, and time of the episode of care. The OR is a confined space and as the number of persons in the room grows inefficiencies and waste may increase due to having to wait until others have completed talking, having to step around someone to access another area of the room, or an increased likelihood of miscommunication. Literature has found that as team size increases, efficiency may suffer (Staats et al., 2012). This data was obtained by summing the number of people who were present for the episode of care.

2.4.2.7 Staff Tenure

Senior staff is expected to know more than junior staff, as they have had greater opportunities for learning. They may know how to get things done more quickly or whom to contact to help complete a task. Junior staff is less set-in-their-ways as compared to senior staff and may be more efficient performing some tasks. The number of years at the hospital for each staff member within the OR is summed and averaged. It ranges from 0 to 32 years, with an average of 5.25 years of service at the hospital. This data was obtained from the hospital's human resources department.

2.4.2.8 Scheduling of the Episode of Care

A binary variable indicating whether the episode of care was scheduled or not is created. Episode of cares that not scheduled are often added to the workday as time permits or in the case of an emergency. Differences in the amount of time to obtain all the necessary supplies and equipment and information to efficiently perform the episode of care may be different than those episode of cares which had more planning involved. This data was obtained from secondary data provided by the hospital.

2.4.2.9 Number of Supplies on the PPC

The number of supplies on the PPC was controlled for, as it may impact the amount of unplanned costs. A larger, longer, or more complex episode of care will have more items on the PPC, compared with a more routine, shorter duration episode of care. This data was obtained by summing all the supplies listed on the PPC for each episode of care.

2.5 Data

To test the hypotheses a combination of observational, survey, and secondary data is used. First, access to a hospital's OR was gained. This hospital is a large teaching hospital located in the mid-west US. They complete over 20,000 inpatient and outpatient episode of cares each year. Attendance by the primary researcher for an episode of care was randomly selected based on the start time of the next surgery amongst more than two dozen inpatient and outpatient operating rooms. Explicit permission to attend a specific episode of care was granted by those hospital personnel working in the OR for each episode of care. Only once was attendance denied and this was due to the patient's preference not to allow any non-essential personnel in the room.

Several months and hundreds of hours were spent sitting in the OR collecting data. The participants were aware of the researcher's presence, but his presence was largely ignored thus minimizing the introduction of any bias into the results. The communication within the room was collected on a matrix style sheet so that directionality, content, and temporal aspects were captured, along with all of the supply and instrument usage. After each episode of care, the surgeon, scrub tech, and circulating nurse completed a survey about the episode of care that had just been performed. At the end of each episode of care, instrument usage was catalogued before the items were re-sterilized. At the end of each observation day, supplies were catalogued to determine actual usage for each episode of care. The hospital provided secondary data concerning supply and instrument costs, patient outcomes and characteristics, and staff tenure.

A total of 101 episodes of care were attended. The first five episodes of care were used to refine the data collection techniques. Two other episodes of care were excluded from the analyses due to incomplete data. Thus, data from 94 episodes of care are used to test the hypotheses.

2.6 Research Methods

Seemingly unrelated regression (SUR) is used to test the hypothesized model. SUR is preferred over ordinary least squares regression (OLS) if you have a group of equations whose error terms may be correlated ((Greene, 2003; Preacher et al., 2007; Zellner, 1962)). In general, using SUR will improve the asymptotic efficiency of the estimator. SUR assumes that all of the regressors are exogenous, otherwise, both OLS and SUR would be inconsistent estimators.

To test hypotheses 1 and 2, we use the following model:

<u>Model 1:</u> $= \beta_0{}' + \beta_1 PlanningInstances_i + \beta_2 PlanningInstances_i^2 +$
$\beta_3 NetworkDensity_i + \beta_4 PatientSeverity_i + \beta_5 EpisodeofCareLength_i +$
$\beta_6 EpisodeofCareLocation_i + \beta_7 PatientWeight_i + \beta_8 EpisodeofCareType_i +$

$\beta_8 NumberofStaff_i + \beta_{10} StaffTenure_i + \beta_{11} Scheduled_i +$
$\beta_{12} NumberofSuppliesonPPC_i + \varepsilon_i{}'$ (1)

To test hypothesis 3, we use the following model:

***Model 2*:** $= \beta_0{}' + \beta_1 UnplannedCosts_i + \beta_2 PatientSeverity_i +$
$\beta_3 EpisodeofCareLength_i + \beta_4 EpisodeofCareLocation_i + \beta_5 PatientWeight_i +$
$\beta_6 EpisodeofCareType_i + \beta_7 NumberofStaff_i + \beta_8 StaffTenure_i + \beta_9 Scheduled_i +$
$\varepsilon_i{}'$ (2)

To test hypothesis 4, we use the following model:

***Model 3*:** $= \beta_0{}' + \beta_1 UnplannedCosts_i + \beta_2 EpisodeofCareLength_i +$
$\beta_3 EpisodeofCareLocation_i + \beta_4 EpisodeofCareType_i + \beta_5 NumberofStaff_i +$
$\beta_6 StaffTenure_i + \beta_7 Scheduled_i + \beta_8 NumberofSuppliesonPPC_i + \varepsilon_i{}'$ (3)

The correlation matrix was evaluated for multicollinearity, as well as the variation inflation factors (VIF) calculated (Peng & Lai, 2012). With no correlation above 0.50 and an average VIF of 1.28, we are reasonably confident that multicollinearity is not an issue in the model (Cohen et al., 2003; Diamantopoulos & Siguaw, 2006).

Endogeneity and simultaneity are always a concern when conducting research. Endogeneity may be found whenever there are omitted variables, measurement error, or common method variance occurring in the data. While thoughtful design of the data collection was taken to ensure that endogeneity would not occur, planning instances or communication intensity may be endogenous to unplanned costs. However, since planning instances occurred before an episode of care was observed, we can be assured that unplanned costs in the episode of care did not prompt any of the updates that had already occurred. Additionally, since the participant observer recorded the communication taking place in the episode of care and knows that the communication taking place during the episode of care was never about the accuracy of, addition to, or subtraction from the information on the PPC, we are reasonably confident that endogeneity and simultaneity is not an issue here. However, to further ensure that endogeneity is not skewing the results, the Durbin-Wu-Hausman test was performed by following the Davidson and MacKinnon (1993) approach of using an augmented regression test. First, the SUR was performed with all the variables in the model, then the predicted values of the residuals of the endogenous variable was included in the second step. Finally, a test to determine if the predicted values of the residuals is significantly different than zero is performed to determine if endogeneity is present. An insignificant p-value ($p > .10$) is obtained, indicating that our SUR is consistent and endogeneity is not a concern. Finally, heteroscedasticity is tested for to ensure that the errors are independent and identically distributed by conducting the Breusch-Pagan / Cook-Weisberg test and an insignificant value was obtained ($p > 0.10$) (Breusch & Pagan, 1979; Cook & Weisberg, 1983). Thus, it is unlikely that heteroscedasticity is an issue in the model.

2.7 Results

The descriptive statistics as well as correlations are displayed in Table 1. The average number of planning instances during the two years before the procedures is 3.9. Communication intensity, or ego density, averages 0.76, with a standard deviation of 0.15. Over $1800 in unplanned costs occur on average, while patients stay within the hospital over 3.5 days. The mean of the perceived waste is 0.08 and the patient severity averages 2.5. On average, an episode of care lasts about an hour, with more than 60% of the procedures occurring in inpatient rooms. Patients weighed 183 pounds, on average, and almost 40% of the episodes of care observed were considered general surgery. An episode of care had 5.48 people present with 5.1 years' experience, on average. On average, 77% of the episodes of care were scheduled and they included almost 23 supplies.

Table 1: Correlation Matrix

	Mean	S.D.	Planning Instances	Communication Intensity	Unplanned Costs	Length of Stay	Perceived Waste	Patient Severity	Length of Episode of Care	Location	Patient Weight	Type of Episode of Care	Number of Staff	Tenure of Staff	Scheduled	Number of Supplies
Planning Instances	3.88	2.93	1													
Communication Intensity	0.76	0.15	-0.034	1												
Unplanned Costs	1804.85	4220.37	0.267	0.007	1											
Length of Stay	3.65	5.99	0.054	0.077	0.156	1										
Perceived Waste	0.08	12.36	0.256	-0.027	0.145	0.103	1									
Patient Severity	2.49	0.63	0.048	0.04	0.188	0.461	0.146	1								
Length of Episode of Care	59.15	46.2	0.063	0.023	0.182	0.229	-0.394	0.056	1							
Location	1.23	0.43	-0.219	0.132	-0.212	-0.209	-0.089	-0.15	-0.216	1						
Patient Weight	183.28	58.14	0.191	-0.235	0.201	0.06	-0.004	0.232	0.098	-0.193	1					
Type of Episode of Care	0.38	0.49	-0.134	0.125	-0.146	0.051	0.097	0.117	-0.104	-0.074	-0.013	1				
Number of Staff	5.48	1.91	0.154	-0.132	0.124	0.145	0.11	0.071	0.277	-0.324	0.268	0.055	1			
Tenure of Staff	5.1	8.52	-0.066	-0.111	0.077	-0.106	-0.164	-0.059	0.033	-0.125	-0.005	-0.029	0.018	1		
Scheduled	0.77	0.43	0.15	0.023	0.138	-0.264	0.052	-0.168	0.056	0.068	0.131	-0.03	0.047	0.02	1	
Number of Supplies	22.87	11.57	0.346	-0.133	0.367	0.176	-0.065	0.029	0.445	-0.212	0.085	-0.111	0.331	0.044	0.055	1

The results of the regression models are presented in Table 2 with standardized coefficients. As shown in the results, the number of planning instances and its squared-term are significant providing support for hypothesis 1 ($\beta = 0.799$; $p < 0.01$ & $\beta = -0.529$; $p < 0.05$, respectively) that planning instances has an inverted U-shape relationship with unplanned costs. We find support for hypothesis 2, which hypothesized that greater network density would result in lower unplanned costs ($\beta = -0.142$; $p < 0.05$).

To better understand if the perception of waste in the OR leads to additional planning instances, a post hoc analysis exploring the number of planning instances for one year after a procedure was performed was analyzed. The regression results of perceived waste on planning instances for one-year after a procedure is significantly positive ($\beta = 0.217$; $p < 0.05$). This further substantiates the results that OR personnel notice the waste and that they are trying to limit the amount of waste by further refining their procedure plans.

Table 2: Regression Analyses

	Dependent Variable →	Unplanned Costs		Length of Stay		Perceived Waste	
	Independent Variables ↓	Coeff. (S.E.) 2-1	Coeff. (S.E.) 2-2	Coeff. (S.E.) 2-3	Coeff. (S.E.) 2-4	Coeff. (S.E.) 2-5	Coeff (S.E) 2-6
Hypothesized Variables	Planning Instances		***0.799***				
			(0.230)				
	Planning Instances Squared (***H₁***)		**-0.529**				
			(0.252)				
	Network Density (***H₂***)		**-0.142**				
			(0.072)				
	Unplanned Costs (***H₃***)				**0.285**		**0.394**
					(0.134)		(0.176)
Controls	Patient severity	0.065	0.08	***0.292***	***0.274***		
		-0.09	-0.091	-0.083	-0.084		
	Episode of care length[a]	***0.333***	***0.361***	***0.244***	***0.118***	**-0.425**	**-0.557**
		-0.106	-0.09	-0.08	-0.096	-0.182	-0.184
	Episode of care location	***-0.283***	***-0.204***	***-0.283***	***-0.198***	-0.139	-0.014
		-0.089	-0.078	-0.096	-0.109	-0.119	-0.139
	Patient weight	**0.195**	**0.116**	-0.079	-0.131		
		-0.089	-0.081	-0.105	-0.111		
	Episode of care type	**-0.146**	**-0.093**	0.028	0.075	0.059	0.116
		-0.072	-0.074	-0.085	-0.086	-0.083	-0.085
	Number of staff	-0.022	-0.067	**0.223**	**0.218**	**0.188**	**0.178**
		-0.085	-0.082	-0.112	-0.11	-0.085	-0.084
	Staff tenure	-0.006	-0.016	-0.08	-0.083	**-0.215**	**-0.21**
		-0.091	-0.088	-0.081	-0.081	-0.11	-0.104
	Scheduled	0.041	0.008	-0.143	-0.156	0.087	0.065
		-0.077	-0.075	-0.097	-0.097	-0.112	-0.122
	Number of supplies	**0.232**	**0.174**			0.086	0.002
	on PPC	-0.1	-0.111			-0.176	-0.191
	R^2	52.25%	64.04%	45.01%	49.21%	19.07%	25.19%
	Chi^2-test	***102.99***	***167.8***	***75.77***	***90.78***	***21.98***	***34.16***
	Parameters	9	12	8	9	7	8
	N	94	94	94	94	94	94

Note: Standardized coefficients reported. ***Bold and Italicized*** for *p<0.01* and **Bold** for *p* <0.05.
Bootstrapped standard errors in parentheses. 5000 bootstrap replications were performed.

[a] Natural log of variable was used in the regression.

2.8 Discussion

The results of the analyses strongly support our hypotheses. The predicted inverted U-shape curvilinear was found for planning frequency, so that those who continue to revise their PPC will eventually learn what is needed during an episode of care so that unplanned costs are lowered. The results indicate that those who plan the least have a stable list of items and handle foreseen uncertainty by relying on nurses and technicians' familiar with their processes to gather additional supplies are likely to be needed. Alternatively, those who plan the most have developed schemas that are leading to PPCs which only have what is needed for an episode of care, so that unplanned costs are minimized and the need to work with familiar personnel is lessoned. In supply chain management, a reproducible process that achieves the same outcome over and over is thought to be in control. Similarly, if a surgeon has the same patient outcomes with the least amount of unplanned costs possible, it is an indication that they have achieved a good PPC.

Friedlander (1983) stated that learning may result in new insights that can lead to new alternatives. This allows for an awareness of unplanned costs to lead to new planning instances. Huber (1991) took this a step further by recognizing that learning may occur when information is processed and a potential new model is formed. Therefore, by recognizing unplanned costs, the opportunity for new schemas to be formed or existing schemas to be modified, so that action towards updating a PPC may occur, we assume that learning is taking place and the learning partially stems from the wastes occurring during the episode of care.

However, not much thought is going into the decision concerning whether the items will be needed again in a future episode of care. This is a common occurrence across most hospitals who deal with PPC inflation (Ben-Zvi, 2014). Those who plan the most frequently are truly trying to dial in their plan, so that it achieves the highest level of efficiency, while still providing the highest quality of care.

Hypothesis 2 was supported for higher communication intensity lowering unplanned costs, indicating that frequent exchanges of communication are providing learning opportunities. Medical researchers recognize that culture influences learning (Sexton et al., 2006) and safety (Van Beuzekom et al., 2007). Personnel that are familiar and comfortable with one another will find communicating more frequently easier, than personnel who have not worked together. Surgeons should take heed of the literature focused on higher performance being achieved through increases in collaboration and communication (Burke & Wilcox, 1969; Kacmar et al., 2003; Kirmeyer & Lin, 1987). Also, this adds to the literature on communication accommodation theory (CAT), as the surgeons and others in the OR may be using communication strategies to lower the power distance. These strategies are known to put others at ease, thus creating the opportunity for greater learning and mutual accommodation (Willemyns et al., 2006). Knowing how to quickly achieve team comradery is critical to lowering costs, which has implications for patient outcomes. As hypothesis 3 shows, support is found for teams with lower unplanned costs to have patients with better outcomes. Each day a patient remains in a hospital, the risk of secondary infection increases, as well as costs to the patient and any insurance they may be using. The need to lower the length of a patient's stay is balanced by the desire to not have the patient need to return (Abbo, 2008; Kaboli et al., 2004; Silow-Carroll et al., 2011).

The results showing that communication intensity leads to lower unplanned costs could be due from the lowering of hierarchical barriers from the surgeon and the other personnel in the room. Senot et al. (2016) found that greater collaboration is found by those who know how to communicate effectively with those in positions that may be higher or lower than themselves in terms of organizational hierarchy. Learning is higher with more diverse teams, but it is dependent on their social capital (van Emmerik et al., 2011). Our results show that greater performance, perhaps through learning, is being achieved by those teams which are able to lower organizational hierarchical boundaries and achieve greater team potency.

The location of the episode of care is significantly related to the unplanned costs. Human behavior often leads one to fill an empty space or not take ownership and declutter an area. By filling a space with additional supplies, it does not mean that costs or time will be saved. It only means that more supplies will be decentralized, raising the risk of local stock outs and more time spent searching for needed items. By reducing the space in which an OR team has to operate, they are forced to root out unnecessary items before an episode of care through careful planning. The benefits of decluttering the OR and avoiding overcrowding have been shown to influence patient outcomes (Alarcon & Berguer, 1996; Sandberg et al., 2005) and lends support for efforts to customize the OR for specific specialties and procedures (Herron et al., 2001). Outpatient rooms are smaller and may provide and allow for greater integration of personnel into the OR team culture, which could encourage communication due to the proximity of actors to each other. In this research, the culture is held constant by conducting the data collection at one facility.

The act of planning's mediating effect on a patient's length of stay may indicate the willingness to go beyond the best practices set by the healthcare industry. Best practices are set by other surgeons and are done so only after significant testing and data collection. Extant literature has shown that best practices improves patient outcomes (Grol & Grimshaw, 2003; Woolf et al., 1999). The significant mediation results of planning instances on length of stay indicates that as the plan changes it may be going further away from the original best practices, such that additional unplanned costs are incurred and a patient's length of stay is lengthened.

