NETWORK ALIGNMENT IN HEALTHCARE: A SOCIO-TECHNICAL APPROACH TO SYSTEM-WIDE IMPROVEMENT AND PATIENT SAFETY

by

Sarah M. Bonzo

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Industrial and Operations Engineering)
in The University of Michigan
2012

Doctoral Committee:

Professor Jeffrey K. Liker, Chair
Professor Jeffery L. Myers
Professor Lawrence M. Seiford
Professor Albert J. Shih

DEDICATION

To my mother, father, and husband.

- *With love and gratitude*

ACKNOWLEDGEMENTS

For the past five years, I have been fortunate enough to work with several people who have been kind and patient enough to teach me about true process improvement. Additionally, I owe many thanks to those who have taken the time to immerse an interested graduate student into the field of healthcare. This research would not have been possible without their guidance.

I would first like to thank my advisor, Dr. Jeffrey Liker. It was a privilege to be a student of Jeff who is one of the most recognized scholars in our field. I am indebted to his patience and guidance over the course of the past five years. In addition to teaching me about true problem solving, he forever peaked my interest in the role of organizational culture and leadership in continuous improvement. Furthermore, Jeff was one of the few faculty advisors who encouraged his graduate students to work in the field while completing their dissertations. It is because of the time I spent with the University of Michigan Health System and the Rochester General Health System that I was able to incorporate aspects of the organizational culture into each case study and this research is better for it.

I would also like to thank Dr. Jeffrey Myers at the University of Michigan Health System and Dr. Robbin Dick at the Rochester General Health System for including me in their process improvement endeavors. Dr. Albert Shih also engaged me early on in my studies by introducing me to the Medical Innovation Center at the University of Michigan. Additionally, a special thanks to all of the team members at both organizations that went out of their way to help me collect data, participate in interviews, as well as giving their honest and unfiltered opinions about how we can improve healthcare.

Many thanks also go to the faculty of the Industrial and Operations Engineering department; specifically Dr. Lawrence Seiford, Dr. Mark VanOyen, and Dr. Nadine Sarter. Dr. Seiford was able to give me guidance when I faced tough decisions and I appreciate his advice. I'd also like to thank Dr. VanOyen and Dr. Sarter for their early guidance and influence on my patient safety focus.

I would also like to thank the National Science Foundation for awarding me their Graduate Research Fellowship. The fellowship gave me the flexibility to study out-of-state as well as study directly in the healthcare field while completing the dissertation. Without the fellowship, this would not have been possible.

A special thanks to all of my colleagues at Michigan who supported me along the way including Dr. Katrina Appell, Dr. Megan DeFauw, Arleigh Waring, and Dr. Michael Lau. I would also like to thank my friends and mentors from the Rochester Institute of Technology for your encouragement and support.

Finally, I would like to thank my family. A special thanks to John Bonzo for his love and support, especially as my research concluded. Lastly, I would like to thank my parents, Thomas and Susan, for their unwavering support over the past 28 years. My parents taught me the value of hard work and determination and have given me encouragement along every step of the way. I couldn't have done this without you.

TABLE OF CONTENTS

DEDICATION ii

ACKNOWLEDGEMENTS iii

LIST OF FIGURES viii

LIST OF TABLES ix

LIST OF APPENDICES x

LIST OF ABBREVIATIONS xi

ABSTRACT xii

CHAPTER I: INTRODUCTION 1

- PROBLEM STATEMENT 1
  - Quality Improvement in Health Care 3
  - Fragmented Systems 4
  - Complexity, Communication, and Quality in Healthcare 6
- RESEARCH STATEMENT 9
  - Organization of Document 9

CHAPTER II: MANAGING THE COMPLEX, NON-LINEAR VALUE STREAM FOR IMPROVED PATIENT SAFETY 12

- INTRODUCTION 12
  - A Systemic Approach to Patient Safety 16
  - The Internal Customer-Supplier Relationship 21
  - Theories on Coordination and Resilience 23
- APPROACHES TO COMPLEXITY AND PROCESS IMPROVEMENT 26
  - High Reliability and Requisite Variety 26
  - Lean and the ‘Rules-in-Use’ 30
  - Integrating the Two Perspectives 31

EXTENDING THE VALUE STREAM MAP TO THE COMPLEX, NON-LINEAR SYSTEM 33
The Network Alignment Model 36
The Technical Flow Network 39
The Safety Control Network 40
Aligning the Technical Flow and Safety Control Networks 43
NETWORK ALIGNMENT APPROACHES: IDENTIFYING THE GAPS 44
Detailed Analytic Approach 45
Visual Management Approach 49
DISCUSSION AND CONCLUSIONS 51
CHAPTER III: CROSS-UNIT COORDINATION: METHODS AND IMPLICATIONS 54
INTRODUCTION 54
Safety Culture 56
Organizational Boundaries and Patient Safety 58
Problem Solving across Organizational Boundaries 61
The Coordination Assessment 62
HYPOTHESES DEVELOPMENT 64
Cross-Unit Coordination 64
Process Improvement Efforts 65
Error Documentation 66
Standard Work 66
Safety Culture and Quality 67
DATA AND METHODS 67
Industry Setting: Anatomic Pathology 67
Unit of Analysis 72
Methodology 72
Variable Operationalization 73
RESULTS 79
Quantitative Results 79
Qualitative Feedback 82
DISCUSSION AND CONCLUSIONS 85
Interpretation of Results 85
Managerial Implications 87

Limitations and Future Work 89

CHAPTER IV: TRANSFORMING COMPLEX VALUE STREAMS IN HEALTHCARE: AN ORGANIC APPROACH TO SYSTEM-WIDE PATIENT SAFETY 91

INTRODUCTION 91

Approaches to Improvement: Mechanistic vs. Organic 95

Approach to Improvement and Organizational Learning 97

Design Elements for Iterative Improvement 99

Requisite Variety 100

Structured and Self-Diagnostic Communication 101

DATA AND METHODS 103

Research Methods 103

Interviews 104

Participant Observation 104

Process Metrics 105

RESEARCH SETTING AND BACKGROUND 105

Cultural Barriers to Coordinating Critical Care 107

Motivation and Approach to Change 109

Phase I: The Burning Platform (May - June 2010) 110

Phase II: Cross-Unit Collaboration and Process Improvement (June - September 2010) 113