The significant direct effects of planning instances and its squared term indicate is interesting. At first these findings further solidify the results that as planning instances increase additional unplanned costs occur. However, these unplanned costs eventually decrease as planning instances increase. A similar finding is not being found between the squared term of planning instances and perceived waste, indicating that the personnel in the OR may not equate planning as a method to reduce the amount of waste occurring within the OR. This finding agrees with other researchers (Giraldo et al., 2015) and further solidifies our finding that OR personnel have not been trained to fulfill the desires of administrators to lower waste in the healthcare system. Also, this points to another commonly found issue in healthcare, in that personnel are constantly adapting their work due to changing conditions (Tucker, A. L. & S. J. Spear, 2006). When plans are stable, predictability takes hold and less adaptation may be needed.

2.9 Limitations

This paper has several limitations. First, we were unable to discern the types of changes that occurred when a PPC planning instance occurred. This means that at times supplies or instruments could be added, subtracted, or substituted from the PPC. Additionally, the change may not have involved supplies or instruments, but instead was more focused on patient positioning or other requests that a surgeon may have for an episode of care. However, in our experience, most of the changes we witnessed involved supplies and instruments, as most surgeons do not include any information concerning patient positioning within their PPCs. Also, we were unable to know who requested the change or came up with the idea for a change to occur. Thus, we are unable to know if the surgeons or nurses were more likely to make good or bad decisions in planning. Our unplanned costs variable does not account for those episodes of care where additional items brought in may have become cheaper in price. Since the data collection was performed over a 3-month period, we are reasonably confident that this issue does not affect the results.

2.10 Theoretical Contributions and Managerial Implications

Currently, learning is taking place opportunistically within the OR. While an initial hurdle of planning resistance may need to be overcome (Pich et al., 2002), the potential benefits are great. *Incremental learning* does not frequently occur in healthcare or in other organizations, as the information to achieve this type of learning is difficult to obtain. As price transparency continues to gain traction in healthcare (Phillips et al., 2016), surgeons and other employees will more easily have the power to estimate the payoff to making changes to the plan. This should result in a positive for hospitals and other similarly complex environments.

Hospital administrators should push efforts to increase OR personnel training in supply chain management practices, so that a more process oriented view can be obtained. Those involved in the training and educating of healthcare workers should also offer courses and other opportunities for future workers to understand waste reduction techniques, as this may reduce barriers to future changes and create an environment where the best opportunities for improvement come directly from the front lines.

2.11 Conclusion

There will always exist some variation in complex tasks, such as those undertaken within the OR. Through the use of monitoring and information sharing, the elimination of foreseen and unforeseen uncertainty can occur, such that the correct coordination is achieved and incentives put in place, so the correct planning system is put in place. Achieving this will allow for a shift from a position of *learning* to a position of *instructionism*. This goal may seem lofty, but is vital to simultaneously achieve lower costs and a high quality of care.

CHAPTER 3 – Systematic Literature Review of Hospital Disruptions

3.1 Motivation

"Who knows only his own generation remains always a child." - George Norlin.

Hospital disruptions occur regularly and contribute to the 750 billion dollars of waste occurring each year in healthcare (Committee on the Learning Health Care System in America, 2012). Additionally, they contribute to the third leading cause of death in the United States (US), medical errors (Makary & Daniel, 2016). In the supply chain management literature, it is well know that disruptions decrease operational performance (Narasimhan & Talluri, 2009). Within hospitals it is less clear, as some disruptions improve patient care, such as when a nurse interrupts a surgeon to notify them of an important problem that may affect the patient (Rivera-Rodriguez, A. J. & B. T. Karsh, 2010). A comprehensive search of the literature using the keyword *disruption* produces thousands of articles, however a synthesis via literature reviews or meta-analyses can only be found for a small subset of the articles. The narrow focus of these reviews may help with the understanding of a specific facet of disruptions, but it further fragments the field and doesn't allow one to piece together the various nuances and may impede further synthesis and development of theory.

In the management domain, as well as the healthcare domain, healthcare *disruptions* have received widespread attention (Burda, 2008; Fargen et al., 2012; Froehle & White, 2014; Heaphy, 2013; Lewis et al., 2012). However, there has been little crossover between the two domains. The intention of this study is to bring together all the extant research in both domains, elaborate the connections between them, and identify research gaps. Thus, a systematic literature review is conducted of the healthcare disruption research to provide a comprehensive framework of healthcare disruptions.

Disruptions have been defined and described in many ways within the research literature. The first mention of disruptions in hospitals concerns the installation of air conditioning within a hospital, one of the prerequisites was that its installation could not interrupt the operations of the hospital (Tippett & Terrell, 1957). And, except for an article discussing the adoption of computers within medical practices (Brownbridge et al., 1984), hospital disruptions was not discussed in the management literature until the turn of the century. Jett and George (2003) classified organizational interruptions as a type of disruption and offered four categories for classification: intrusions, breaks, distractions, and discrepancies. Disruptions in healthcare can take several forms and there is a lack of clarity as to what constitutes a service disruption (Sevdalis et al., 2008; Sevdalis et al., 2014). In this study, we use a broad definition of disruptions to capture the breadth of our research objective. Combining the Froehle and White (2014) definition of interruptions and the Baron (1986) definition of distractions, *we define disruptions as any type of interruption or distraction that diverts attention away from the task at-hand*.

This definition acknowledges the various ways in which disruptions can manifest, while remaining broad enough to encompass all areas of a hospital. Additionally, it allows for good and bad disruptions, but restricts itself to those disruptions that are consciously recognized by healthcare providers. Several researchers have focused on noise pollution within a hospital, such as various machines beeping, ventilation systems turning on, and other background sounds (Adatia et al., 2014; Brennan et al., 2008; Buxton et al., 2012; Dube et al., 2008; Guerin et al., 2013; Hasfeldt et al., 2014; Kahn et al., 1998; Parente & Loureiro, 2001; Ryherd et al., 2008; Way et al., 2013). These types of noises are not disruptions until they reach a level that disturbs the healthcare providers or patients. If they are not noticed or no effort is made to maintain focus on the task at-hand, then no disruptions has occurred.

When a disruption does occur, there is consensus that it will have an effect on performance. The range of influence on performance is large, which coincides with our broad scope of this systematic literature review. This was intentional, as the breadth of research analyzed allows for use to provide a greater understanding of all types of disruptions, as well as its related measures, models, and characteristics. Service disruptions in healthcare could range from being harmful to being beneficial for patient outcomes. An example of a 'good' disruption includes interruptions that prevent medical errors, such as administering the wrong medication or performing surgery on the wrong site. An example of a 'bad' disruption includes distracting the physician who is performing a procedure, which could result in administering the wrong drug to a patient. Distractions such as these are known to create attentional conflict by requiring the healthcare provider to attend to two or more events simultaneously (Baron, 1986), which can lead to patient harm (Froehle & White, 2014).

In this research, the method established by Tranfield et al. (2003) for conducting systematic literature reviews is followed. First, we search for, review, and categorize the research literature. Next, we synthesize the literature by using the identified categories to create a comprehensive framework of healthcare disruptions using the Input-Mediator-Output-Input (IMOI) framework. Using the IMOI model allows us to discover the typical outcomes of disruptions and actions one can take to prevent or reduce their impact in the future. Using this method, this study answers the following questions: What is the current state of the literature concerning service disruptions in hospitals? What are the gaps and needs for future research in this domain?

3.2 Methodology

3.2.1 Methodology Choice

Almost all of the research identified in this review can be classified as qualitative and was conducted in the interest of uncovering the *context of discovery* (Hunt, 1991). The 'context of discovery' includes research observation, speculation, recording of data and assumptions, classification of findings and creating hypothetical models, and inducing and deducing generalizations (Hunt, 1991). These works of research are not attempting to predict the phenomenon, but rather are attempting to document, discover tools and procedures that assist researchers in uncovering them. Thus, while this literature stream has been building for decades, very little theory testing has occurred, which leaves us with a large body of literature that has yet to move to the *context of justification (Hunt, 1991)*. Without theory testing hypotheses and without consistent conceptualization of relevant measures and constructs, a meta-analysis approach is not appropriate.

The need to systematically review the literature on disruptions in hospitals is still warranted, even if a meta-analysis is not practical. Literature reviews found in most peer-reviewed research may be conducted in various ways. The author(s) may decide to conduct a review of the literature "employing a panel of experts to identify relevant papers; using knowledge of the existing literature to select articles; and [/or] searching various databases using keywords" (Crossan & Apaydin, 2010). Most literature reviews are non-analytical, are subjective, contain researcher bias, and lack formality (Tranfield et al., 2003).

To reduce subjectivity and enhance validity, an analytical literature review should be performed. We have already shown that a meta-analysis, which analyzes existing literature and tests hypotheses using the correlations obtained from the literature (Nair, Anand, 2006), is not appropriate within the context considered in this study. Another common analytical method employed in the literature is a matrix approach (Salipante et al., 1982). This method logically groups concepts from the literature into a matrix-style table. This method is subject to the biases of the authors, as the criteria for inclusion do not necessarily follow an analytical method, nor does this method allow for non-matrix style presentation of findings. A third method, and the one employed in this study, is a systematic literature review (SLR) (Tranfield et al., 2003). A SLR is an analytical process that uses an algorithm to search and review the literature in a specific field or topic. This method allows one to tackle a broad topic, rather than a deep dive into a specific topic. Like the aforementioned methods, the process utilized can be conducted by following the rigorous methodology employed. This transparency improves the quality of the review by ensuring it meets rigorous scientific research standards.

To properly synthesize the breadth of the literature within this topic, a SLR is conducted. SLRs are comprised of three stages: planning the review, conducting a review, and reporting and dissemination (Khan et al., 2001). The objective of this SLR is to produce new knowledge based on the careful and systematic analysis of the extant literature. Using this idea, we identified many types of disruptions that may occur within hospitals and gained an understanding of their potential impact, as well as what is being done to prevent similar disruptions. Disruptions and their outcomes were mapped onto the IMOI model to highlight the recursive nature of events when it comes to disruptions happening in hospitals. Also, theories are identified that provide useful lens to view hospital disruptions.

3.2.2 Stage I - Planning the Review

The field of research being reviewed in this study crosses disciplinary boundaries. Thus, due considerations of the journals and keywords used when searching for literature is necessary due to the alternative ways in which the research topic may have been conducted.

During the planning stage, we tackle the challenge of discovering the breadth of research on the topic of interest. Key data sources were identified and validation rules for inclusion were refined. Specifically, Thomson Reuters Web of Science (WoS) and PubMed databases were searched with the following query: ((interrupt* OR distract* OR disrupt*) AND ("healthcare" OR "health care" OR hospital OR "operating room")). Since this review's focus is on a topic that crosses disciplinary boundaries, more than one database search was needed. WoS is a multidisciplinary research search platform, while PubMed focus on the biomedical literature warranted its inclusion as well. All years were included on the day of the search, which resulted in literature published from 1957 to 2015 (January 26, 2015) being included.

3.2.3 Stage II – Conducting the Review

The systematic approach of a SLR removes much of the subjectivity out of traditional literature reviews. Once the data is collected, each article is analyzed using a process that aggregates the results of the studies with the goal to provide a comprehensive view of the literature.

Since this study crosses disciplinary boundaries, multiple databases should be searched to provide a comprehensive review of the literature. By using a predefined algorithm for searches, much of the subjectivity is removed from the literature review. After the results are downloaded and compiled, a descriptive categorization is conducted for each article. The goal is to provide a conceptual overview of what has been done in the past within the research domain. Most of this analysis is descriptive and explanatory. Familiar qualitative methods, often employed by case study researchers, may be used such as pattern matching and explanation building (Crossan & Apaydin, 2010; Yin, 2008).

3.2.4 Stage III – Synthesis: Reporting and Dissemination

This last stage is responsible for reporting the findings and analyzing them so that they are useful to researchers and practitioners. By providing a comprehensive overview of the current, fragmented research being conducted in this field, we show what has been done and recommend future research in this important domain. A framework depicting the existing research, along with pertinent theories that provide a guide for future researchers is shown. Further explanation explores the comprehensiveness of the study and need for further theorizing and research in the topic of interest.

3.3 Method Description

This SLR follows the methodology outlined by Tranfield et al. (2003) described above. During Stage I, the planning stage, we identify the sources and define the objectives of this research. Due to the cross-disciplinary nature of this research, the objectives are broad and multiple sources are needed to ensure that we cover both domains of social science and healthcare. The intention is to review and categorize the research, so that new insights can be gained.

3.3.1 Identifying Initial Selection Criteria: Keywords and Search Terms

WoS includes access to dozens of databases and hundreds of journals, including the Social Sciences Citation Index (SSCI), which is commonly used in meta-analyses. The National Center for Biotechnology Information (NCBI), which is part of the US National Library of Medicine, provides access to the most popular medical resources. NCBI databases are commonly used in SLRs conducted in the medical field. The same search was performed within WoS and NCBI databases. Specifically, the search was comprised of two requirements. One was that at least one version/combination of the following words was included in the article: distract, interrupt, or disrupt. Secondly, at least one version/combination of the following words was included in the article: hospital, healthcare, health care, or operating room.

The two searches were conducted on January 26th, 2015 and resulted in 35,066 articles (WoS = 14,857; NCBI = 20,209). Within the NCBI results, only the results from the NLM Catalog (NLM), Pub Med, and PubMed Central (PMC) databases were included. This was done because the databases within NCBI are split in terms of 'literature' and 'health'. The health results were eliminated, as these results mostly pertain to clinical effectiveness, disease, and drug reports (n = 530). Also, the results for books in the literature section were eliminated (n = 642). This resulted in 33,894 articles between four databases (WoS, NCBI, NLM, and PMC).

The titles and abstracts of each article were downloaded into Microsoft Excel® 2013. A COUNTIF statement was used to find duplicate entries amongst the titles. Some titles appeared more than once. We found 1,535 titles that appeared more than once, but a total of 1,805 duplicates were deleted as some of them appeared more than twice. To delete the results, the following process was used: (1) if duplicate article was in the same database, all additional occurrences within that database were deleted, (2) if duplicate article existed within the NLM database, the NLM version was deleted, (3) if duplicate article existed between PubMed and WoS, the PubMed version was deleted, (4) if duplicate article existed between PMC and WoS, the PMC version was deleted, and (5) if the duplicate article existed between PubMed and PMC, the PubMed version was deleted. The resulting unique records yielded 32,089 articles. 16,848 articles were found in PMC, 14,419 articles were located in WoS, 814 articles were found in PubMed, and 8 articles were located in NLM.

Next, the titles and abstracts were reviewed for each of the 32,089 articles. The article was assessed for relevancy. To be included, the article must have included some form of discussion of the focal topic within the title or abstract. This included articles directly concerning our topic, those that may have alluded to how our topic affected the research being conducted, or an indication that the articles findings related to our topic. This resulted in a large reduction of potentially relevant literature. The results left us with 2,487 articles, with 465 articles from PMC, 1,996 articles from WoS, 18 articles from Pub Med, and 8 articles from NLM.

Each of these 2,487 articles was downloaded. Many of the articles were not freely available through existing university subscriptions, thus requests to university librarians were sent to obtain these articles. In total we were able to obtain 2,481 articles by following this process.

Once obtained, each article was analyzed along several criteria. During this process, several articles warranted exclusion. They were excluded, because their topic ultimately was not applicable to this research, the article was a conference proceeding with only the abstract available (attempts to eliminate these had previously been done, but several slipped through anyway), or it was determined that it was not a peer-reviewed article. The final number of articles included in this study is 1,303 (WoS = 1,072, Pub Med = 17, NLM = 4, and PMC = 210). Table 3 provides an overview of the results of this search process.

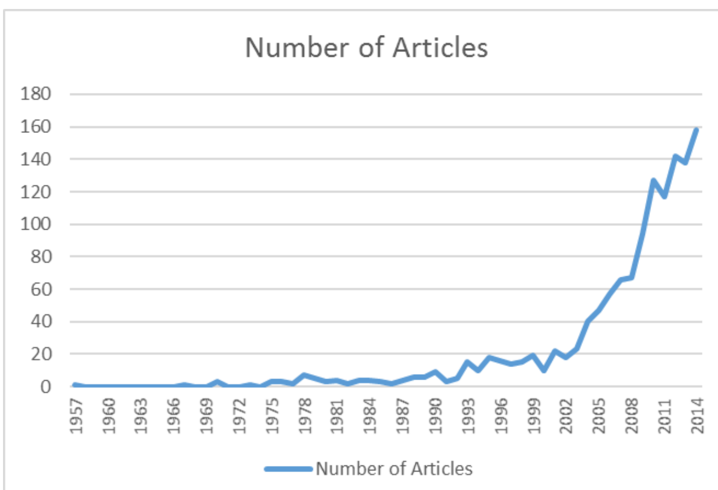
Table 3: Breakdown of Results by Database

	Initial Search	Databases chosen	Duplicates removed	Relevant Literature	Final Count
WoS	14,857	14,857	14,419	1,996	1,072
NCBI	20,209				
PubMed		1,715	814	18	17
NLM		77	8	8	4
PMC		17,245	16,848	465	210
Total	35,066	33,894	32,089	2,487	1,303

3.3.2 Description of Data

Upon analysis of the data many insights are revealed. First, interest in the topic searched is increasing as the number of articles published each year has grown significantly over the years; with the last decade seeing an explosion of articles.