Phase III: System-Wide Improvement (September - November 2010) 115

EVIDENCE OVER TIME 117

Qualitative Evidence 117

Quantitative Evidence 125

DISCUSSION 126

Organic vs. Mechanistic Approaches to Improvement 126

Structured and Self-Diagnostic Connections 128

CONCLUSIONS 129

CHAPTER V: CONCLUSIONS 132

SUMMARY AND IMPLICATIONS 132

LIMITATIONS AND FUTURE WORK 136

APPENDICIES 138

REFERENCES 145

LIST OF FIGURES

Figure 1: Coordination Continuum 32
Figure 2: Waste Reduction Model (Liker and Meier, 2006) 34
Figure 3: Admitted Medical Patient Technical Flow Network 38
Figure 4: Cross-unit Coordination 41
Figure 5: Admitted Medical Patient Safety Control Network 42
Figure 6: Network Alignment Approach 43
Figure 7: Detailed Analytic Alignment 46
Figure 8: Calculating the Coordination Assessment 48
Figure 9: Anatomic Pathology Flow Network 71
Figure 10: Coordination Assessment Example in AP 75
Figure 11: Interdependence and Cross-Unit Connections 99
Figure 12: ICU Patient Flow Network 107
Figure 13: ED to ICU Transfer Times 125

LIST OF TABLES

Table 1: Summary of Supplier and Customer-Specific Questions 77
Table 2: Summary of Non Unit-Specific Questions 77
Table 3: Summary of Quality Questions 77
Table 4: Summary of Safety Culture Questions 78
Table 5: Summary of Process Improvement Questions 78
Table 6: Correlations 80
Table 7: Regression Results 81
Table 8: Open-Ended Question Responses 84
Table 9: Respondent Problem Solving Values and Associated Comments 86
Table 10: Comments over Time Regarding Structure between the ED and ICU 120
Table 11: Comments over Time Regarding Problem Solving between the ED and ICU 121
Table 12: Comments over Time Regarding Structure between ICUs 122
Table 13: Comments over Time Regarding Problem Solving between ICUs 123
Table 14: Comments over Time Regarding Structure & Problem Solving between the ICUs and Floor Units 124

LIST OF APPENDICES

APPENDIX A: ANATOMIC PATHOLOGY SURVEY……………………………………138

APPENDIX B: ICU PATIENT FLOW INTERVIEW GUIDE………………………...144

LIST OF ABBREVIATIONS

In order of appearance:

IOM – Institute of Medicine

TPS – Toyota Production System

AP – Anatomic Pathology

HRO – High Reliability Organization

ED – Emergency Department

MICU – Medical Intensive Care Unit

AHRQ – Agency for Healthcare Research and Quality

IPOX – Immunohistochemistry

CP – Clinical Pathology

PI – Process Improvement

ICU – Intensive Care Unit

PDCA – Plan, Do, Check, Adjust

SICU – Surgical Intensive Care Unit

CTICU – Cardio-Thorasic Intensive Care Unit

MAT – Medical Assessment and Treatment [Unit]

ENIT – Emergency Nurse Intervention Team

ABSTRACT

Network Alignment in Healthcare: A Socio-Technical Approach for System-Wide Improvement and Patient Safety

by

Sarah M. Bonzo

Chair: Jeffrey K. Liker

Local process improvement efforts have permeated the healthcare industry, yet the ability to extend these improvements across the system continues to be a challenge. Coordinating services, or patient care, across organizational boundaries can be difficult and can impact leadership's ability to enable widespread organizational change. This research presents a socio-technical approach to cross-unit coordination and system-wide improvement by forwarding a network alignment methodology that can aid in the identification of gaps throughout a system. The proposed model examines the alignment of patient or diagnostic information flow, *the technical flow network*, with the ability to clearly define customer requirements and problem solve with suppliers, *the safety control network.*

This research uses a case study approach to assess the current situation and demonstrate an improvement approach to coordinate across organizational boundaries for improved quality in health care. Using both qualitative and quantitative data, we observe empirically a relationship between unit coordination and quality, safety culture, and process improvement efforts. This work provides a method for analyzing value streams that differ from the linear, sequential value stream mapping techniques commonly employed in manufacturing and introduces a coordination assessment measurement approach to quantify mismatches between technical flow and organizational structure. The ability of leadership to understand where breakdowns occur and develop countermeasures can impact the effectiveness of system-wide problem solving which, in turn, becomes the basis for continuous organizational learning and improvement.

CHAPTER I: INTRODUCTION

PROBLEM STATEMENT

Today's healthcare is delivered as a system of highly specialized yet interconnected parts. The large number of care givers and departments that are involved in providing timely, quality patient care increases the complexity in an already highly complex profession. This complexity continues to grow as new specialties, services, tests, and treatments are developed. In addition, the intrinsic variability in individual patient needs creates a vast network of potential interdependencies required for diagnosis, treatment, and health maintenance (Rouse, 2008). While these interdependencies continue to emerge, a lack of coordination and communication between interdependent units has resulted in highly fragmented systems (Shortell, Gillies, Anderson, Erickson, & Mitchell, 1996). This lack of communication between units has been identified as a leading source of preventable medical errors (The Joint Commission on Accreditation of Healthcare Organizations, 2005; (Volpp & Grande, 2003). Departmental silos and fragmentation in these complex, loosely coupled systems makes it increasingly difficult to effectively manage and improve patient outcomes (Fisher, Staiger, Bynum, & Gottlieb, 2006; Wilensky, Wolter, & Fischer, 2007).

Organizational failures leading to safety issues have been an area of increased focus in healthcare. The concept that preventable medical errors are often a result of poorly designed systems, rather than personal negligence, gained recognition in the mid-nineties and continues to be emphasized in the literature (Bogner, 1994; Reason, 1997; Leape, Woods, Hatlie, Kizer, Schroeder, & Lundberg, 1998; Kohn, Corrigan, & Donaldson, 2000; Rasmussen, 2000; Reid, Compton, Grossman, & Fanjiang, 2005a; Leape, 2009). While system breakdowns have been increasingly included in discussions of patient safety, there continues to be an underlying sense of fear that inhibits open and honest disclosure of medical errors. Resistance to disclose errors may stem from fear for provider reputation, fear of job loss, legal liability, and most of all, the guilt associated with causing harm to a patient (Gallagher, Waterman, Ebers, Fraser, & Levinson, 2003). Upon deeper investigation, many of these errors are found to be a product of systems that fail to protect against erroneous actions and decisions by operators at the sharp end (Woods, Johannesen, Cook, & Sarter, 1994; Reason, 1997), yet barriers surrounding error disclosure make it difficult to openly learn from and improve upon these system vulnerabilities (Billings, 2000).

Increasing complexity, interdependencies, fragmentation, and the potential for catastrophic outcomes create serious and persistent barriers to improving healthcare quality (Cebul, Rebitzer, Taylor, & Votruba, 2008). Improved communication and coordination across organizational boundaries is necessary to improve outcomes in the complex, dynamic healthcare organization (Senge, 1994). While lack of full error disclosure makes problem solving and continuous improvement difficult, it strengthens the case for proactive investigation into organizational weaknesses.

Quality Improvement in Health Care

Continuous quality improvement has been a topic of discussion in health care since the publication of landmark articles by Berwick, Laffel, and Blumenthal in the late eighties and the establishment of the Institute for Healthcare Improvement in 1991 (Berwick, 1989; Laffel & Blumenthal, 1989). While process improvement in healthcare gained momentum throughout the nineties, no medical error report has garnered as much attention as the Institute of Medicine's (IOM) *To Err is Human: Building a Safer Health System* (Kohn et al., 2000). The report's most notable statistic is based on results from two retrospective Harvard Medical Practice studies of large samples of hospital admissions in New York, Colorado, and Utah. When extrapolated to the over 33.6 million admissions to U.S. hospitals in 1997, the results of the two Harvard studies suggest that between 44,000 and 98,000 Americans die each year as a result of preventable medical errors. Several articles disputed the report and argued that these estimates were exaggerated (Hughes, Honig, Phillips, Woodcock, Anderson, McDonald, Weiner, & Hui, 2000; Lebanon & Hanover, 2000; McDonald, Weiner, & Hui, 2000; Lee, 2002), while others suggest numbers may be higher due to the fact that many errors go unrecorded (Leape, 2000). Several studies followed the report to gauge the extent of preventable medical errors (Thomas, Studdert, Runciman, Webb, Sexton, Wilson, Gibberd, Harrison, & Brennan, 2000; Weingart, Wilson, Gibberd, & Harrison, 2000). One study that explored the underlying causes of preventable medical errors from 1994 to 2004 suggests that latent organizational failures, particularly breakdowns in communication, played a large role in two-thirds of the adverse events (The Joint Commission on Accreditation of Healthcare Organizations, 2005).

After the release of the IOM report, the practical methodology of lean became popularized in healthcare as a method for improving quality, efficiency, and the continuity of care. Lean management is built on the model of the Toyota Production System (TPS) which evolved in Toyota over a 60-year period and is intended to eliminate quality defects while reducing lead time and increasing efficiency. TPS has its own embedded philosophy of error prevention, and hospitals have recently been working to adopt versions of lean for healthcare to increase efficiency and reduce errors. As in manufacturing, healthcare organizations have had limited success with the lean management methodology. Researchers have found considerable variation in organizations' abilities to implement lean (Liker, 2004) and have stressed the role that culture plays in problem solving throughout the organization. Complex and fragmented systems have made problem solving throughout the high-risk, healthcare organization difficult.

Fragmented Systems

As process improvement efforts in healthcare increased, several articles were published marking the end of the beginning in the patient safety movement (Barach, 2003; Altman, Clancy, & Blendon, 2004; Wachter, 2004; Bleich, 2005; Leape & Berwick, 2005). These articles noted a failure to find significant reductions in medical error or system-wide changes. The motivation for change after the IOM's report was stronger than ever, but process improvement efforts continued to be implemented in pieces, at local levels, thereby resulting in negligible improvements. Fragmentation continues to impede the ability of the healthcare organizations to improve patient outcomes at a systems level (Cebul et al., 2008). Therefore, to improve communication, collaboration, and ultimately patient safety, several agencies and independent researchers have emphasized the need for collaboration across the healthcare system to reduce preventable medical errors (Kohn et al., 2000; Corrigan, Donaldson, Kohn, Maguire, & Pike, 2001; Leape, Berwick, & Bates, 2002).

Following the call for a systems approach to error reduction, and little documented progress, organizational contributions to medical errors became a focal point for prominent researchers in both the operations management and human factors domains (Patterson, Cook, Woods, & Render, ; Cook, Render, & Woods, 2000; Patterson, Roth, Woods, Chow, & Gomes, 2004; Spear, 2005; Spear & Schmidhofer, 2005). Spear describes these fragmented, error-prone systems as systems that tolerate ambiguity in processes and workarounds when issues arise, "which creates many opportunities for ambiguity in terms of how an individual's work should be performed and how the work of many individuals should be successfully coordinated into an integrated whole" (Spear, 2005). He describes highly reliable systems as those that make clear exactly what is expected and what results should occur. When results deviate from expectations, highly reliable systems promptly investigate the deviations to ensure they do not happen again (Spear & Schmidhofer, 2005). Cook, Render, and Woods similarly identify the danger of gaps in healthcare delivery that result from complex and fragmented systems. "Gaps themselves mark the areas of vulnerability and show the mechanism by which complexity flows through health care to individual patients" (Cook et al., 2000). They suggest the proactive identification of gaps in care to provide a usable picture of potential organizational weaknesses that may lead to future safety problems. The reliable organization will proactively attempt to understand where these gaps exist, how they emerge throughout the organization, and how they can effectively be managed in complex systems with many potential interdependencies. These perspectives recognize the complexity inherent in healthcare and stress the importance of reducing fragmentation to establish a system that is capable of identifying dangerous deviations, and course correcting, to proactively avoid negative outcomes.