Figure 3: Number of Articles from 1957 – 2014



The journals that publish the highest number of papers concerning disruptions in hospitals are provided in Table 4.

Table 4: Top Overall Journals

Journal Title	**Number of Articles**
International Journal of Medical Informatics	22
Bmj Quality & Safety	20
Journal of the American Medical Informatics Association	17
Physician Executive	17
Academic Medicine	14
Bmc Health Services Research	14
Journal of Nursing Care Quality	14
Annals of Emergency Medicine	13
Journal of Nursing Administration	12
Joint Commission journal on quality and patient safety / Joint Commission Resources	11
Journal of General Internal Medicine	11
Journal of Hospital Medicine	11
Quality & Safety in Health Care	11
J Am Med Inform Assoc	10
Journal of Nursing Management	10
The Journal of medical practice management : MPM	10

The business journals with the highest number of articles focusing on hospital disruptions are listed in Table 5.

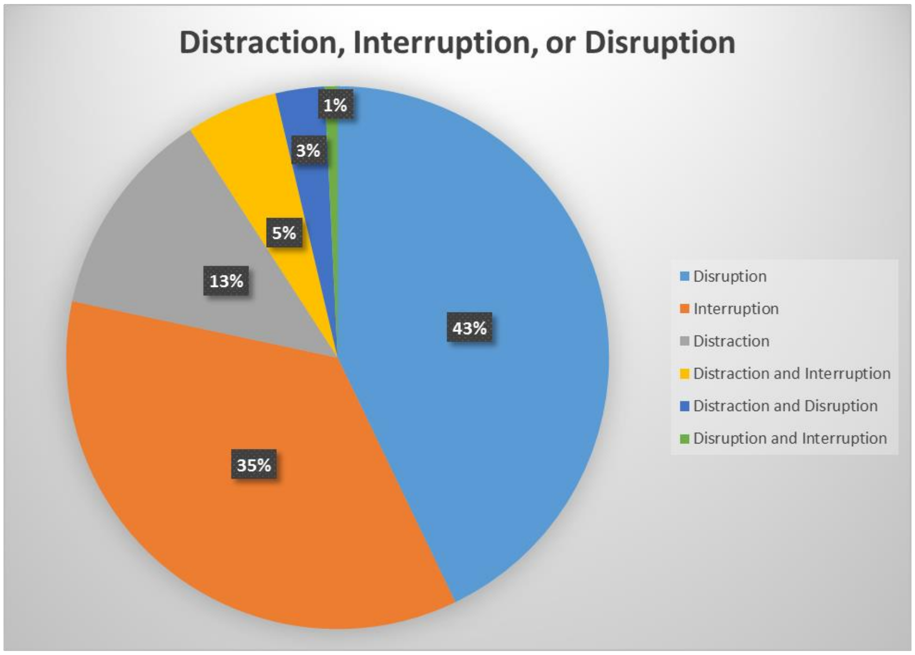
Table 5: Top Business Journals

Top Business Journals	
Journal Title	**Number of Articles**
OR Manager	4
Production and Operations Management	4
Decision Support Systems	2
International Journal of Production Economics	2
Journal of Management Information Systems	2
Manufacturing & Service Operations Management (MSOM)	2
Organization Science	2
Administrative Science Quarterly	1
Decision Sciences	1
European Journal of Information Systems	1
IEEE Transactions on Systems Man and Cybernetics Part a-Systems and Humans	1
Information Processing & Management	1
International Journal of Operations & Production Management	1
Journal of Applied Psychology	1
Journal of Applied Social Psychology	1
Journal of Business and Psychology	1
Management Science	1
Organizational Behavior and Human Decision Processes	1

3.4 Results

This section provides a descriptive analysis of the 1,303 articles in our sample. We provide a review of the disruption literature streams discovered and a summary of the existing literature. Since 1975, the number of articles that focus on the topic of interest grew at almost 25% rate per year, with only 3 articles in 1975 to 158 in 2014 (Figure 3). While we recognize that the results of a disruption, interruption, or distraction may have positive or negative consequences, the terminology used in these articles varied. Most often the word “disruption” was used (43%), followed by “interruption” (35%), and “distraction” (13%). Some articles used a combination of these words (8%), but the majority did not.

Figure 4: Use of Terminology in Sample Articles



The majority of the work has been published in the United States (63%) and only 15% has been published outside of the US and Europe. Also, the level of analysis varied greatly, from industry level to the individual patient or employee.

Figure 5: Location of Analysis from Sample Articles

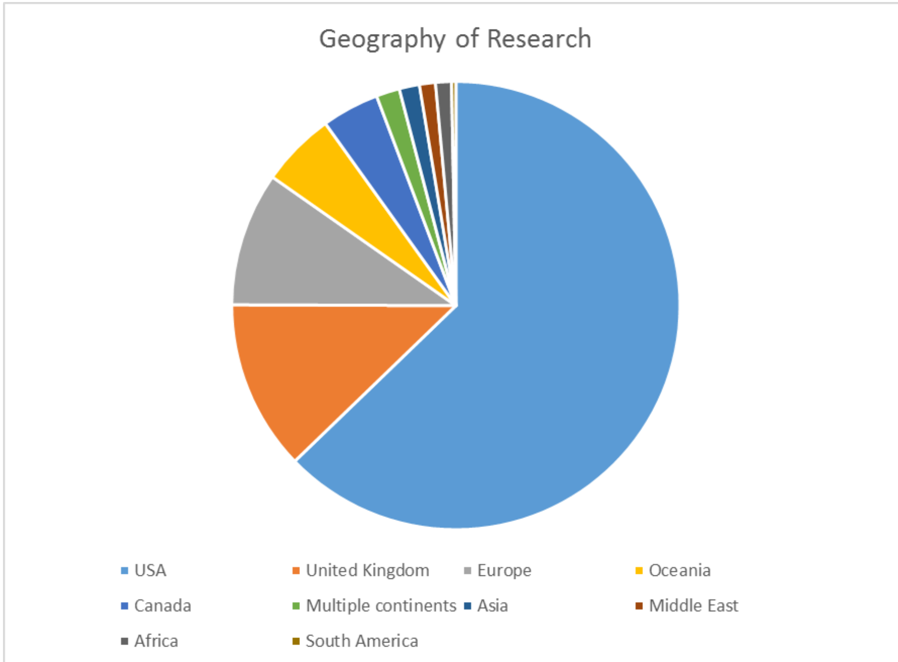
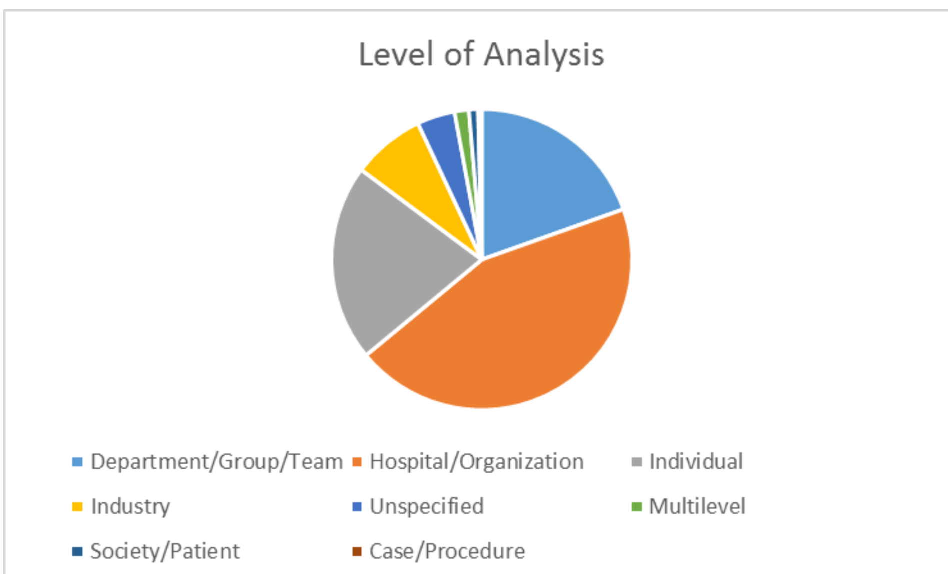
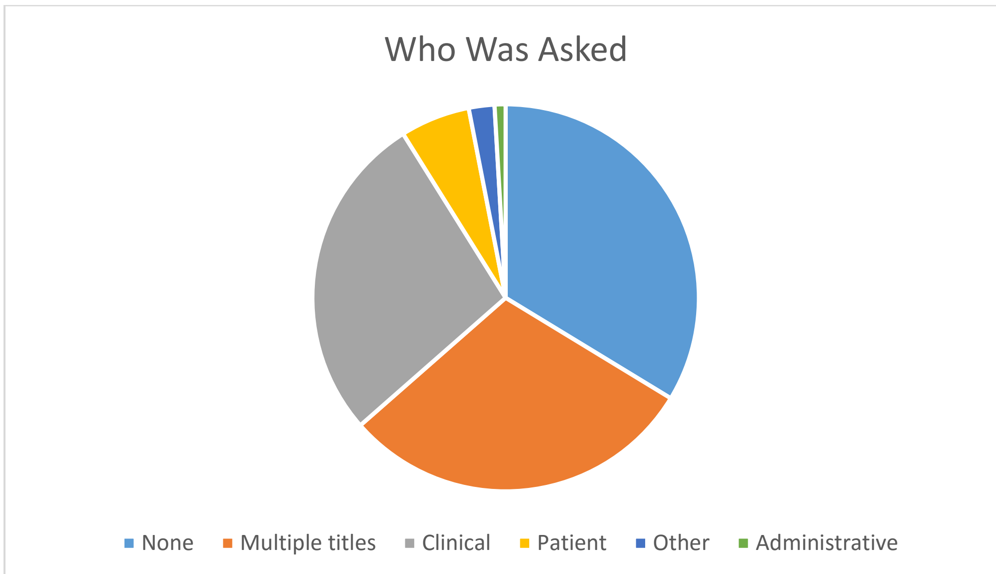


Figure 6: Level of Analysis Studied in Sample Articles



Those who participated in the studies varied in positions and roles within hospitals, so that no specific respondent title within the hospital was singled out. This allows for many viewpoints to be heard. Also, the respondents were not just in administrative roles, but were in clinical roles, were patients, is a role that overlapped these categories.

Figure 7: Title of the Respondents/Subjects in the Studies



The methods used were mostly descriptive and qualitative in nature (80%). This is a sign of an immature field (Hunt, 1991). Only 7% of the research could be considered quantitative and over 70% of the quantitative research was published in the past decade.

Figure 8: Methods Used in Sample Articles

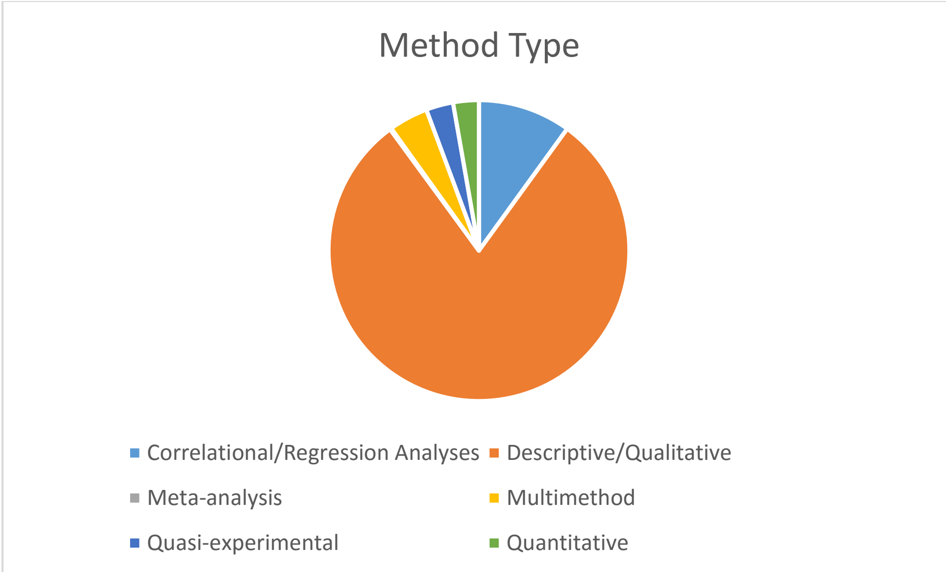


Figure 9: Summary of Qualitative vs. Quantitative Methods used in Sample Articles

The comprehensiveness of our search reveals a domain of research that is disjointed and in need of structure. Numerous themes and theories have been applied in an effort to better understand distractions, interruptions, and disruptions in hospitals, but no comprehensive work has summarized the findings to date, so that one can push forward this field of inquiry.

While certainly not exhaustive, this review identifies several themes and dimensions brought forth in the papers collected for this review. The numerous themes and dimensions of the research performed in this domain make it impossible to concisely portray every variable or combination of variables studied. However, by identifying the majority of dimensions and themes used in the hospital disruption research, it provides an important step towards providing a clear understanding of the state of the field.

The specific theories invoked were few compared to the number of articles collected. The descriptive nature of much of the research may explain much of the missing theory building and testing in the field. Also, many healthcare journals are not focused on theory and instead identifies an issue and possible interventions to overcome the problem. The lack of a theoretical base provides a large gap and opportunity for future research. We elaborate on this later in the study. The major themes and theories are shown in Table 4.

This review highlights the fragmented research field of hospital disruptions and identifies ideas that may not be found within any one article, as well some themes which have yet to be explored. A lack of theory development and testing, numerous dimensions, and overall lack of interconnectedness make this a ripe opportunity for synthesis of existing literature to help push research in this domain further along.

Table 6: Major Themes Researched in Sample Articles

Major Themes	
Technology	**Scheduling**
Innovations	No shows
CPOE	Service offerings
Implementation	Capacity
Lacking Data	Workload
Government	**Structure**
ACA Adoption	Construction
CPOE adoption	Emergencies
Political Unrest	Environmental
	Disasters
Employee	Noise
Colleague behavior	Music
Bullying	Alarms
Fatigue	Paging
Stress	
Relationships	**Processes**
Health	Supplies
Satisfaction	Paperwork
Mindfulness	Hand washing
Training	Hand-offs
Communication	Prescribing errors
	Workflow

3.5 Synthesis

This research seeks to provide a converging, consensus-oriented view on the research that exists on disruptions within hospitals. By exploring the research described above, several themes have emerged. First, from the many themes researched over the years, all are still relevant in the twenty-first century. While technology has changed and has brought forth newer themes that are attracting attention of scholars, journals, and practitioners, themes such as patient safety and outcomes, worker satisfaction, and medical errors remain just as relevant today, as they did when they were first discussed in the literature.

In this section, we synthesize the data gathered into a comprehensive framework of disruptions in hospitals. We do this by organizing the dimensions of disruptions into mediators and outcomes, based on the Input-Mediator-Output-Input (IMOI) model. This analysis leads us to a better understanding and realization of the inputs that create the disruptions.

3.5.1 IMOI Model for Disruptions

Within the small groups literature, the input-mediator-output-input (IMOI) model has been used to show how events (inputs), the severity of them (mediators), and the outcomes of these events (outputs) lead to new emergent states of being (Hollenbeck et al., 1995). Previously, the input-process-output (IPO) model was one of the leading models used in management research (Steiner, 1972; McGrath, 1984; and Hackman, 1987). However, it was missing a temporal component to better our understanding of what occurs after the output (Marks et al, 2001). Hollenbeck et al. (1995) recognized this linear focus and proposed that teams were constantly evolving and that according to complex adaptive systems a new emergent state may be achieved after an event.