Complexity, Communication, and Quality in Healthcare

The healthcare system is complex, and success, in terms of improved quality, will be largely dependent on the organization's ability to coordinate both the social and technical factors across the entire value stream (healthcare delivery system). A system can be defined as a collection of two or more interacting parts or an interdependent group forming a unified whole (Lyons & Walton, 2005). A complex system is one in which there are so many interacting parts that it is difficult, if not impossible, to predict the behavior of the system based on a knowledge of its component parts (Runciman & Walton, 2007). "The health care system of the United States consists of various parts (e.g., clinics, hospitals, pharmacies, laboratories) that are interconnected (via flows of patients and information) to fulfill a purpose (e.g. maintaining and improving health)" (Plsek, 2001). The continuum of a patient's care extends beyond the boundaries of any one entity within the health care system. Beyond the inherent complexity of patient care, health care organizations are adaptive in nature. Healthcare's "parts" are comprised of highly skilled individuals that have been trained to adapt to and diagnose each patient's unique needs. For this reason, the pieces of the healthcare organization give rise to very complex global behavior. The system becomes, on the whole, greater than the sum of its parts (Laughlin, Curie, & are out while Jurassic, 2005). These emergent system properties can manifest as either innovation or error (Plsek, 2001).

In addition to being a complex adaptive system, the healthcare organization is a socio-technical system. Much like the emergent properties of complex systems, the interaction between the technical and human aspects of patient care are greater than either aspect considered alone (Trist, 1981). As medical technology advances, thereby increasing the complexity of processes, the socio-technical paradigm offers an organizational model which regards man a resource to be developed to troubleshoot a changing environment. "Thus, the study of modern complex systems requires an understanding of the interactions and interrelationships between the technical, human, social, and organizational aspects of systems" (Qureshi, 2007).

Thompson's work (1967) contributed to this theory by classifying the different types of organizational interdependence. He classified these differences based on the type of technology employed, the level of interdependence among the tasks performed, the degree of power/dependence between the organization and competitors, the stability of the environment, and the extent of ambiguity in standards employed to evaluate organizational performance (Thompson, 2003). The hospital, under Thompson's interdependence classifications, should have a reciprocal form of interdependence, strong horizontal communication channels, and coordination requiring mutual adjustment and cross-departmental meetings.

The product of healthcare, like many service industries, can be both tangible and intangible. It can be in the form of a patient, lab work, and/or information that leads to a correct diagnosis. The processes required to transform these products into quality patient care often requires coordination and communication between specialized and somewhat autonomous departments. Each department or process is dependent on another, yet the medical culture often emphasizes autonomy and working within professional and organizational boundaries. Karou Ishikawa was the first to formally state that the next process is the customer within the quality literature (Ishikawa, 1985). This concept of internal customers is one that is critical to providing quality patient care in highly complex, specialized, and fragmented healthcare systems. While Ishikawa is credited with the quality contribution of identifying and communicating with internal customers to improve quality, this concept is inherent in Toyota's processes. Rule two in Steven Spear's thesis *Rules-In-Use as a Codification of TPS* (1999) suggests that part of Toyota's success stems from its ability to align information flows with workflow. When coordinating workflows and social interactions in the socio-technical system, customers and suppliers (both internal and external) should be connected through clearly defined, overlapping request/response channels. Aligning both the product and information streams has implications for architectural simplification, information clarity, and problem identification (Spear, 1999). This type of alignment should reduce the risk of the supplier receiving multiple, possibly conflicting requests, which ultimately reduces errors throughout the entire delivery process.

While the customer/supplier dynamic offers valuable insights to effective coordination and improved outcomes, a fundamental barrier to improvement efforts in healthcare lies in indentifying the customer. Is it the patient or the next process? Complex, adaptive socio-technical systems with highly specialized and autonomous departments have made coordination throughout the system difficult. Fragmented systems and discontinuity in the healthcare delivery process continues to prevent healthcare organizations from achieving the resiliency, reliability, and safety they desire. Additional research is necessary to better understand where these gaps exist, how they emerge throughout the organization, and how they can effectively be managed to improve patient safety.

RESEARCH STATEMENT

The objective of this research is to provide a methodology for analyzing and improving safety from a systems perspective. This work will synthesize research on complex systems, organizational reliability, and lean management. A network approach will be used to evaluate how closely employees' knowledge of upstream problem resolution and downstream requirements aligns with technical flow. The goal is to create a model which reduces ambiguity by aligning the technical flow of patients and lab work with clearly defined request and response channels between internal customers and suppliers.

Organization of Document

Since the intent is a proven practical methodology, the research approach will combine theory and practice through actual case studies of implementation. This work will uncover insights about the prevalence of discontinuities in the healthcare delivery system and will establish a model for achieving safety at a system level. A review of the literature surrounding complexity and error in healthcare will be presented in Chapter II to provide context and support for this work in addition to pertinent organizational theories on patient safety. Chapter II will build upon these theories to propose a methodology for proactive and continuous identification of organizational weaknesses between departments which we refer to as gaps in cross-unit coordination. These gaps between departments, when identified and continuously improved upon, should theoretically enhance problem solving, reduce errors, and improve patient safety across the system. This work will aim to answer our first research question: ***How can complex systems tie patient safety efforts across interdependent, yet semiautonomous, units to enable system-wide improvement?***

The network alignment approach presented in Chapter II examines the alignment of patient or diagnostic information flow, the technical flow network, with the ability to clearly define customer requirements and problem solve with suppliers, the safety control network. The model, in conjunction with the case studies presented in chapters III and IV, strengthens the argument for coordination across organizational boundaries to improve patient safety in healthcare. The case studies present two very different clinical contexts, where similar organizational weaknesses have the ability to compromise patient safety. Each case will review the unique clinical setting and use variations of the proposed model to analyze and understand the organizational factors required for system-wide improvement. While a number of factors will be examined, both cases will focus on the ability of the system to coordinate and problem solve across organizational boundaries. Chapter III will utilize an embedded, single-case study design to demonstrate how a variety of organizational factors impact safety culture, and in turn how that safety culture impacts quality within one Anatomic Pathology (AP) department. Additionally, this study will investigate the role of problem solving across organizational boundaries for system-wide process improvement. This case will present a quantitative application of the model described in Chapter II and will aim to answer the second research question: ***How can practitioners utilize the network alignment approach for cross-unit gap identification and how do these gaps impact safety culture and quality?***

Chapter IV will expand upon the model to examine patient flow of Intensive Care Unit (ICU) patients throughout a large community hospital. This case will present an organic, team-driven approach to system-wide process improvement and will address the third and final research question: ***How does the approach to system-wide improvement impact problem solving and process improvement across the interdependent, yet semiautonomous departments within a complex system?***

This work will uncover insights about the prevalence of discontinuities in the healthcare delivery system, the importance of problem solving across organizational boundaries, and the role of leadership in establishing a model for system-wide improvement.