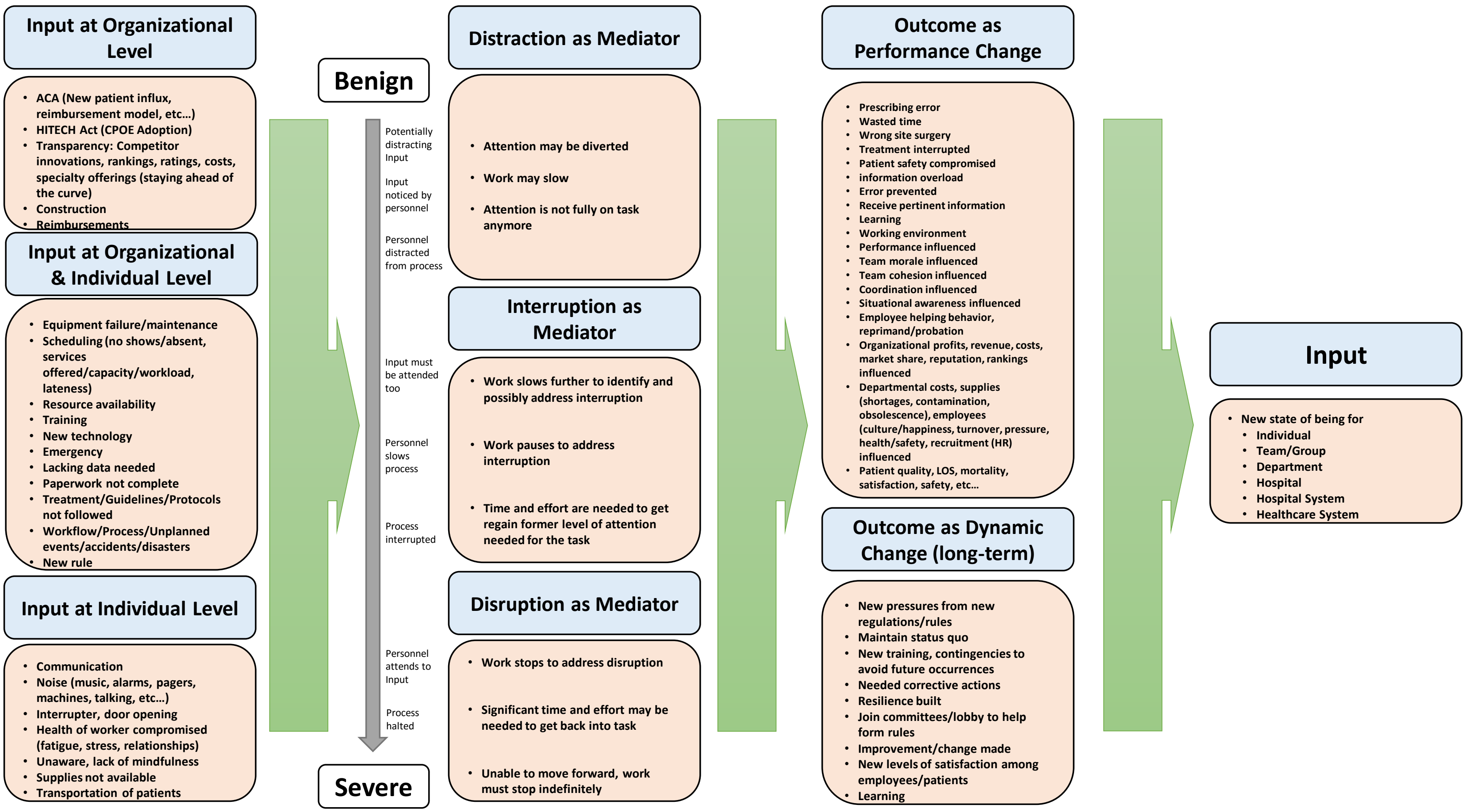
By using the IMOI model, we can gain a better understanding of how hospitals are influenced by disruptions and how these outcomes may influence a new set of inputs to emerge. The IMOI model is a recurring model and provides a flexible lens to view disruptions in healthcare. The structure of the IMOI model begins with "inputs", which are the various disruptions that may occur at a hospital. The "mediator" is the severity of the disruption that may range from benign too severe. The type of input, reaction to it, and a hospital's organizational structure and its components may play a role in the determining the mediator. The "outcome" of the disruption event will determine the new emergent state or "input" going forward. Often, this output may involve a performance outcome and dynamic change outcome. This simple, but powerful model allows one to evaluate disruptions differently than has been previously done. Also, it may allow one to account for more factors that influence the event than other methods. For example, instead of looking for one outcome that is positive or negative, such as the care that a patient is receiving, this model allows for the team or organizational changes to be addressed as well. This is important, as the new emerging state may be more or less resilient to subsequent disruptions based on the previous response and outcome of the former disruption. For example, if learning occurs due to a disruption, the likelihood of the same disruption occurring may be lowered going forward.

Another strength of this model is the temporal nature. Many disruptions are small and occur in seconds, rather than minutes, hours, days, weeks, or months. These mini-disruptions do influence the team and may add up over time. Literature on forgetting, re-work, and learning highlight the influence that even a small interruption can have on performance and patient care (Froehle & White, 2014). By using this model, we can begin to better understand how disruptions are impacting individuals, teams, and an organization. This will lead to greater learning and adaptation to build resilience systems for disruptions and protocols to avoid them.

Figure 8 displays the IMOI model for disruptions in hospitals. The inputs include disruptions that may occur to the organization, the individual, or both. Organization may be thought of as a stand-alone hospital, hospital system, chain organization, or other grouping of healthcare entities. Individuals include anyone working within a hospital. Many of the disruptions that occur within hospitals are similar to what one experiences at any position working for any organization, even if outside of the healthcare domain. However, the urgency, criticality, and potential negative consequences of practicing medicine make disruptions in hospitals unique to those occurring in other organizations.

Adapting the ordinal scale used in Healey et al. (2007) and Healey et al. (2006), we are able to assign a severity ranking to the disruption that occurs during the input. This is important, as depending on the severity of the disruption the outcome will vary. The mediator of the model is split between distractions, interruptions, and disruptions. A *distraction as a mediator* may be thought of as often benign in nature, as it may not influence the outcome. Often, a distraction may be filtered out and not noticed by an individual. However, these distractions should not be dismissed so readily. Research shows that even a small distraction may divert our attention, which will split the amount of attention we are able to devote to the task at-hand (Baron, 1986; Froehle & White, 2014). When our attention is diverted from a task, our brain's ability to maintain the same level of effectiveness is severely reduced (Bannister & Remenyi, 2009). With a distraction, the task being performed may take longer and the individual will have to work harder as their attention has been diverted (Hembrooke & Gay, 2003). Ultimately, there is consensus in the literature that important tasks should be done free of any type of distraction, interruption, or disruption (Dzubak, 2008; Hembrooke & Gay, 2003), such as many of the tasks performed in hospitals.

Figure 10: IMOI model for disruptions in hospital



The *interruption as a mediator* occurs when the input demands the attention of the worker. While some distractions may be fleeting, an interruption takes more attention to address it. The increase in needed brain processing power leads to a slowing of the task being performed or it may halt the task. When an individual is interrupted, it can take upwards of 25 minutes to fully return all of one's attention to the task that was interrupted (Bannister & Remenyi, 2009; Froehle & White, 2014). Thus, even when one has returned to the task at-hand, their attention has not fully returned as they may continue to partially think about the interruption that just occurred.

The *disruption as a mediator* occurs when the task is stopped due to the disruption. This is more than an interruption. A significant amount of time passes before the work can be restarted, as the disruption must be addressed. The most significant of these disruptions results in work that cannot be completed and is thus stopped indefinitely.

After the impact of the disruption occurs through the mediator of the model, the outcome follows. The outcome from a disruption is as varied as the disruption type itself. Initially, and most often, one returns their attention to the task and continues on with the process that was influenced by the disruption. However, the outcome of the process was influenced by the disruption. Perhaps the process will take more time to complete, extra supplies may be needed, and/or the patient's care was adversely affected. All of these could happen when one is distracted, interrupted, or disrupted. Each of these outcomes is in the short-term as well. Over time, other outcomes may occur due to a disruption. The disruption could be scrutinized and learnt from.

Finally, once the outcome occurs, a new state of being emerges. This could be a new state that overcomes the disruption with negligible downside or it could be a new state that has developed and could manifest in the form of new guidelines being implemented for a process.

Additionally, in the short- and long-run positive results could emerge, such as when a process is disrupted to the benefit of the patient (i.e. wrong-site surgery avoided).

3.5.2 Theory

Many of the articles in this review are case studies that highlight a problem found through observation, highlights a change that is implemented to hopefully correct the problem, and reports the results of the change after a certain amount of time has passed. These types of research are important. We contend that even though these studies do not explicitly invoke a theory, they often are alluding to learning theory (Daft & Weick, 1984; Levitt & March, 1988). Learning theory has four interpretation modes which vary according to their degree of intrusiveness and assumptions about the organizational environment (Daft & Weick, 1984). The majority of the case studies used in this review utilized active discovery on an analyzable problem as their interpretation mode. Active discovery involves a formal search, usually by the hospital staff, involving observation, survey, and other data gathering to learn what is the "right" way to do something. More recently, with the advent of big data one may find conditioned viewing becoming more common. Conditioned viewing uses data already being collected to interpret the environment. This can be powerful, but is limited to what the organization has deemed important enough to gather.

Aside from indirectly invoking learning theory, there is a scattering of theory use amongst the articles in this review. Just over 1% of the papers use a theory to help explain the phenomena being studied. Thus, it is worth noting the few that have used theories for their arguments. Bardram (2009) uses activity theory to explain how one recovers more quickly from technology interruptions by illustrating how coordination of activities helps ensure that the overall objective is achieved. Al-Hakim (2014) uses lean thinking to show how almost one-quarter of the time to handle an emergency situation can be saved by improving the flow of information. The gains are achieved mostly by cutting out disruptions due to information availability. Another paper explores why hygiene compliance fails using behavioral theory (Fuller et al., 2014). The theme of medication errors has been viewed on multiple fronts, specifically from mindfulness (Pezzolesi et al., 2013), human error theory (Chui et al., 2014), prospective memory perspective (Grundgeiger & Sanderson, 2009), and a human factors perspective (Sanghera et al., 2007). Others use voice (Rosenthal & Schlesinger, 2002) and organization theory (Sicotte et al., 1993) to look at different types of coordination, actor-network theory with regards to information technology (IT) implementations (Cho et al., 2008), and Markov theory to operating room scheduling (Tancrez et al., 2013).

3.5.3 Determinants of Disruptions

The literature does not offer any complete framework for hospital disruption determinants. Review papers mostly focused on disruptions that occur in one area of a hospital (Brixey et al., 2008; Sevdalis et al., 2008) or all types of healthcare settings (Rivera-Rodriguez, A. & B.-T. Karsh, 2010). Other papers generally focused on specific types of disruptions, ranging from frequent, such as pagers, phones, and others talking (Brixey et al., 2008) to less often, like medication errors (Pezzolesi et al., 2013), shortages (Adkins, 2012) or supplies (Tucker, Anita L. & Steven J. Spear, 2006).

The reasons for these disruptions are numerous, thus one must understand an organization and its surroundings to understand why these disruptions are occurring and why certain actions are taken when disruptions occur. Additionally, this understanding is needed for changes to be made in the healthcare industry, so that disruptions do not occur as often, the right type of disruption occurs when it should, and for higher levels of resiliency to be achieved. An organizational change to overhaul how disruptions are handled may be thought of as an organizational innovation.

Organizational innovations determinants have been heavily researched (Damanpour, 1991, 1996; Lam, 2005) and their relationships for influencing disruptions in healthcare are similar. These determinants are mapped out by Crossan and Apaydin (2010) in the appendix. They describe how the organizational environment and the groups and individuals within the organization influence organizational innovation. These same influences and determinants shape the disruptions that are occurring in any organization. Specifically, organizational innovations can be disruptive by forcing change on individuals and organizations. To adopt innovations, physical or digital infrastructure may need to be changed, thus creating stress on individuals who must navigate the changes. Other innovations may displace people, need learning to occur, and uncertainty attached to them, thus creating additional conflict. Recent adoption of electronic medical records forced new infrastructure, learning, uncertainty, frustration, and more upon hospitals. This organizational innovation provides insights into how other, smaller, innovations can cause disruptions in the short-term and long-term depending on their scope and scale with an organization.

3.5.4 Issues, Gaps, and Tensions

The literature reviewed reveals a few issues. Prior research has viewed disruptions only through a few different theoretical lenses. With a dearth of theories being invoked and used in the literature, this review highlights this gaping hole in the literature. Within hospital disruptions, Table 5 lists the theories that were directly discussed in the articles included in this SLR. One may immediately notice that many of the most frequently used management theories, such as RBV, Agency, Focus, etc…, are not present. There are several opportunities for researchers to extend research on disruptions into hospitals by viewing them in new and different ways.

Table 7: Theories Used in Sample Articles

Theory
Activity based computing (ABC)
Actor-Network Theory
Behavioral theory
Complexity Theory
Evidence-based practice viewpoint
Goals theory and prospective memory theory
Grounded theory
Human error theory
Human factors perspective
Information and communication technology (ICT)
Lean
Markov theory
Mindfulness
Organization theory
Pareto's Principle and Parkinson's Law
Prospective memory; Distributed cognition
Voice

Disruptions stem from people and machines. Disruptions may have an effect cognition, attitude, and behavior (Cohen, 1978). When disruptions occur, it is natural to have a reaction to overcome the disruption. This reaction requires a person or persons to attend to two or more inputs, which is known as "attentional conflict" (Baron, 1986). Some of these disruptions are minor and divert little attention away from the more dominant task, while others are of equal or greater importance and may create *structural or capacity interference* (Kahneman, 1973). Structural interference occurs when two inputs require the same amount of mental attention, such as watching a computer screen and the patient. Capacity interference occurs when one does not have the mental or physical capacity to do both tasks at the same time, such as stopping a procedure to answer a question. Several theories could address this phenomenon in healthcare, such as the attention based theory could help us understand why our attention is diverted under these different types of interferences (Hoffman & Ocasio, 2001). Furthermore, the resource based view could help understand which structures could be put in place to minimize unnecessary interference, so as to gain an advantage in terms of quality outcomes and other measures, such as employee morale.

Learning theory allows us to adopt new ways to avoid disruptions or minimize their impact to become more resilient. Productively theory allows us to understand the impact that disruptions are having on the patient, group/team, and the organization. Sometimes the impact is good, as it may prevent errors. Sometimes the impact is bad, as it causes poor performance. Sometimes the performance for the patient will increases, while performance for the organization decreases simultaneously during a disruption. However, normal accident theory has been viewed from the likelihood and severity that a disruption may have. This does not include facets, such as the proximity to the patient, frequency in which the interruptions occur (rapid succession or not), and the type of disruption could be categorized along a continuum from least harmful (benign) to most harmful (work stops). By understanding the roles played by people within the hospital to minimize the number of interruptions and their impact, one can start to better understand how we might lower the number of disruptions, while increasing patient quality/safety and the performance of the hospital. As this is a multi-faceted effort by all parties, we will explore the different ways in which this can be done.

Where can disruptions occur? Disruptions can occur anywhere within a hospital, but will vary by type. Administration, OR, ER, Triage, and other areas of a hospital are subject to unique disruptions in each area. Clinical and Administrative could be a different categorization. The facility layout will influence disruptions as well. Smaller rooms will allow disruptions to affect more individuals. In a larger space, the impact may be localized. Also, the layout of a room will influence how much movement is needed by personnel to perform a task. Less movement will lead to less disruption. By rearranging the layout of a room or hospital we can lower excess movement of goods and people, while lowering the likelihood of a disruption.

Anything that doesn't add value to the patient or organization should be viewed as a waste. Many of these wastes are actually distractions that can lead to poorer performance. If extraneous technology or communication prohibits an individual from performing another tasks, then it may need to be eliminated to simplify the user experience and overall process of the task. Are their supplies and people that should be removed from situations and only brought in if needed, because they do not add value. These ideas go along with Lean Systems thinking. Simplifying processes by eliminating waste should lessen the number of and likelihood of disruptions.

In the psychology literature, Learned Helplessness Theory explores how external, temporary events can lead to affective resilience and persisted efforts to cope with problems (Albert, 1994). By understanding how one personally interprets a life event (personal), the reach of the event (pervasiveness), and how long it will last before one returns too normal (permanence), one can begin to develop resilience. Similarly, hospitals and other organizations can learn what enhances and influences disruptions, so as to lower their vulnerabilities and strengthen their resiliency from distractions.

Within the disruption literature, it is recognized that after a disruption, a new way of being or baseline of work is achieved (Asbjørnslett and Rausand, 1999). However, the disruption vulnerability input-output model used in Asbjørnslett and Rausand, 1999 article does not address the complexity of processes that occur in between the input (disruption) and the output (new emergent state) to arrive at the new baseline. Zobel et al., 2012 builds upon on the input-output model of disruptions by exploring the temporal nature of a disruption. Specifically, they explore how long it takes for the disruption to be felt, the response to the disruption, and the time it takes to recover from the disruption. However, Zobel et al., 2012 does not recognize that a new emergent state may come about and instead looks for the point at which the initial state is returned too. Thus, by combining these streams of thought, one can reach a better understanding of the reaction (mediator) to the disruption (input) and the subsequent conclusion (output), so that a new starting point emerges once the disruption has been recovered from.

Another issue that the literature has yet to find consensus on is how to measure the impact of a disruption. By focusing on one event or procedure within a hospital, a disruption may appear to have hurtful outcomes. However, things are more complex than this one event. The disruption may have been necessary to keep another event, perhaps one that is more urgent, moving forward. For example, a doctor's rounds or a hand-off between nurses is interrupted, which has implications for the safety of patients. However, this interruption allows another patient's treatment to move forward from which otherwise would have been delayed and possibly causing more harm and money. These nuances are what make the study of disruptions interesting, but they also make it difficult to understand which ones are good or bad. Finally, one should account for the length of time, response, and effect on the team to a disruption to better grasp the full influence.

This review offers a lens into the disjointed research that has been conducted in the hospital disruption domain. Aside from a handful of theories, most management theories are underutilized. This disjointedness provides an opportunity to synthesize the literature and help move the discussion on hospital disruptions forward. By using the IMOI framework one can view what has been done and what questions are still left unanswered, as well as what theories may be useful for viewing new and old questions from various lenses.

By matching the theories in Table 5 to the IMOI framework in this paper, we can gain new insights. Mindfulness theory and many others on the list cross organizational and individual levels.

However, voice and prospective memory theories are mainly directed towards the individual level. Most of the theories have the opportunity to span the spectrum from benign to severe depending on the event that occurs. However, the outcomes may be different and will occur at different times. For example, when someone uses their ‘voice’, a distracting-benign disruption may occur, but an even larger disruption may have been avoided. Thus, the outcome is multi-faceted. First, the process has been slowed to understand the distraction and will take longer to complete. Looking more long-term, the quality of care to the patient may have increased and trust between team members may increase as well, as they learn to rely on one another.

Additionally, many theories have yet to be applied to the issues raised in this research. Calls to action are made frequently within the journals to advance theory (Craighead et al., 2016). The hospital disruption research space is mostly devoid of theoretical research. By applying attention-based theory (Ocasio, 1997), we can better understand individual level disruptions. Using the resource-based view of the firm (Barney et al., 2001) one can discover what organizational characteristics are creating competitive advantages by the avoidance of disruptions (i.e. risk mitigation). Or, by invoking the theory of swift, even flow (Schmenner & Swink, 1998), we can learn how the process productivity is altered by a disruption and the implications that may arise from it. By using the IMOI we can easily see how these theories and others fit into the framework and what their likely to lead towards within an organization.

3.6 Discussion

Disruptions have been studied at all levels of a hospital and have been measured in a myriad of ways. How we handle different types of disruptions matters in terms of hospital profit, patient outcomes, and employee satisfaction. While these benchmarks and others are very important, the research to date, is disjointed, not tested in many areas of a hospital, and is not theoretically grounded.

3.6.1 Distractions, Interruptions, and Disruptions

In this study, we have stated that all distractions and interruptions are a form of disruption. This is because the distinction between distractions, interruptions, and disruptions is not always apparent. A knock on the door may distract someone, while it would interrupt another and it could possibly cause a disruption. Understanding that each individual will react differently to their state of being is important for healthcare workers to understand. When someone is about to cause a disruption they should pause to think about the potential implications of the disruption to determine if it is needed.

As the IMOI framework of healthcare disruptions highlights, a distraction may not have severe consequences, but knowing when the input will lead to a distraction, interruption, or disruption is not easily discerned. Additionally, the outcome is even less uncertain as culture and context blend so that mediators can lead to less severe outcomes that do not result in any long-term changes or just the opposite may occur. It is this uncertainty that may provide the largest opportunities for researchers. The gap between what is likely to happen, what should happen, and what action(s) can be taken, when an Input presents itself, to ensure a specific outcome are typically unknown. As we learn how to predict these paths, we will be able to better understand the boundaries between distractions, interruptions, and disruptions.

The IMOI framework of healthcare disruptions allows for the application of theory toward old and new questions as well. Certain theories may be more applicable to more severe disruptions. Often it is easier to understand how a theory applies to a situation when an extreme situation is studies, as it highlights the worst possible outcomes, thus, providing a stark contrast. However, the more frequent, benign disruptions may find that certain theories, such as the theory of swift, even flows (Schmenner & Swink, 1998) better explains the pitfalls of certain paths across the IMOI framework.

3.6.2 Learning and Disruptions

Learning provides the key to controlling the number of disruptions and their impact. The knowledge based view (Grant, 1996) can provide understanding of why hospital staff and the teams they work with are able to work more confidently and efficiently react to disruptions, so that the impact is minimized. Essentially, they know how to handle disruptions and are thus more resilient. Also, due to learning, an individual or team may adopt processes that lessen the likelihood of a disruption occurring. For example, by anticipating disruptions one can make it more difficult for external disruptions to occur, such as putting a “do not disturb” sign on the operating room door.

Of course, not all interruptions should be avoided. But, learning when it is appropriate to disrupt is very important. First, a culture of safety that encourages people to speak up is vitally important in hospitals. Secondly, if a disruption will avoid another disruption, then the pros and cons should be evaluated. For example, if someone comes by an operating room and asks the surgeon a question about a different case it could be a good or bad interruption. If the question was quick and easy, then very little attention may have been diverted. If the action in the OR had to be stopped to address the interruption, then the need for the interruption must outweigh the negatives having complete attention being diverted away from the task at hand. Primarily through learning and feedback one learns the difference between these two situations.

3.6.3 Managerial Implications

Hospital managers and administrators should consider adopting processes that make the likelihood of a disruption lower. Educating staff about the consequences of disruptions, so that they think twice before interrupting someone may provide benefits, as well as creating a culture that distinguishes necessary interruptions from others which can wait until later.

Disruptions break one's focus. When we are focused, the quality of our work is higher and it often takes less time. When our focus is broken, our attention is no longer 100% dedicated to the task at-hand. This not only slows you down, but it may influence the quality of your work. Furthermore, once the disruption is over, it may take even more time to return 100% to what you were doing. Thus, the physical layout of the workplace can be analyzed to identify opportunities to create an environment conducive to focusing on a task, free from disruptions. Productivity, quality, and happiness at work are all jeopardized when one is unable to be effect and focus on what is most important to being successful at their job (Newport, 2016), which in this case is providing high quality, affordable patient care.

Personnel and managers should understand that disruptions are inevitable. It is our reaction in managing them that makes the difference and it is our reactions that reveal if disruptions rule us. For example, if you work at the front desk of a hospital, you were hired and trained to handle disruptions. In fact, most of your workday is comprised of handling one customer after another. However, if you are a nurse or physician you should hand over control of your time to disruptions. Instead, you should be clear on your priorities are and act accordingly so that everything is properly completed.

3.6.4 Limitations

The location of the disruptions is not accounted for in the model, as most of them can occur anywhere within a hospital. However, the distinction between clinical versus administrative disruptions could be considered, as those tasks that do not directly have contact with a patient's service may not ever experience some of the disruptions within the model. For example, some of the back-office functions of a hospital, such as billing, will not be influenced by the transportation of a patient from one area of a hospital to another.

The likelihood of a disruption is not accounted for in the model. Less severe activities are more likely to occur most often, such as a door opening or being interrupted to answer a question versus an emergency patient case coming into the emergency room. However, this should not diminish the importance of how sequential, repeated, or just frequent disruptions may influence outcomes. The average worker has their work attention diverted every 3 minutes of the work day (González & Mark, 2004) and managers are often interrupted within the first minute of starting a new task (Mintzberg, 1970).

3.7 Conclusion

The primary contribution of this paper is the distilling of a large amount of research on disruptions into an IMOI framework of disruptions. The IMOI framework allows us to highlight how disruptions can change an individual, team, hospital, or hospital system, so that a new state of being emerges. This underscores the idea that we can improve and change to avoid future disruptions. Secondly, we have used a rigorous review method, which may be duplicated by others. By using the systematic literature review methodology, we have avoided many of the traditional biases, such as selection bias.

Thirdly, we connect the type of disruption with its likely severity. By outlining the range at which disruptions are most likely to influence the outcome, we provide context as to the importance of a disruption. Also, it provides researchers and practitioners a guide as to where to focus their efforts in building up resiliency to disruptions and changing processes or providing training to avoid further disruptions.

Fourth, we recognize that not all disruptions should be avoided and that there must always be a process for ensuring that needed disruptions occur to ensure patient safety. Finally, the gaps in the literature in regards to future research are provided.

The world's habit of needing immediate gratification may be contributing to an increasing number of disruptions in the workplace. In hospitals, this may be hurting patients and the bottom line. Hospitals should take advantage of the current changes occurring throughout the industry, to also consider a culture overhaul and adopt a process-oriented view to root out steps and areas that are prone to causing disruptions. Additionally, educating hospital personnel at all levels of the organization on the ill-effects of interruptions and how to decide when it is better to disrupt or wait, could lead to large benefits. These benefits include, but are not limited to, higher customer service, ability to stay on schedule, and happier staff.

Jett and George (2003) label disruptions as intrusions, breaks, distractions, and discrepancies. At each level of the organization, different disruptions may occur. Also, the duration, frequency or succession, type, and appropriate reaction may differ. By exploring disruptions in these different contexts, we can better understand how to minimize them and their impact. Finally, by using the IMOI model, we have shown that disruptions can have a myriad number of effects on patients and their providers, which will help and influence future researchers studies of disruptions within hospitals.

CHAPTER 4 – Complexity and Service Disruption Risk in Acute Episodes of Care: Moderating Role of Information Exchange and Risk Management Infrastructure

4.1 Motivation

Health care is affected by various types of disruptions as were outlined in Chapter 3. Combining the location and experience gained from Chapter 2 with the insights and future directions provided in Chapter 3, this essay examines the causes of service disruptions in healthcare by considering service disruption risk in acute episodes of care. The OR offers a location that is of high priority to hospitals due to it providing the highest revenues and expenses compared to all other departments within a hospital (Cardoen et al., 2010; Denton et al., 2007; Healthcare Financial Management Association, 2003; Macario et al., 1995; Resnick et al., 2005).

Disruptions occur with regular frequency in hospital settings. Many disruptions in acute episodes of care are similar to those found in manufacturing or other service industries, such as not having the correct supply when needed or miscommunication. However, within acute episodes of care, the team leader is the medical specialist/surgeon. In healthcare, team leaders directly influence team performance (Shortell et al., 1994). Members of an acute episode of care team are different from other disciplines. Edmondson (2003, p. 1421) defines these "interdisciplinary action teams" (IATs) as: "teams in which members with specialized skills must improvise and coordinate their actions in intense, unpredictable situations (Sundstrom et al., 1990)." In IATs within acute episodes of care, the medical specialist or surgeon is able to see the big picture and understand how the various roles within the team fit together and thereby help the members of the team see how they fit in the process (Edmondson, 2003). Even so, when various members from different disciplines merge, communication errors can arise (Dougherty, 1992). Hollenbeck et al. (1995) referred to these types of teams as "hierarchical teams with distributed expertise." Since the medical specialist or the surgeon is the leader and has the final say in any decisions, the other personnel in the room must support the surgeon to complete the project without error. The circulating nurse is responsible for being an advocate for the patient. This nurse will often input data into the electronic health record system, gather supplies and instruments, as well as many other tasks that are needed before, during, and after a procedure. The circulating nurse is typically not "scrubbed in," which allows them to move freely throughout the room, answer phones/pages, enter data into systems, ready necessary equipment, and leave the room if necessary. The surgical technologist (often referred to as a scrub technician) is responsible for setting up the instruments and supplies so they are ready for the procedure. During the procedure, this individual is right next to the surgeon and patient, therefore, they are "scrubbed in." They will hand the instruments and supplies to the surgeon and any other person operating on the patient. In many procedures a first assistant will assist the surgeon by prepping the patient, working with the surgeon during the procedure, and most often performing the final suturing. The anesthesiologist is responsible for putting the patient to sleep and monitoring the person's vitals during the procedure. Depending on the procedure, preference of the surgeon, and the type of hospital, other persons may be present, such as residents, vendors, and observers. These are hierarchical teams with distributed expertise because each of these individuals has received specialized training in their field to perform their job and are thus interdependent upon each other since their knowledge is not redundant within the team.

Due to the complexity, criticality, and group work performed in acute episodes of care, there are also some unique challenges. Since time is often a precious resource when caring for patients, consensus building among the team is rarely available. It is important that we better understand service disruptions risk so that we can curb some of the costs of medical errors and billions of dollars of waste occurring each year in healthcare (Committee on the Learning Health Care System in America, 2012).

Often acute episodes of care are some of the costliest processes performed as well as one of the most profitable services offered in a hospital. This makes the context important since hospitals are seeking ways to cut costs to help maintain profitability and reduce medical errors. This is especially important after the passing of the Affordable Care Act (ACA), as many profitable procedures are being moved out of hospitals to specialized medical centers and outpatient clinics. What we do not fully know is what factors contribute in increasing the service disruption risk faced by acute episodes of care. This lack of understanding makes it difficult to implement improvement processes.

By exploring the antecedents to the risk of a service disruption one can better understand how to lower the probability and magnitude of future service disruptions. Complexity has often been considered as an important determinant of disruption risk in literature (Rivera-Rodriguez, A. J. & B. T. Karsh, 2010). Additionally, complexity in service environments pose unique challenges compared to the manufacturing environment (Roth & Menor, 2003). Specifically, acute episodes of care exhibit different types of complexities from manufacturing and other service environments. These complexities are comprised of systems detailed complexities, such as determining if a patient is allergic to a particular medication or interpreting the noise from the dozens of machines that may be in a room to ensuring patient health and system task complexity, such as performing different processes for each unique patient.

The purpose of this paper is to expand our understanding of service disruption risk by identifying what types of complexity lead to increases in service disruption risk and how the levels of information exchange among team members and risk management infrastructure moderate this relationship. The following research questions addresses this issue: (1) What is the relationship between complexity and service disruption risk?

Acute episode of care teams are also unique due to the leader being the primary “doer.” Not only must the surgeon lead, but they must perform the most critical process of working on the patient. The other members of the team play a supporting role. This is in contrast to traditional business structures in which the manager leads by assigning tasks to others. Even other action teams, such as fire fighters and sports teams often find their leaders directing others to do the critical tasks, while they remain in the more traditional management role. Additionally, the acute episode of care team changes frequently such that a surgeon may not be familiar with other team members. Thus, these teams are more loosely coupled than other teams, which remain intact (Leach et al., 2011). This suggests that a certain amount of coordination must be formalized by institutional norms and hierarchies.

IATs within healthcare operate as if in a high-reliability organization (HRO) (Kohn et al., 2000). Mistakes or accidents are considered normal in the course of a day (Perrow, C., 1984), but in HROs they are not allowed. Thus, HROs must have high reliability and be aware of unavoidable risks (Tamuz & Harrison, 2006). HROs create processes, such as double-check medication, implementing CPOEs to gather data, and develops a culture of learning to ensure that team members use expert judgement to make the right decisions (Shrivastava et al., 2009; Tamuz & Harrison, 2006). Alternatively, NAT is characterized by a focus on structure in which instituting fail-safe practices (i.e. polka-yoking) and tightly coupling complex processes yields safe and high quality results (Shrivastava et al., 2009; Tamuz & Harrison, 2006). While these are needed in healthcare, HRO-NAT concepts have their pitfalls. NAT can lead individuals to be reliant on the structures in place, such that they do not remain attentive to disruptions. HROs need frontline workers to be able to think and act on their behalf, which requires top management to give up some control. By using the HRO and normal accident theory (NAT) frameworks we can better understand why complexity contributes to service disruptions and what can be done to mitigate the ill effects on performance.

The following research question considers the important role played by norms of information exchange and risk management infrastructure in mitigating the ill-effects of service disruptions in acute episodes of care: (2) How do information exchange and risk management infrastructure moderate the relationship between magnitude and probability of service disruption and performance? One learns when information is shared by another. Often information is shared electronically or verbally. Within the OR, information is exchange by team members in formal and informal ways. Performing a "time-out" before the procedure begins to ensure patient safety is a type of formal information exchange. Informally, much more information is shared as it flows in a more natural way through conversation with coworkers. As team members become more comfortable with each they develop predictable ways of communicating with each other. The comfort and knowledge of how to communicate with each other allows for proper flow of information, so that disruptions effects are minimized. When one experiences a disruption, the response can be much quicker when one is able to get the information they need to resolve it quickly.

We are bombarded by messages and noises throughout the day that draw our attention away from the task at hand. Within the OR, distractions can lead to disruptions and it is a place filled with noise from others and machines. By using risk management techniques by installing infrastructure that helps detect when something is amiss is thought to build resilience (Ambulkar et al., 2015). This infrastructure can assist with the speed of recovery by lessening the effects of the disruption due to early detection. Also, it can improve the performance of a team or organization by avoiding some disruptions altogether.

To answer these questions, survey data was collected. The respondents include surgeons, nurses, physician assistants, surgical technologists, and other personnel found in operating rooms across the United States working within many specialties (Tables 10 and 11). Respondents were found using a variety of techniques, including internet searches, partnering with hospital systems, and partnering with 3^{rd} party healthcare organizations (Table 9). The results show that system task and operational complexity result in increased magnitude and frequency of service disruptions and these disruptions adversely impact procedure performance. Interestingly, the findings suggest that norms of information exchange and risk management infrastructure play different role in mitigating the effect of disruptions on performance. While norms of information exchange help in reducing the effects of frequent disruptions whereas risk management infrastructure helps in mitigating the adverse association between magnitude of service disruption and performance.

4.2 Hypothesis Development

4.2.1 Complexity on Disruption Magnitude and Likelihood

Service disruption results when a process is disturbed (Zellmer-Bruhn, 2003; Froehle et al, 2014). The disturbance to the service may come from many sources. Jett and George (2003) categorize disruptions into four categories: breaks, distractions, discrepancies, and intrusions. A list of some of the service disruptions that may occur within the operating room is found in Sevdalis et al. (2008) article, which created the “Disruption in Surgery Index” (DiSI). This index includes six disruption types, with a total of 29 individual items. Within this index, the likelihood and magnitude are measured and reported. The distinction between a disruptions likelihood and magnitude is important. Magnitude measured the intensity of an event, but does not address how frequently it may occur. For example, a volcano eruption is often thought of as very intense and would be classified as having a large magnitude with low likelihood; meaning it would have a large impact on its environment, but not happen very often. Thus, likelihood of a disruption is referring to the frequency at which it occurs, so that an event occurring often may have low or high magnitude.

An acute episode of care is like processes conducted within HROs in that deviations from a process or routine can have significant implications to human life. Jett and George, 2003 define an intrusion as “an unexpected encounter initiated by another person that interrupts the flow and continuity of an individual’s work and brings that work to a temporary halt” (Jett and George 2003, p. 495). Yet, some of the disruptions or interruptions are expected by clinical service providers to avoid medical errors. Zellmer-Bruhn (2003) found that teams who were interrupted more frequently paid greater attention to their work. Due to the likelihood of a disruption, the team maintained a higher level of attention. Teams in acute episodes of care have adapted to a disruptive workplace (Gersick 1988, 1989; Okhuysen and Eisenhardt 2002). However, the adaptation of a team to a disruptive workplace does not mean that all disruptions are okay. Instead, the elimination or lowering of service disruptions still provides opportunities for providing higher quality at less cost.