CHAPTER II: MANAGING THE COMPLEX, NON-LINEAR VALUE STREAM FOR IMPROVED PATIENT SAFETY

INTRODUCTION

The healthcare industry in the United States is faced with the challenge of increased demand for healthcare services, fewer hospitals as a result of consolidation into integrated delivery systems, ever-changing medical and technological advancements, and diminishing reimbursements. External factors are placing more pressure on healthcare organizations to provide both effective and efficient patient care. Internally, a growing array of specialty and diagnostic services are creating increasingly complex systems. Variability in individual patient needs and severity spawn complex webs of interdependent agents that must be able to coordinate care, adapt to the environment, and collectively improve to provide the best possible care.

While healthcare has unique challenges, coordinating and improving the complex system is a challenge faced by many industries. These types of systems are commonly referred to as complex, adaptive systems (Holland, 1992). Miller and Page (Miller & Page, 2007) define the complex adaptive system as a collection of adaptive, diverse, connected entities with interdependent actions. Complexity science, or the study of complex systems, is a broad, interdisciplinary research area that studies emergent system behaviors in diverse applications such as computer science, biology, economics, organizational theory, and physics. Emergence is a key concept in this field and has been used as early as 322 BC by Aristotle to describe higher order system behavior that is not reducible to the sum of its parts.

Holland (1992) defines the complex, adaptive system as "a dynamic network of many agents (which may represent cells, species, individuals, firms, nations) acting in parallel, constantly acting and reacting to what the other agents are doing. If there is to be any coherent behavior in the system, it has to arise from competition and cooperation among the agents themselves. The overall [emergent] behavior of the system is the result of a huge number of decisions made every moment by many individual agents." In addition to emergence, another characteristic of the complex, adaptive system found in several definitions is that interactions between agents are often non-linear (Dooley, 1997). The presence of multiple and changing connections between agents create complicated, interdependent networks. It is in this respect that healthcare is aptly described as a complex, adaptive system (Begun, Dooley, & Zimmerman, 2003). The healthcare delivery process can vary greatly for each patient. As disease and illness are diagnosed and treated, the path for providing service to the patient can deviate from initial expectations, requiring ad hoc coordination between a large number of providers and departments. The healthcare delivery process can easily diverge from a linear, sequential path as a patient's health changes and as clinical information is gathered.

Overly complex processes can have implications for both operational efficiency and patient safety. Over the past decade, several researchers have investigated the ways in which complexity, and associated variability and ambiguity, impact one of the fundamental principles of medicine, 'first, do no harm.' Preventable medical errors, as a result of increasingly complex and strained healthcare systems, have become a focus of academic research, popular media, and governmental agencies. During this time, the concepts of lean manufacturing gained attention in healthcare as an organizational approach to improve processes and reduce waste in an attempt to provide timely, quality care in an increasingly complex environment.

Lean production, based on the Toyota Production System (TPS) has been benchmarked worldwide for the production efficiencies it creates through empowering workers to eliminate wasted time, material, and other resources – all towards the goal of reducing lead time from customer order to product [or service] delivery (Liker, 2004). Lean has been adopted in many complex applications and industries including research and development, product development, aerospace, supply chain management, and government. The focus on shortening lead time through the elimination of waste, in any setting, allows problems to surface. As problems are exposed, they are systematically addressed by employees through structured problem solving.

While there are many examples of successful process improvements, real and lasting lean implementation has been less noticeable. Many organizations fail to differentiate between the lean toolset and the way an organization approaches waste, problem solving, and people development (Womack, Jones, & Roos, 1991; Spear & Bowen, 1999; Liker, 2004). While system-wide transformations require a different way of thinking, many healthcare organizations hit barriers that make even small-scale improvements challenging. Process improvement becomes increasingly difficult as patient care is coordinated across organizational boundaries. Silos, ambiguity, and incomplete knowledge of the system make coordination, and thus process improvement efforts, between departments difficult.

Healthcare delivery systems have many potential interdependent connections that need to mutually adjust to provide timely and quality patient care. A number of semiautonomous entities must interact with one another to provide the right care at the right time. Depending on the individual and their unique situation, a patient may require the following: intensive care, emergency services, diagnostic images, laboratory tests, specialist consultations, home care, and many other services. All of these entities are loosely coupled in an intricate network of individuals and teams of people, procedures, regulations, communications, equipment, and devices that function in a variable and uncertain environment with diffused, decentralized management control (Van Cott, 1994). While all of these connections have the potential for mutual adjustment, some fall victim to turf battles and mistrust that result in loss of collaboration. Like many complex systems, the health system's service components – a particular medical floor, the emergency department, radiology, laboratory services, perioperative services, or an outpatient clinic – each have a distinct culture with unique goals, values, beliefs, and norms of behavior (Van Cott, 1994). Each area is managed separately but is dependent upon several other departments and individuals to provide care to each patient.

The increasingly complex healthcare system makes improving patient safety across the fragmented service components difficult. This research will present a novel approach to process improvement in the complex system which emphasizes coordination between semiautonomous units in a way that improves problem solving and ultimately patient safety. Since this work strives to establish a systems approach to error reduction and safety in highly complex and risky environments, we focus on the role of horizontal, cross-unit communication between interdependent entities and incorporate aspects of expertise and authority when appropriate. It is at these organizational boundaries that broad-based patient safety in the complex, adaptive system becomes difficult.

A Systemic Approach to Patient Safety

The medical industry is trying to move away from a culture of blame in improving patient safety and establish a new culture of understanding adverse events as a result of system inadequacies (Kohn et al., 2000). This shift in thinking brings many previously hidden issues to the forefront for investigation since the blame does not lie solely on the individual. Errors that bridge connections such as nurse to physician, patient to physician, radiology to the Emergency Department (ED), ED nurse to floor nurse, OR to pathology… are now often labeled as system errors. Even errors that occur with a single individual can often be attributed to inadequate protocol or training, workplace design, or communication. These are system errors in that sense that the system, in which the individual or entities interacted, did not protect against the often unpredictable and inevitable failure. But stopping the understanding of the error at that point is just as ineffective as concluding a root cause analysis with an 'operator error' verdict. In order to create reliable and resilient complex systems, we need to understand how system features fail to prevent against front-line operator error, or failure at the sharp-end.

When serious system failures occur, they are a result of multiple, and apparently harmless, faults that occur together (Perrow, 1984; Reason, 1990; Turner & Pidgeon, 1997). In complex systems, these apparently small faults happen regularly and rarely result in serious adverse outcomes. For the most part, the minor faults are inactive, play no role in system operation, and are therefore described as latent failures (Reason, 1990). These types of failures, especially in complex, high-risk environments, tend to be extremely complex in nature and are therefore difficult to categorize. This may explain the new tendency to broadly define certain events as system errors, since the explanation is likely to be extremely nuanced. In organizations and industries where latent failures are more common, systems are so complex and are operated under such variable conditions that only human operators can be expected to have both the flexibility and judgment necessary to control them (Cook & Woods, 1994).

In order to better understand how these complex failures emerge, we must first define error. Reason defines error as circumstances in which planned actions fail to achieve the desired outcome (Reason, 2000). Therefore if the action taken was not the one that was or should have been intended, there has been an error (Senders & Moray, 1991). This definition does not suggest or imply there was an adverse event. Adverse events may happen without an error and errors may occur with no negative outcome. According to Senders, an accident is an unplanned, unexpected, and undesired event, usually with an adverse consequence. An adverse outcome after an error, by this definition, is an accident (Senders & Moray, 1991). The literature often uses the word error to represent accidents. What results is a large number of taxonomies and statistics regarding accidents with little understanding about the errors that occurred.

The Harvard Medical Practice Study, made popular in the 1999 Institute of Medicine report To Err is Human (Kohn et al., 2000), found that nearly 4% of patients hospitalized in New York in 1984 suffered an adverse event, defined as an unintended injury caused by treatment that resulted in prolongation of hospital stay or measureable disability at the time of discharge (Leape, Brennan, Laird, Lawthers, Localio, Barnes, Hebert, Newhouse, Weiler, & Hiatt, 1991). Two years later, another study was performed using these records to determine which injuries may have been preventable. The records were reviewed, and each adverse event was classified as preventable, unpreventable, or potentially preventable by physician reviewers. An adverse event was classified as preventable if it resulted from an error (Leape, Lawthers, Brennan, & Johnson, 1993). From this study, more than two-thirds (70%) of adverse events were found to be preventable, 24% were judged unpreventable, and the remaining 6% were classified as potentially preventable. The errors contributing to the adverse events were grouped into the following four categories:

- *Diagnostic* – Error in diagnosis or delay in diagnosis; Failure to employ indicated tests; Use of outmoded tests or therapy; Failure to act on the results of monitoring or testing
- *Treatment* – Technical error in the performance of an operation, procedure, or test; Error in administering the treatment (including preparation for treatment or operation); Error in the dose of a drug or in the method of use of a drug; Avoidable delay in treatment or in responding to an abnormal test; Inappropriate (not indicated) care
- *Preventive* – Failure to provide indicated prophylactic treatment; Inadequate monitoring or follow-up of treatment
- *Other* – Failure in communication; Equipment failure; Other system failure

More recently than the Harvard Medical Practice Study (citation), HealthGrades' analysis of 41 million Medicare patient records suggested that patient safety incidents cost the federal Medicare program $8.8 billion and resulted in 238,337 potentially preventable deaths from 2004 through 2006 (Health Grades, 2008). This is an improvement upon their 2004 study that estimated that approximately 304,702 Americans die each year due to preventable errors (Health Grades, 2004). The U.S. Department of Health study suggests that 32,500 patients die as a result of preventable medical errors in U.S. hospitals each year (Zhan & Miller, 2003). The researchers in this study stated that their numbers were much lower than other estimates because their methodology only covered selected types of medical injury that were discovered during hospitalization. According to the Centers for Disease Control, nearly two million patients suffer from a hospital acquired infection each year, resulting in 99,000 deaths (Scott, 2009).

Estimates regarding the extent of medical error and adverse events vary widely as methodologies, interpretations, and datasets differ. In addition to nationwide estimates of preventable errors and adverse events, taxonomies of error can be found by service and specialty including but not limited to laboratory services, medicine, surgery, orthopedics, pediatrics, obstetrics, urology, radiology, intensive care, emergency services, and primary care offices. Many of these studies classify adverse events based on the type of error. Unfortunately, these classifications tend to be vague as previously noted. 'Error in diagnosis' does not provide the granularity needed to truly understand each error and, consequently, how to improve. A focus on broad classifications, and not all the contributing factors unique to each event, may lead administrators and care givers to employ incomplete or inappropriate safeguards that add unnecessary complexity to the system. These adverse event estimates and broad classifications only raise awareness of the need to improve problem solving and collaboration between system components.

If we attempt to understand these errors and events as systems failures, a more contextual and nuanced explanation is necessary. The healthcare delivery process requires the coordination of many caregivers, services, equipment, and technology. In a simple production series, system reliability is a function of each component's reliability and its position in the series. The simple, linear series can improve overall reliability when the least reliable component is improved or removed. In complex, adaptive systems, improving reliability is not as simple.

The systemic view of patient safety suggests that adverse events result from a combination of several seemingly small, latent errors. Thus reliability in the complex system is considered to be a dynamic nonevent (Weick, 2001). "It is dynamic because safety is preserved by timely human adjustments; it is a nonevent because successful outcomes rarely call attention to themselves" (Reason, 2000). What makes some complex, adaptive systems more successful than others is the ability to coordinate between agents or entities to catch small errors and problem solve before they propagate into larger adverse events. This is where cross-unit coordination between internal customers and suppliers becomes critical to identifying small deviations and problem solving to prevent more serious adverse events. No one person or department has a complete picture of the system or even the care plan for one patient. Individual perspectives and abilities of doctors, nurses, technicians, aids, and pharmacists enable a system of checks and balances that can adapt to change and create a more flexible, resilient system. These individuals and departments are the nodes that link the components of healthcare; they are critical to its reliability and safety (Van Cott, 1994).