Episodes of care may be routine or non-routine, which will affect the level of system task complexity present. An episode of care may involve many departments and organizations, which increases the flow of information and products. For example, many episodes of care involve unique technologies and processes that require outside vendors to run. Using unique technologies or performing non-routine tasks provide opportunities for a disruption to occur. The disruption magnitude is likely to increase with the use of unique and less routine processes or tasks, as the certainty of one's actions decreases. Additionally, with the increased complexity, there is a need for more coordination, which may further impair a team's ability to perform process error free. To handle added complexity, HROs may introduce redundancies, establish standard operating procedures (SOP), and rely on expert decision-making. However, NAT would caution us that these redundancies actually add complexity to the process. Thus, with increasing system task complexity the quality of decision-making will be impacted and ability to prevent a disruption is lowered. Therefore, we hypothesize that:

Hypothesis 1: System task complexity of acute episodes of care will be associated with higher magnitude of service disruption risk.

The severity of a disruption does not fully lead one to understand the effects of service disruptions. The likelihood for a service disruption occurring must also be considered (Bode & Wagner, 2015). The more variability that is introduced into a process makes it more unstable. Variability may be introduced from any number of factors, but it is known that the more steps in a process are needed to complete a task, the likelihood of a disruption increases, as there are more points at which something to go wrong (Bozarth et al., 2009). As was previously mentioned, adding steps to a process to improve reliability and safety may put the theoretical positions of HROs and NAT at odds. However, they do not have to be at odds with each other. HROs develop a culture of reliability over time. Actions are taken to ensure reliability and safety of patients at all times. However, inevitably disruptions will occur. Thus, when the system becomes overloaded, the likelihood of a disruption will increase and NAT posits that we should respond by becoming more tightly couple and falling back on trusted methods of handling the disruption (Shrivastava et al., 2009).

This increase in the number of details that must be accounted for during a process, as the task increasingly becomes complex due to the number of items requiring one's attention, leads to a higher likelihood of a disruption occurring. As the number and variety of tasks within a process increase, the greater the system task complexity of an acute episode of care. Therefore, we hypothesize that:

Hypothesis 2: System task complexity of acute episodes of care will be associated with higher likelihood of service disruption risk.

Operational detailed complexity refers to the complexity in the roles played by acute care service providers and the complexity of processes that are needed to handle acute episodes of care. As communication paths among service providers increase, it results in a more complex environment in which individuals must navigate. This complex environment presents more opportunities for disruptions to occur, such as products not arriving on time or miscommunication between team members.

Furthermore, increases in required supplies, instruments, technologies, and tools that are needed for an acute episode of care may be an indication of an increase in time needed to complete the procedure. As additional time is taken, it leads to more opportunities for service disruptions to occur. Thus, as the number of elements increases within an acute episode of care and interact the magnitude of the service disruption will grow. HROs should normally overcome these challenges by developing processes that make a disruption extremely rare. However, this could mean that when a disruption does occur, it has greater affects than if the process broke down earlier or more frequently. Therefore, the greater the necessary number of interactions amongst the elements of an episode of care results in a larger impact when a service disruption occurs. Thus, we hypothesize that:

Hypothesis 3: Operational detailed complexity within acute episodes of care will be associated with higher magnitude of service disruption risk.

An increase in the number of interacting elements also increases the likelihood of a service disruption. Each interacting element of a process increases the opportunity for a service disruption. NAT agrees and recommends that safety is prioritized so that processes are tightly coupled to help avoid any disruptions. It is this idea that has led to the simplification of processes across all types of businesses and industries. Thus, when one observes a process that is adding supplies, instruments, as well increasing the time to complete the task, we expect a corresponding increase in the likelihood of a service disruption. Increases in the operational complexity of an acute episode of care due to increased use of supplies and instruments, additional process steps, will lead to greater likelihood of a service disruption. Thus, we hypothesize that:

Hypothesis 4: Operational detailed complexity within acute episodes of care will be associated with higher likelihood of service disruption risk.

4.2.2 Disruption Magnitude and Likelihood on Procedure Performance

A disruption exposes hospitals to operational and financial risks, thus leading to decreased performance (Narasimhan & Talluri, 2009). As the magnitude of a service disruption increases, contingencies must be taken to overcome the disruption. To not take action would allow for poor results to result. In HROs, this is not an acceptable behavior as it would make the system less reliable. The criticality of the situation demands a reaction to the adversity that disruptions bring.

Therefore, as the magnitude increases, one must manage the potential impact so that the overall procedure performance is not compromised for the patient. This is in agreement with NAT, which leads one to understand that service disruptions are inevitable and expected (Gersick, 1988, 1989; Okhuysen & Eisenhardt, 2002), but it is the management of the disruption that leads to the final magnitude of the event.

During a disruption, OR personnel have certain number of actions that they can take during a service disruption. They may use additional supplies or instruments. They may take more time to complete the procedure. They may use other resources at their disposal, which will ultimately add to the cost of a procedure and delay procedures scheduled later in the day. These actions are to be encouraged, as we would not want patient harm to occur. However, these actions are likely to lead to have short-term consequences for a hospital, as it will incur additional costs from greater use of supplies and time. By extending theoretical precepts from HRO and operations management literature to the context of an acute episode of care, service disruption magnitude is expected to lower procedure performance. Therefore, we hypothesize that:

Hypothesis 5: Higher levels of service disruption magnitude within acute episodes of care will be associated with lower procedural performance.

As in any industry, performance is expected to be lower when a disruption occurs. If the likelihood of the disruption is high, the impact may not be great. In the case of HROs, any drop in performance can have dire consequences for the patient. However, according to NAT, we know that disruptions will occur even in HROs (Perrow, Charles, 1999). Without discounting these facts, the impact to the OR team and hospital is apparent, as costs increase, team and individual behaviors may be affected, and even when the service disruption is minor, there may a be a frustration felt by all parties. NAT suggests that this reaction will add steps and time to the process, which would increase the likelihood of a disruption. With an increase in the likelihood of a disruption, team and individual behavior may altered such that overall performance is lower due to the impending service disruption. This may be due to the knowledge that disruptions are usually avoidable and do not have a welcomed place in HROs. Thus, we hypothesize that:

Hypothesis 6: Higher levels of service disruption likelihood within acute episodes of care will be associated with lower procedural performance.

4.2.3 The moderating role of information exchange

We know that the relationships of the team members will influence their behavior (Heide & John, 1992), but we do not know how this behavior will manifest itself within interdisciplinary teams working in high-reliability organizations. To build an HRO, a culture of reliability needs to be built (Tamuz & Harrison, 2006). This culture requires a certain level of trust that one’s team members will help in times of need, such as during a disruption. In a HRO, as the probability of a service disruption increases, actions will be taken to minimize the chances for the disruption or actions that would potentially lower the impact of the service disruption.

Because of the culture of HROs, the exchange of information is important. Information exchange refers to how easily information is exchanged throughout the team. To further minimize the magnitude of service disruptions in the OR, the exchange of information within the OR team should play a role. By increasing information exchange one can reduce opportunism (Rindfleisch & Heide, 1997), which would typically hinder the ability of a team to respond to a service disruption.

The ability to exchange information allows the team to understand and learn from each other, so that adjustments are made to ensure reliability before or during a service disruption to minimize its impact. Information exchange through technology or by verbal means is known to occur during disruptions, but it is the quality of the information that results in dampening the performance impact of the disruption (Bello & Gilliland, 1997). Beyond quality, it is also the willingness of team members to exchange helpful information. The teams with greater quality information exchange have attained a comfort level that encourages team members to share information. These teams will weather a disruption better than those teams with poorer information exchange. Thus, we hypothesize that:

Hypothesis 7a/7b: Information exchange within acute episodes of care moderates the relationship between magnitude/likelihood of service disruption risk and the procedure outcome.

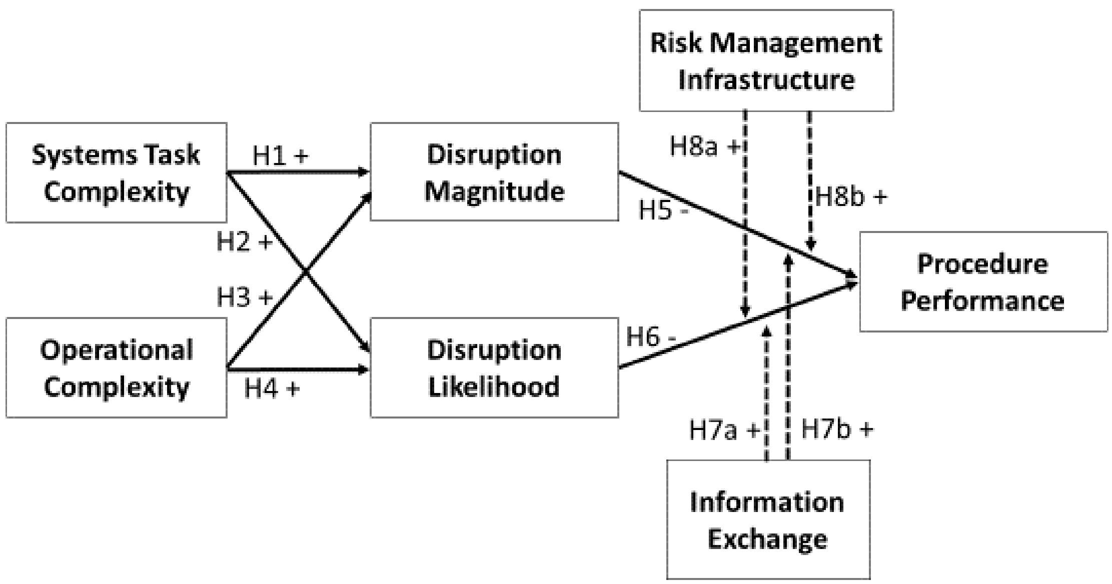
4.2.4 The moderating role of risk management infrastructure

Beyond the information being exchanged in the OR, the infrastructure that supports a hospital and its OR teams can influence the procedure performance. In a recent study, Ambulkar et al. (2015) found that organizations can limit their exposure to supply disruptions by developing resilience via their resource infrastructure. Risk management infrastructure is put in place by organizations to provide an early warning system to potential risks and disruptions. The infrastructure within acute episodes of care plays a role in minimizing the effects of a disruption and building resiliency into the process. Equipment with alarms and other cues may alert members of the team to problems. Information provided via the information systems and any training that is provided to personnel may help as well (Blackhurst et al., 2011). The structure that is provided by the hospital for acute episodes of care teams will enhance the team's resiliency by lowering uncertainty and increasing information (Perrow, 1986; Bonner et al., 2002). Acute episodes of care teams with access to greater levels of risk management infrastructure will have greater resiliency and will experience less impact when a disruption occurs. Thus, we hypothesize that:

Hypothesis 8a/8b: Risk management infrastructure within acute episodes of care moderates the relationship between magnitude/likelihood of service disruption risk and the procedure outcome.

The hypotheses are outlined in the conceptual model located in Figure 11 below.

Figure 11: Conceptual Model



4.3 Research Design

To test the hypothesized model, a survey was developed for OR personnel with the goal to administer the survey at hospitals throughout the U.S. By conducting the survey online, this affords the researcher an opportunity to collect data from a large group of individuals across a wide area without needing to be physically present. Appropriately collected data may be analyzed using parametric and nonparametric methods. To begin this process, IRB approval was obtained. Then, the survey instrument was developed, tested, and administered. After confirming that the necessary validity and reliability were obtained, the hypotheses are tested and results obtained.

4.3.1 Instrument Development – Item Generation and Pilot Test

This study employs a nationwide multi-respondent survey. Psychometric methodologies are used to test the hypotheses, as well as the validity and reliability of the instrument. The following constructs are validated for reliability and inclusion in this dissertation: likelihood of a disruption (PRO), magnitude of a disruption (MAG), system task complexity (SCTSK), operational detail complexity (OCDET), information exchange (INFO), risk management infrastructure (RMGMT), and procedure performance (PERF). This section will discuss the instrument development process, including the item generation, pilot testing, large-scale data collection, instrument validation, and analyses.

4.3.2 Item Generation

To begin developing the survey, a comprehensive literature review was conducted (Churchill, 1979). The constructs used in this research have been built upon the work of extant literature and academic and practitioner interviews. We adapt these constructs for the context of acute episodes of care. The definitions for the constructs used in this research are provided in Table 1.

This study adapted the constructs for the probability and magnitude of supply disruptions developed by Ellis et al. (2010) to test for the probability and magnitude of service disruptions within the OR. Gresov (1989) is used to test for the level of system task complexity by adapting the task uncertainty construct. Operational detailed complexity is based on detailed complexity construct developed by Bozarth et al. (2009). The information exchange construct from Heide and John (1992) was adapted for this study's context, along with the risk management infrastructure construct from Ambulkar et al. (2015). The procedure performance construct was adapted from Bode and Wagner (2015) study.

Table 8: Construct Definitions

Construct	Construct Definition	Literature
System Complexity		
- Task Complexity	The extent to the task at-hand is difficult to do and/or it has variability in the process from what is normally done.	Gresov (1989)
Operational Complexity		
- Detailed Complexity	The level of detail needed to perform a procedure based on its: number of supplies and instruments, steps in the process, and time for completion.	Bozarth et al. (2009)
Service Disruption Risk		
- Likelihood of a Disruption	The perceived likelihood that a disruption will occur.	Ellis et al. (2010)
- Magnitude of a Disruption	The perception of the loss that may occur due to a disruption.	Ellis et al. (2010)
Information Exchange		
- Norms of Information Exchange	The extent to which the team members actively engage in helping behaviors of providing information to each other	Heide and John (1992)
Risk Management Infrastructure	The extent to which the OR has placed structures within the environment to manage service disruption risk	Ambulkar et al. (2015)
Procedure Performance	The operational and financial consequences of a disruption	Bode and Wagner (2015)

4.3.3 Pre-testing

After adding and adapting the survey items, the first round of refinement was done with one academic, one supply chain director at a major hospital, one nurse, and one surgeon. Each of these individuals are considered experts in their fields, which includes a long list of publications by the academic and surgeon and many career accolades earned by all of them. Following the approach used by Swink and Song (2007), these individuals were provided clarity where needed and the feedback from discussions concerning their opinion of the survey resulted in many changes. The greatest changes occurred in the wording of the survey instrument so that it more closely matches the terminology used by healthcare workers. Also, the tone of the instrument was adjusted due to the sensitive information being collected about disruptions occurring in the OR.

A second round of pre-testing was done with 3 academics, 3 nurses, 3 doctors, and 1 healthcare worker, for a total of ten individuals. These persons helped refine the flow, eliminated some wordiness, and helped lower the time needed for respondents to complete the survey. Additionally, they confirmed that terminology would be understood by front-line workers in the OR.

4.3.4 Survey Data Collection

For surveys to be affective and generalizable, they must have a large enough sample size and response rate (Malhotra & Grover, 1998). Following the advice provide by Dillman (2011), the survey was coded into Qualtrics' online survey software. The design was easy to navigate and an easy-to-read font, and appropriate font size, was used. Michigan State University (MSU) has a Qualtrics license that is available to researchers, thus the survey had a MSU branded look and feel to it. Survey researchers have recommended and often used incentives to drive participation (Dillman, 2011). Two incentives were provided. First, a $20 gift card was offered for a successfully completed response. This amount was chosen based on discussions with the pre-testers, as it struck a balance between being enticing to OR workers, but remained reasonably affordable to the researcher. Secondly, a high-level summary of the results was sent to each of the respondents that provided a valid email address.

This survey was intended for personnel that actively work within the OR. When the survey was distributed, as much personalization, as possible, was incorporated into the outgoing email to help increase response rates (Dillman, 2011). Additionally, employing more than one method of data collection is encouraged, as it is thought to enhance validity of the results (Dillman, 2011). Thus, a multi-pronged approach was used for obtaining respondents.

4.3.5 Survey Sample Characteristics

This survey was sent too front-line OR workers throughout the U.S. To achieve this, as shown in Table 9, several methods were used. When possible, up to three messages were sent to potential respondents (an initial email and two reminders), per the Dillman (2011) guidelines. First, executives and managers at hospitals and hospital system for which the researchers had contacts were requested to help distribute the survey at their locations. This resulted in two hospitals and one hospital system agreeing to distribute the survey to a portion of their staff. The multi-hospital system did not provide specific details about the number of personnel emailed. Using the ratio of employees per hospital bed data published by IMS Health, one is able to approximate the number of personnel located within a hospital. Specifically, the average reported ratios per hospital beds in 2013 were added up for “Staff Physicians”, “Residents”, “Registered Nurses”, and “Physician Assistants” for multi-hospital systems. According to the Healthcare Cost Report Information System (HCRIS) published by CMS, the total number of beds for the 3 hospitals is 1,411. Dividing the two numbers (3.82 personnel/1,411 beds) resulted in approximately 369 respondents being contacted to take the survey. This is most likely conservative, as many of these personnel probably do not work in the OR. However, without better data, this appears to be a reasonable estimation. Overall, these three hospitals provided an average response rate of 29%, with 14% on the low end and 41% on the high end.

Next, an online search provided two lists of emails. One list was for a large hospital and the other was for orthopedic surgeons throughout the U.S. Within the potential respondents who opened the survey request e-mail a response rate of 35% from the hospitals and 47% from orthopedic surgeons was obtained.

Several healthcare organizations that focus on acute care and operating room personnel were contacted. A request to survey their members was sent via email and, when possible, phone calls were made. The Michigan Surgical Quality Collaborative (MSQC) agreed to participate. MSQC has 73 Michigan member hospitals and their focus is on improving surgical outcomes (http://www.msqc.org/about-us). The survey was sent to 238 of their members and 90 responses were obtained, resulting in a 38% response rate. Finally, a personal contact who works in the healthcare industry as a consultant agreed to distribute the survey. It was sent to 85 contacts and resulted in a 26% response rate.

Table 9: Data Collection Summary

	Number of Emails	Emails Opened	Completed Surveys	Response Rate (per emails sent)	Response Rate (per emails opened)	Percentage of data available for analysis
Participating Hospitals						
Hospital 1	61	-	20	33%	-	7.9%
Hospital 2	37	19	15	41%	79%	5.9%
Hospital System (3 hospitals)	369 (estimated)	-	52	14%	-	20.5%
Online Hospital Lists						
Hospital 3	1312	106	37	3%	35%	14.6%
Surgeon List						
Online List of Orthopedic Surgeons	983	38	18	2%	47%	7.1%
Organizations						
Michigan Surgical Quality Collaborative (MSQC)	238	-	90	38%	-	35.4%
Convenience Sampling Through Personal Contacts						
Healthcare Consultant	85	-	22	26%	-	8.7%
Total Count & Average Response Rates			254	22%	54%	100%

Data was collected over a 90-day period, starting on April 12th, 2016 and ending on July 11th, 2016. Overall, a conservative 22% response rate was achieved based on the number of emails sent. If one considers the response rate based on emails opened (for those distributions that could be tracked) an average of 39% is achieved.

As summarized in Tables 10 and 11, most of the respondents work at non-profit (75%) teaching hospitals (92%), with an average of 507 staffed beds. The respondents work across 11 different surgery specialties, have 9 different job titles, an average of more than 10 years of experience at their place of work, and are from 22 different states in the U.S. A final total of 249 surveys were collected.

Table 10: Hospital Profile

Hospital Profile		Mean	Count	Percentage
Number of Staffed Beds		507		
Teaching Status		0.93		
Profit Status				
	Profit		3	1.3%
	Non-profit		179	74.9%
	Government		57	23.8%
State				
	Michigan		161	65.7%
	Florida		16	6.5%
	Colorado		13	5.3%
	New York		14	5.7%
	Other		41	16.7%

Table 11: Respondent Profile

Respondent Profile		
Tenure		
<1 year	21	8.4%
1-5 years	70	28.1%
6-10 years	43	17.3%
11-15 years	34	13.7%
16-20 years	27	10.8%
>20 years	54	21.7%
Job Title		
Director of Operations/ Supply Chain	1	0.4%
OR Department Manager	12	4.9%
Nurse Circulator	27	10.9%
Physician Assistant	101	40.9%
Surgeon	40	16.2%
Surgical Technologist	14	5.7%
Resident	31	12.6%
Anesthesiologist	6	2.4%
Other	15	6.1%
Employment Status		
Salaried employee	147	59.8%
Part-time hourly employee	10	4.1%
Full-time hourly employee	55	22.4%
Non-employee Contractor: Contracted <50%	23	9.3%
Non-employee Contractor: Contracted >50%	8	3.3%
Other	3	1.2%
Specialties		
Cardiology	11	4.4%
ENT	10	4.0%
Emergency	3	1.2%
General	90	36.3%
Gynecology	16	6.5%
Neurosurgery	14	5.6%
Orthopedics	59	23.8%
Podiatry	2	0.8%
Urology	7	2.8%
Vascular	6	2.4%
Other	30	12.1%

4.3.6 Factor Analysis and Hypothesis Testing

The latent variable modeling program, Mplus version 6, was used to validate the measures for the constructs used in this study. Structural equation modeling (SEM) within Stata 13.1 was used to test the hypotheses. By combining factor analysis and multiple regression, we are able to explore the interrelationships between the constructs (Hair et al., 2006). Since the constructs in the hypothesized model are not directly observed, but are manifested through the individual expressions answered in the survey, reflective measurement models are used to perform confirmatory factor analysis (CFA) (Jarvis et al., 2003).

To make inferences from the data collected, a valid and reliable instrument is needed. Reliability measures how internally consistent the items are, while validity provides an indication of how well we are truly measuring what was intended (Hair et al., 2006). Mplus allows one to test for convergent and discriminant validity, as well as reliability (Bagozzi & Yi, 1988; Fornell & Larcker, 1981; Jarvis et al., 2003). Therefore, a CFA was conducted to evaluate the convergent and discriminant validity of the latent constructs for this study. When a latent construct's measures load on a single dimension, convergent validity is achieved. To better understand how well the measures "fit" the construct, goodness-of-fit measures are provided. For goodness-of-fit statistics, a non-significant chi-square score, a root mean square error approximation (RMSEA) of less than 0.08, a comparative fit index (CFI) greater than 0.9, and a standardized root mean square (SRMR) less than 0.08 are recommended (Hair et al., 2006; Kline, 2011). Finally, reliability refers to a construct's ability to produce the same result repeatedly. Cronbach's alpha is the measure of reliability provided in this study and values greater than 0.70 are generally considered valid (Cohen et al., 2003). Additionally, the construct reliability and average variance extracted are reported.

For those constructs that consist of two measures, reliability scores are reported, instead of an alpha score.

Seemingly unrelated regression (SUR) is used to test the hypotheses within the structural model. Due to the theoretical connection between the probability and magnitude of disruptions within the model, it is most appropriate to use SUR to account for the correlation between the error terms from the probability and magnitude regressions. This method is known to be effective at estimating models with mediating and/or moderating conditions based on cross-sectional data (Preacher et al., 2007), ensures that our variables are consistently estimated (Zellner, 1962) and equations are simultaneously evaluated (Greene, 2003). All hypotheses are estimated with Stata 13.1's SUREG command. To test hypotheses 1 through 4, the following equation is used:

<u>Equation 1</u>: $MAG_i\ (PRO_i) = \beta_0 + \beta_1 SystemTaskComplexity_i\ (+\beta_1 OperationalDetailedComplexity_i) + \beta_2 NumberofPeopleInRoom_i + \beta_3 Experience_i + \beta_4 ProcedureLength_i + \varepsilon_i$ (1)

To test hypotheses 5 and 8, the following equation is used:

<u>Equation 2</u>: $ProcedurePerformance_i = \beta_0 + \beta_1 MAG_i + \beta_2 PRO_i + \beta_3 InformationExchange_i * MAG_i\ (PRO_i) + \beta_4 RiskMgmtInfrastructure_i * MAG_i\ (PRO_i) + \beta_5 NumberofPeopleInRoom_i + \beta_6 Experience_i + \varepsilon_i$ (2)

4.4 Results

To ensure that multicollinearity is not a concern we examine the variance inflation factors (VIFs) (Peng and Lai, 2012). The VIFs were less than 3.3, indicating that multicollinearity is not a concern in the model (Cohen et al., 2003; Diamantopoulos and Siguaw, 2006). All items for all latent constructs were tested simultaneously for the CFA. The model had a significant chi-square (chi^2=575.742; df=279), RMSEA of 0.065 (90% confidence interval: 0.058 to 0.073), a CFI of 0.906, and a SRMR of 0.071. These results are acceptable except for the significant chi-square test, but this is often the case with larger sample sizes (Kline, 2011). Appendix A reports the survey questions for each construct and their alpha or reliability scores. In summary, all the constructs achieve adequate validity and reliability. When collecting survey data common method bias (CMB) may be an issue. To limit CMB careful survey construction protocols were followed, respondents had the option to respond anonymously to the survey, and questions were segmented throughout the survey, so that respondents could not easily go back and adjust their initial answers (Podsakoff et al., 2003). To test for CMB, Harmon's one-factor test was used. First, the single latent factor yielded a chi-square value of 3210.38 (df = 377, p <0.01). This was use to perform a chi-square difference test with the chi-square value from the chosen model. The difference test indicated that the one-factor model was significantly worse (Δchi-square = 2634.64, Δdf = 98, p <0.01), thus CMB is not an issue in this model. This method for testing for CMB has come under scrutiny in recent years and marker variable analysis has been advocated for as a better alternative to the Harman factor test (Craighead et al., 2011; Podsakoff et al., 2003). Thus, a marker variable test was conducted (Lindell & Whitney, 2001). Using a theoretically unrelated marker variable comprised of survey items for a previously validated construct for one's propensity to use the Web when searching for healthcare information ($\alpha = 0.89$, $\rho = 0.87$, $AVE = 0.69$) was included in the survey (Hansen, 2012). This marker variable was included in the CFA and in the regression analyses. The results did not change, which provides further confidence that CMB is not a problem in this research.

Due to the sample size obtained, latent variable modeling using is not possible due to convergence issues. Additionally, if convergence was achieved the reliability of the estimates could not be trusted, as one would have a ratio of sample size to parameters of less than 10 to 1 (Kline, 2011). Therefore, the latent variables within the model were transformed by adding the values of each of the measures within a construct and dividing it by the number of items to achieve an average latent variable score. The descriptive statistics and correlations of all the model variables may be found in Table 12.

SUR with bootstrapping was performed on the sample constructs to test the hypotheses and obtain accurately estimated standard errors. A stepwise regression of controls, IVs, and then moderators are entered into the models. The full set of results are found in Tables 13, 14, and 15 and significant paths are shown in Figure 13. This section reports the final results obtained in Table 15. Hypothesis 1 is not supported, which stated that system task complexity leads to higher magnitude of service disruption risk ($\beta = 0.052$; *n.s.*). Hypothesis 2 is supported ($\beta = 0.379$; $p < 0.01$), such that system task operational complexity leads to a higher probability of service disruption. Hypotheses 3 and 4 are supported, which lends support for operational complexity leading to higher magnitude and likelihood of a service disruption ($\beta = 0.325$; $p < 0.05$, $\beta = 0.271$; $p < 0.05$, respectively). Support is found for hypotheses 5 and 6, showing support that as the magnitude and likelihood of service disruption risk increases that a procedure's performance suffers ($\beta = -0.108$; $p < 0.10$, $\beta = -0.122$; $p < 0.05$, respectively). When the moderating effects of information exchange is tested, we find support for hypothesis 7a, which stated that the probability of a service disruption on procedure performance is lowered by information exchange ($\beta = 0.110$; $p < 0.10$). The path for the moderating effect of information exchange between the magnitude of a service disruption to procedure performance is not found to be significant ($\beta = -0.057$; *n.s.*). Also, we fail to find support for risk management infrastructure's moderating effect between the likelihood of a service disruption and procedure performance ($\beta = -0.023$; *n.s.*). Support is found for risk management infrastructure's moderating effect between the likelihood of a service disruption and procedure performance ($\beta = 0.110$; $p < 0.10$).

Table 12: Descriptives and Correlations

	Mean	S.D.	Num of People in the Room	Avg Exper of Team Members	Length of Procedure	Structural Complexity	Operational Complexity	Risk Mgmt Infrastructure	Information Exchange	Disruption Magnitude	Disruption Likelihood	Procedure Performance
Num of People in the Roor	2.72	0.75	1.000									
Avg Exper of Team Membe	2.65	1.34	*-0.126*	1.000								
Length of Procedure	4.90	1.64	*0.400*	-0.070	1.000							
Structural Complexity	2.63	1.00	0.075	-0.071	0.111	1.000						
Operational Complexity	3.55	1.74	0.035	-0.067	*0.223*	0.047	1.000					
Risk Mgmt Infrastructure	4.26	1.63	-0.032	-0.070	-0.079	-0.012	-0.003	1.000				
Information Exchange	5.40	1.12	0.056	0.105	-0.017	*-0.244*	0.024	*0.246*	1.000			
Disruption Magnitude	3.86	1.80	-0.053	0.015	0.080	0.011	*0.204*	-0.077	*-0.168*	1.000		
Disruption Likelihood	3.57	1.52	-0.026	0.087	0.095	*0.223*	*0.150*	0.006	-0.044	0.076	1.000	
Procedure Performance	4.05	0.70	-0.015	0.113	*-0.161*	-0.121	*-0.191*	0.110	0.117	*-0.175*	-0.136	1.000

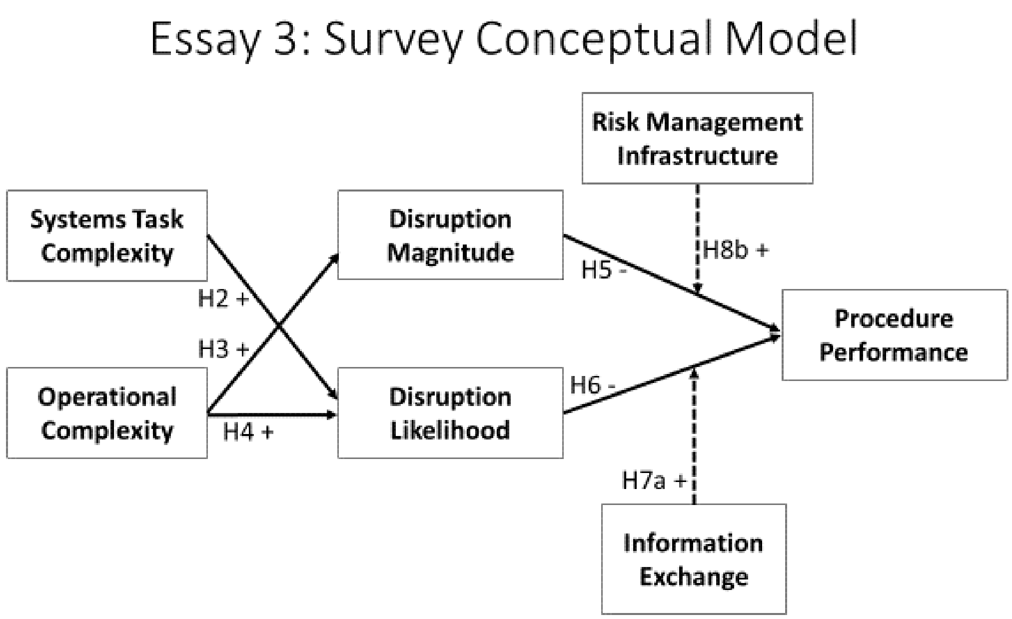
Note: Italics denotes significance at 0.05.

Table 13: Results Table 1

	Standardized estimates (*bootstrapped standard error*)		
	Magnitude	Likelihood	Procedure Performance
Control variables			
Number of People	-0.149	-0.040	0.017
	(0.146)	(0.129)	(0.054)
Experience	0.006	0.149	0.076
	(0.109)	(0.093)	(0.055)
Procedure Length	0.240*	0.115	-0.112**
	(0.137)	(0.114)	(0.055)
Constant	3.812***	3.545***	4.035***
	(0.130)	(0.107)	(0.049)
R-squared	1.6%	1.6%	3.5%
Chi-square	3.2	3.1	6.9
N	192	192	192

Note: *** p<0.01, ** p<0.05, * p<0.10. 1,000 bootstraps were performed.

Figure 12: Summary of Results



<u>Control variables</u>:

1) Number of people in the OR
2) Average experience of those people in the OR
3) Length of the procedure

Table 14: Results Table 2

	Standardized estimates (*bootstrapped standard error*)		
	Magnitude	Likelihood	Procedure Performance
Independent variables			
System Task Complexity	0.041	0.380***	
	(0.133)	(0.115)	
Operational Detailed Complexity	0.316**	0.255**	
	(0.150)	(0.104)	
Probability			-0.129**
			(0.057)
Magnitude			-0.106*
			(0.062)
Control variables			
Number of People	-0.076	-0.056	-0.006
	(0.144)	(0.120)	(0.055)
Experience	0.022	0.197**	0.093*
	(0.109)	(0.094)	(0.055)
Procedure Length	0.122	0.050	-0.082
	(0.138)	(0.111)	(0.054)
Constant	3.834***	3.510***	4.033***
	(0.134)	(0.102)	(0.047)
R-squared	4.2%	11.5%	8.0%
Δ in R-squared	2.6%	9.9%	4.5%
Chi-square	8.2	24.5	18.8
N	186	186	186

Note: *** p<0.01, ** p<0.05, * p<0.10. 1,000 bootstraps were performed.

Table 15: Results Table 3

	Standardized estimates (*bootstrapped standard error*)		
	Magnitude	Likelihood	Procedure Perf.
Independent variables			
System Task Complexity	0.052	0.379***	
	(0.133)	(0.117)	
Operational Detailed Complexity	0.325**	0.271**	
	(0.148)	(0.109)	
Probability			-0.122**
			(0.057)
Magnitude			-0.108*
			(0.058)
Info Exchange			0.023
			(0.054)
Risk Mgmt Infrastructure			0.075
			(0.055)
Probability x Info Exchange			0.110*
			(0.061)
Magnitude x Info Exchange			-0.057
			(0.069)
Probability x Risk Mgmt Infrastructure			-0.023
			(0.057)
Magnitude x Risk Mgmt Infrastructure			0.138**
			(0.061)
Control variables			
Number of People	-0.066	-0.062	0.020
	(0.148)	(0.126)	(0.057)
Experience	0.016	0.174*	0.106*
	(0.121)	(0.104)	(0.060)
Procedure Length	0.127	0.066	-0.085
	(0.133)	(0.112)	(0.055)
Constant	3.827***	3.516***	4.036***
	(0.133)	(0.106)	(0.052)
R-squared	4.3%	11.3%	13.4%
Δ in R-squared	0.1%	-0.2%	5.5%
Δ in R-squared *overall*	2.7%	9.8%	9.9%
Chi-square	8.3	23.7	31.3
N	183	183	183

Note: *** p<0.01, ** p<0.05, * p<0.10. 1,000 bootstraps were performed.