This people-centered aspect of healthcare can provide a buffer against unpredictable latent system errors.

In order to harness the potential reliability capable within a complex system, the components must be able to function in a coordinated manner to identify deviations and problem solve when necessary. The healthcare system, though, tends to be largely fragmented making coordination and system reliability difficult. Instead of coordinating to improve safety throughout the continuum of care, individual units focus primarily on improving their unit performance with little regard for the impact on others (Reid, Compton, Grossman, & Fanjiang, 2005b). Therefore, coordination between internal customers and suppliers becomes critical for system-wide improvement and reliability.

The Internal Customer-Supplier Relationship

Joeseph Juran, Edwards Deming, and Karou Ishikawa were pioneers in the industrial quality movement. Juran defined quality as “fitness for use” (Juran, 1988) by the customer while Deming stated that quality “should be aimed at the needs of the customer, present and future” (Deming, 1992). In both definitions, the customer determines the quality of a product or service. In healthcare, the patient is the customer. The health system exists to provide a service to its patients. Following with the above definitions, quality is determined by the patient.

Since health systems provide such a vast array of services by many different caregivers, the health service is provided by many individuals throughout the course of a patient’s care. This can include services provided during registration, admission, testing, treatment, discharge, home care, rehabilitation, or follow-up appointments. Each aspect in the continuum of care can impact the others as patient information and care plans are shared between functions. Thus, the overall quality of the service is based upon the entire care-delivery process. This is also true in other complex systems when a product or service is provided by the coordination of several individuals, departments, or organizations. It is with this understanding of interdependence that Ishikawa emphasized the role of internal customer and suppliers in quality improvement and coined the term "the next process is your customer" (Ishikawa & Lu, 1985).

While the notion of internal and external customers and suppliers has existed for decades, terms like fragmentation or silos are more common when describing relationships between service components within healthcare (Shortell et al., 1996; Cebul et al., 2008; Stange, 2009). Additionally, "critical tasks in the financing and provision of health care are distributed across a variety of distinct, often competing, entities each with its own objectives, obligations, and capabilities" (Cebul et al., 2008). Many departments function as semiautonomous units with their own unique capabilities and culture that can impact employee satisfaction, safety, and patient satisfaction (Moody & Pesut, 2006). While departments may differ widely in incentives, capabilities, and staffing, they often are required to coordinate with one another throughout a patient's continuum of care.

There are varying perspectives on the most appropriate way to coordinate tasks between units in the complex, adaptive system. Thompson's early work (Thompson, 1967) identifies three basic structures for interdependence: pooled, sequential, and reciprocal. The complex, adaptive system (i.e. hospitals or new product development) is considered to have reciprocal forms of interdependence as outputs of each task or department provide inputs to the other. "Hospitals are an excellent example because they provide coordinated services to patients. A patient may move back and forth between x-ray, surgery, and physical therapy as needed" (Daft, 2004). Management requirements of reciprocal interdependence are greatest since coordination and mutual adjustment between departments requires high levels of information processing activities such as decision making and communication (Galbraith, 1974; Tushman & Nadler, 1978).

Many early theorists suggest that organizations with reciprocal interdependence require horizontal structures with departments that are collocated or that report to the same person on the organizational chart as a way to reduce information processing requirements (Daft, 2004). Additionally, cross-departmental teams working on shared processes can provide the coordination necessary to support reciprocal interdependence. While Daft suggests that poor coordination in these settings results in poor organizational performance, not all organizational theorists share this view. There are competing theories on the degree to which cross-departmental coordination either enables or limits an organization's ability to problem solve, learn, and adjust in the high-risk, complex organization.

Theories on Coordination and Resilience

Unlike organizations that exhibit strong central control, healthcare organizations are often divided into semiautonomous units that specialize in a particular aspect of patient care (Hasenfeld, 1993). Work unit autonomy gives control to the unit managers who are familiar with the operational demand of providing care within the unit's mandate (Pinelle & Gutwin, 2006) which results in loose coupling between units. Perrow (Perrow, 1984) introduced interactive complexity and loose/tight coupling to determine a system's potential for accidents. He defines interactive complexity as the presence of unfamiliar or unexpected sequences of events that are either not visible or immediately comprehensible. A tightly coupled system is one that is highly interdependent. Perrow suggested that systems that are highly interdependent are more likely to behave in unpredictable ways and stressed that systems with high 'interactive complexity' and tight coupling inevitably result in failure. Weick similarly suggests that loose coupling can be an effective solution to environmental change and limited information-processing capabilities (Weick, 2001). He likens loose coupling in social systems to compartmentalization in individuals "a means to achieve cognitive economy and a little peace" (Weick, 1982).

On the other side of the spectrum, Sabel and Zeitlin (Sabel & Zeitlin, 2004) argue that loose coupling reduces the ability of organizations to coordinate, innovate, and learn. Similarly, tight coupling in complex systems has been found to be beneficial as a way to manage complexity and improve reliability (Grandori & Soda, 1995; Helper, MacDuffie, & Sabel, 2000; Gittell, 2002; Gittell & Weiss, 2004). According to relational theories of coordination forwarded by Gittel, communication and relationship ties provide a powerful source of information processing capacity or bandwidth for coordinating work (Crowston & Kammerer, 1998; Faraj & Xiao, 2006). "By extension, work processes that are either highly interdependent or highly complex require relatively strong communication and relationship ties for their successful coordination. Conversely, work processes with low levels of task interdependence or complexity can be successfully coordinated through weak communication and relationship ties" (Gittell, Weinberg, Pfefferle, & Bishop, 2008).

Simon (Simon, 1973) argues a more moderate perspective stating that "loose horizontal coupling permits each subassembly to operate dynamically in independence of the detail of others; only the inputs it requires and the outputs it produces are relevant for the larger aspects of system behavior." Eisenhardt and Brown (Brown & Eisenhardt, 1998) added that to reduce information overload, organizations must be comprised of individual units that are only partly connected to one another, while simultaneously ensuring that there is not too little coordination. Other theorists also suggest that the most effective complex systems exist "at the edge of chaos," in a state that is balanced between too much and too little coordination (Carroll & Burton, 2000).