The results pertaining to the control variables indicate that a team's experience increases the probability of a disruption, but that this experience of the team can help the overall procedure performance. The procedure length and the number of people in the room are not found to be significant.

4.5 Robustness Tests

To test the robustness of the SUR method, the model was tested using standard OLS (Davies & Joglekar, 2013). The results are found to be consistent between the SUR and OLS regressions. Additionally, a latent variable model of the direct effects was performed in Mplus and the results were consistent. To test for heteroscedasticity, a Breusch-Pagan test of independence was performed (Breusch & Pagan, 1979). The results (chi-square = 2.185, $p = 0.535$) indicate that heteroscedasticity is not an issue in this research.

4.6 Discussion

The purpose of this research is to investigate how system and operational complexity are leading to increases in the likelihood and magnitude of disruptions in the delivery of healthcare. Additionally, we sought to understand how increases in the magnitude and likelihood of a service disruption influence procedure performance. Then, we sought to find what could be done to lower the effects of these increases in the magnitude and likelihood of service disruption risk on procedure performance. The healthcare industry is going through a period of rapid change and without keeping the levels of complexity under control, we risk negating the positive effects that are trying to be made. Specifically, with the current focus on healthcare costs and waste, reducing complexity has the ability to lower costs for the hospital and patient, achieve better outcomes, reduce waste, and increase the value of the service so that satisfaction among patients and employees is improved. The results of this study provide support for some of our predictions, which have theoretical and managerial implications.

4.7 Theoretical Implications

Our study contributes to the literature on complexity, healthcare disruptions, team dynamics and organizational infrastructure. This study extends the research from Bode and Wagner (2015) by redirecting their upward supply chain focus on buyer-supplier relations to those relationships inside an organizations operating room department. Specifically, we answer their call to explore complexity in HROs. Also, this research extends the work from Marley et al. (2014) by taking a confirmatory approach through survey data collection to show that complexity increases the likelihood of a service disruption and further extend it by exploring the impact of complexity on the magnitude of the service disruption. Additionally, this study extends the service disruption literature, which has not previously jointly tested the magnitude and probability of service disruptions on performance.

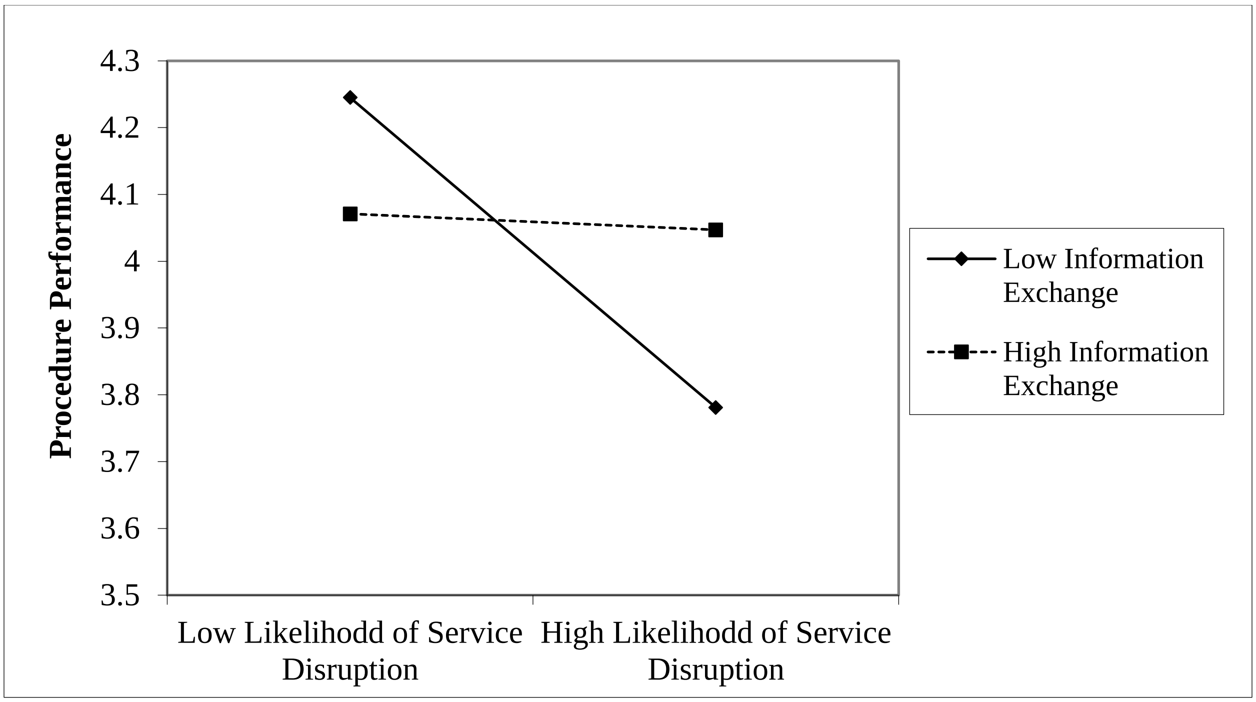
We find that as system task complexity increases, so does the likelihood of a service disruption. This was as hypothesized and confirms what normal accident theory (NAT) posits that more complex systems will experience more disruptions (Perrow, C., 1984). We did not find a relationship that system task complexity increases the magnitude of the service disruption. Since system task complexity refers to the number and variety of elements defining the system to the extent that the task at-hand is considered difficult (Bode & Wagner, 2015; Choi & Hong, 2002), leads one to understand that in a HRO any major variability within the procedure will likely have been addressed. Specifically, contingencies and process changes would have been made before a procedure is started to minimize any major service disruptions. However, without fully knowing if this is the case, one should not assume that these potential redundancies or process changes will prevent future service disruptions (Sagan, 1993).

Operational detailed complexity is found to increase the probability and magnitude of a service disruption. Operational detailed complexity refers to the interactions between the elements of a system (Bode & Wagner, 2015). Thus, as the level of detail of a procedure being performed increases, so do the interaction of all the elements. Therefore, it is more likely that something will go wrong and more likely that the service disruption will be severe. These conclusions are in line with NAT.

As the magnitude and probability of a service disruption increase, the procedure performance decreases. This means that the OR team, hospital organization, and patient suffer due increases in service disruption risk.

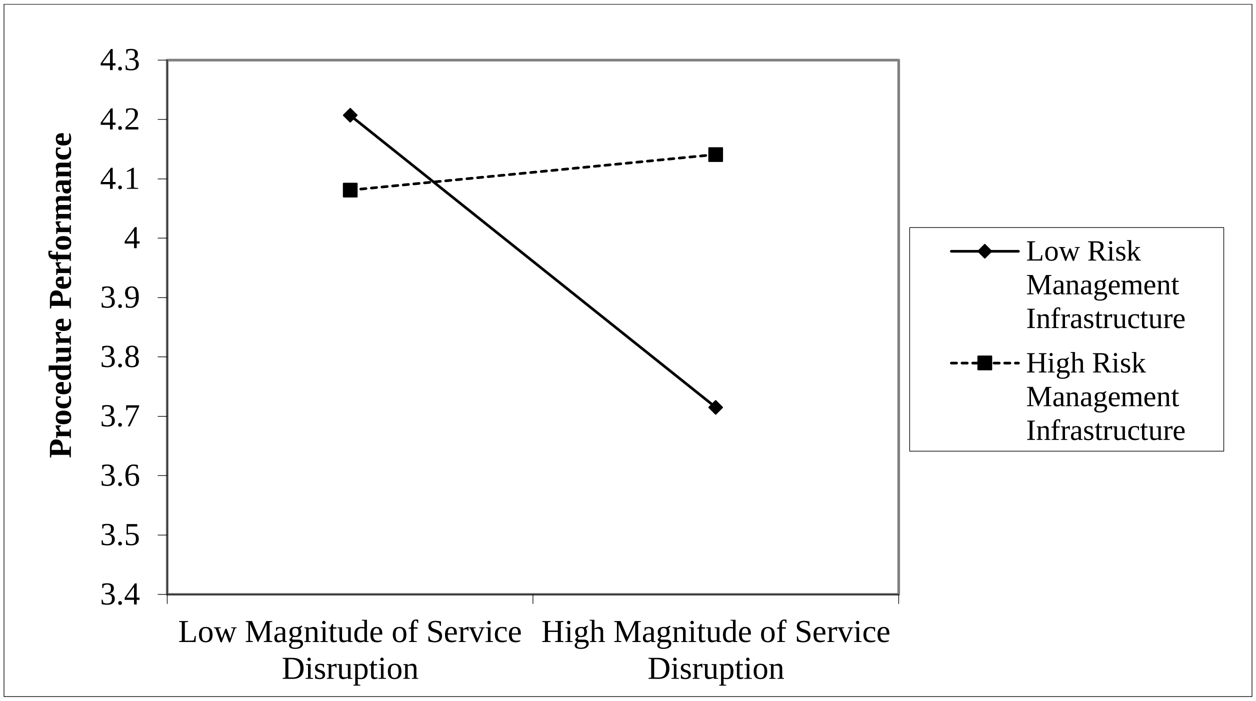
Relational aspects of an organization, such as their culture or social structure may play a role in reducing service disruptions by increasing helping behaviors (Chandrasekaran & Mishra, 2012). Thus, we hypothesized that information exchange would moderate the relationship between service disruption risk and procedure performance. The significant result found on the path from likelihood of service disruption to procedure performance indicates that the teams with greater quality information exchange will weather a disruption better than those teams with poorer information exchange. Figure 14 shows the interaction plot and one should notice that with high information exchange the procedure performance is not significantly different between low and high likelihood's of a service disruption. However, the difference of procedure performance when one has low information exchange is stark. Also, it appears that if the likelihood of a service disruption is low that one would have higher procedure performance with low information exchange. Thus, when a highly routine surgery is performed any exchange of information may be more a distraction than helpful. However, when it comes to HROs, the exchange of information offers the most consistent results.

Figure 13: Interaction Plot of Information Exchange between the Likelihood of a Disruption on Procedure Performance



The significant interaction displayed in Figure 15, depicts risk management infrastructure's impact on the relationship between the magnitude of a service disruption and overall procedure performance. Having proper resilience infrastructure in place leads to greater procedure performance with the risk of a high magnitude service disruption (Ambulkar et al., 2015). With low risk management infrastructure, one loses the ability to sense a disruption approaching, thus when a high magnitude disruption occurs, the procedure performance drops significantly. This results confirms NAT; in that it highlights how having a proper structure in place adds resilience to an organization.

Figure 14: Interaction Plot of Risk Management Infrastructure between the Magnitude of a Disruption on Procedure Performance



The significant results of some of the control variables offer additional insights. The greater the experience of the OR team, the more likely that a service disruption will occur. This could be due to complacency, familiarity, or a lack of updating of one's skills for the tasks needed.

4.8 Managerial Implications

Disruptions cost hospitals time and money. This study provides insights to practitioners, so that they can lower the number of disruptions, thus improving quality and lowering costs. Managers in other industries that often work in teams may find the results applicable to their context. Many organizations are looking to lower their risk of disruption and this research can help them better understand how their organization may be responding to disruptions. By educating those in the OR department concerning the behaviors that lower or increase the risk of disruptions in acute episodes of care, a hospital may experience lower costs and less waste, while saving time. In turn, this could increase the quality of results and satisfaction of patients and team members.

Hospitals and their OR departments should look to increase their levels of information exchange to help maintain high level of procedure performance. Similarly, investments in risk management infrastructure will be beneficial to hospitals struggling with high magnitude disruptions. Hospitals and other HROs should recognize that complexity is increasing not only the likelihood of a service disruption, but also the magnitude. Efforts to control and minimize this complexity by promoting information exchange and building in resilience through risk management infrastructure will yield positive procedural outcomes.

4.9 Limitations and Future Research

Like all research, there are limitations that should be acknowledged. First, the sample is heavily weighted with respondents working in Michigan hospitals, which may impact the generalizability of the results. This is primarily due the researchers sphere of influence. However, operating rooms and the rules within them are similar across the U.S. thanks to adoption of best practices. Thus, it is the people in the room that make the most difference. Secondly, due to the various methods used to collect the survey an accurate response rate is not able to be obtained. While most of the response rates were strong, the large lists of emails did not have large click-through rates, thus lowering the overall response rate.

Third, the use of cross-sectional survey results provides only a snapshot and may not accurately represent normal events. Likewise, relying on single informants may limit the generalizability of the results. Researchers should consider replicating this research using other methods, such as experiments, longitudinal design, or ethnography to confirm the findings. Also, replicating this research through the use of other methods may better help researchers and practitioners understand the results obtained in this study.

Looking forward, practitioners should note which individuals can exert the most influence and which behaviors to promote, so that disruptions are minimized. Researchers should look towards understanding what other variables may exist that influence the risk of a disruption, so that the industry can continue to increase quality and limit unnecessary expenses. In conclusion, existing constructs in the supply chain literature were tested and confirmed in a new context, namely healthcare, and it is found that certain behaviors and individuals significantly impact the probability and magnitude of disruptions that may be experienced at any given time within acute episodes of care.

APPENDIX

APPENDIX – ESSAY 3 SURVEY QUESTIONS

Survey Questions

Construct | **Item Measures**

System Complexity

- *Task Complexity (α = 0.73)*
  1. There is a clearly known way to do my job. (reverse coded)
  2. It was easy for me to know I did my job correctly. (reverse coded)
  3. The procedures I encounter have similar tasks. (reverse coded)
  4. Many of my tasks are the same from day to day. (reverse coded)
  5. I often follow about the same work methods or steps for doing my major tasks from day to day. (reverse coded)

Operational Complexity

- *Detailed Complexity (α = 0.82)*
  1. When thinking about this procedure, I remember that this procedure required more supplies and instruments compared to most other procedures I regularly perform.
  2. When thinking about this procedure, I remember that this procedure required more steps to complete it compared to most other procedures I regularly perform.
  3. When thinking about this procedure, I remember that this procedure required more time to complete it compared to most other procedures I regularly perform.

Process Integration

- *Internal Integration (α = 0.79)*
  1. Operating room teams are aware of each other's responsibilities.
  2. Operating room teams are cross-trained, so that any member can perform the other person's duties. (adapted from Flynn et al.)
  3. Everyone always knows the patient's status. (adapted from Flynn et al.)
  4. All operating room teams use common metrics of performance for treating patients (i.e. EBL).
  5. Information is regularly exchanged between operating room teams.
  6. Rational trade-offs among patient care and operational costs.

- Demand Integration (α = 0.91)

1. We pursue patient relationships and involvement that go beyond standard service seen at other hospitals.
2. Our plans address individual patient requirements.
3. We have clearly defined roles and responsibilities for managing patient relationships.
4. We are constantly exploring new ways of utilizing patient.
5. We synchronize our internal activities so that we can serve patients in a timely fashion.

- *Department Integration (α = 0.85)*
  1. We pursue relationships with other departments that go beyond required interactions.
  2. Our department's schedule accounts for other department's capabilities.
  3. We synchronize our activities with those of key departments.
  4. We exchange relevant information with other departments on a regular basis.
  5. We occasionally exchange relevant information with other departments.
  6. We are constantly exploring new working relationships with other departments.

Team Cohesion

- *Team Cohesion (α = 0.94)*
  1. Team members present during the procedure support each other.
  2. Team members present during the procedure helped each other.
  3. Team members get along with each other.
  4. Team members defend each other from criticism by outsiders.

Service Disruption Risk

- *Probability of a Disruption (r = 0.70, ρ = 0.63, AVE = 0.46)*
  1. It was highly unlikely that we would have experienced this interruption procedure. (reverse coded)
  2. There was a high probability that procedure we would have experienced an interruption.

- *Magnitude of a Disruption (α = 0.76, ρ = 0.82, AVE = 0.63)*
  1. This interruption procedure may have had negative financial consequences for the hospital.
  2. Due to this interruption, my team was unable to meet the patient’s needs.

Procedure Performance

- *Operational and financial performance*

1. How does this procedure differ from an average procedure when considering the unplanned use of supplies/instruments (reverse coded)
2. How does this procedure differ from an average procedure when considering the time for completing the procedure (reverse coded)
3. Compared to an average procedure, everything went smoothly.
4. The costs were probably more than normal for a comparable procedure. (reverse coded)
5. The revenue was probably more than normal for a comparable procedure.
6. How does this procedure differ from an average procedure when considering the ability to stay on schedule for the remainder of the work day

Marker Variable

- *Propensity to Use the Web for Healthcare Information*

1. I typically use the Web when searching for healthcare information in general.
2. I typically use the Web when searching for healthcare information relating to prespecified healthcare services.
3. I typically use the Web when searching for information that compares healthcare services.

[a]Loadings significant at $p<0.001$.

[b]Reverse-coded item; item measure reversed by subtracting response value from 8.

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