Healthcare organizations have historically been loosely coupled due to the high degree of specialization and inherent complexity in providing individualized care for each patient. While these units are largely semiautonomous, they are still dependent on one another to provide patient care. In fact, they are traditionally characterized as having reciprocal interdependence, which denotes the strongest level of interdependence (Thompson, 1967). Therefore, the units within the complex healthcare organization face the challenge of balancing the appropriate organizational structure with process or technical interdependence. While loose coupling enables each unit to adapt to environmental change, it also makes system-wide improvements difficult.

Loose coupling between departments offers particular advantages in complex environments including increased specialization, differentiation, and contextual decision-making. Additionally, loose coupling protects the total system from breakdowns at its elements. Tight coupling between departments maximizes coordination and communication between elements that can reduce the bounded rationality common within complex systems and can improve the ability to tie process improvements across the system. While each perspective has advantages, they both have disadvantages as well. Loose coupling can reduce the ability to mutually adjust in systems of reciprocal interdependence while the information processing requirements of tightly coupled systems can reduce responsiveness and flexibility between units. The challenge for healthcare organizations and other complex systems lies in finding a balance in cross-unit coordination and communication that enables both problem identification and problem solving. This leads us to our primary research question: ***How can complex systems tie error reduction efforts across interdependent, yet semiautonomous, units to enable system-wide improvement?***

APPROACHES TO COMPLEXITY AND PROCESS IMPROVEMENT

Practitioners have been drawn to two popular management approaches, high reliability organization (HRO) theory and lean management, to improve performance in the complex system. Both approaches have recently become popularized in healthcare as a way to reduce error and the potential for failure. While the aspects of HROs and lean are complimentary, each approach has a slightly different perspective on the extent to which cross-unit communication is coordinated.

High Reliability and Requisite Variety

High reliability organizations (HROs) are organizations that are able to avoid catastrophe in high consequence environments where normal accidents (Perrow, 1984) can be expected due to tight coupling and interactive complexity. Following Perrow's analysis of the Three Mile Island disaster and several other investigations into accidents and near misses in high risk industries, many researchers began to investigate the role of coupling and complexity on major organizational failures. Research on these organizations has not led to specific methodologies that can be used by practitioners for actionable improvement. Instead, analysis of high reliability organizations has led to insights and concepts that are meant to change the way administration, practitioners, and researchers understand and respond to error in high-risk systems.

While the various researchers in the high reliability domain each present their own slightly different model for how to achieve reliability and resilience, healthcare literature has largely focused on the work of Karl Weick. Weick suggests that organizations in complex and high risk settings can achieve mindfulness and reliability by following five core concepts: sensitivity to operations, reluctance to simplify, preoccupation with failure, commitment to resilience, and deference to expertise (2007). *Sensitivity to operations* requires attentiveness to the systems and processes that create the product or service. Sensitivity to these processes allows those closest to the work to make adjustments that prevent small errors from manifesting into catastrophic accidents. High reliability organizations also *resist using simplistic explanations* for why processes work or why they don't. This increased granularity allows for deeper understanding and mindfulness. When processes don't work as expected, these organizations have a *preoccupation with failure* that views near misses as a sign that something needs attention, not that safeguards prevented a potential accident. When accidents do occur, these organizations *commit to resilience* by improvising to keep the system functioning.

Finally, *deference to expertise* moves the decisions on how to respond to failures to those on the front line who understand the processes best.

Together, these concepts provide the complex organization with the ability to achieve mindfulness, and thus high reliability, in a high risk environment. Weick defines mindfulness as "a rich awareness of discriminatory detail." The mindful organization will respond to weak signals or small, early indicators of potentially large system failures by improvising short-term workarounds to keep errors small and the system functioning. Workarounds are a non-standard response or countermeasure to managing a complex or unforeseen situation. While workarounds without subsequent problem solving can be dangerous, Weick presents workarounds as an adaptive response to early signals of failure.

A certain amount of ambiguity and variety allows the organization to discover adaptive responses, such as workarounds, it would have otherwise not have discovered. Yet ambiguity can also be the source of error itself. In this respect, Weick suggests that there is a requisite amount of variety that complex organizations must maintain to respond to disruptions with the appropriate degree of sensitivity. The law of requisite variety (Ashby, 1958) states that the larger the variety of actions able to control a system, the larger the variety of perturbations it is able to manage. This is essentially the way that the loosely coupled yet interdependent units within a healthcare organization maintain the flexibility to respond to individual patient needs each day. The semiautonomous units coordinate on an ad hoc basis when patient care or information is passed from one unit to another. While loose coupling and a wide range of potential interdependencies enable greater flexibility, it has made coordinated system-wide error reduction and process improvement extremely difficult. Understanding how to effectively match the variety of technical dependencies with the appropriate amount of coordination becomes critical to error reduction across the loosely coupled, interdependent system. The challenge in these systems lies in striking a balance between excessive complexity and oversimplification that enables both flexibility and coordinated problem solving.

While the social coordination and technical dependencies of an organization can be sequential (linear), as complexity increases, these interactions can quickly become reciprocal (non-linear). Morgan uses the metaphor of organizations as organisms (Morgan, 2006) to describe how social and technical needs must evolve together for the organization to successfully adapt to the ever-changing environment. Optimization of each aspect alone (social or technical) tends to increase not only the quantity of unpredictable, 'un-designed' relationships but also those relationships that are injurious to the system's performance (Jenkins, Stanton, Walker, Salmon, & Young, 2006).

At Toyota, the product value stream and the people value stream are intertwined in a system that makes up the DNA of the Toyota Way (Liker & Hoseus, 2008). Spear suggests that what makes Toyota so successful is their ability to couple the process of doing work with the process of learning to do it better as it's being done (Spear, 2005). These aspects of Toyota's socio-technical system are what set them apart from the competition in terms of efficiency and quality. As technical and safety requirements are coordinated horizontally, problems are addressed, and the system as a whole becomes more reliable.

Lean and the 'Rules-in-Use'

Many people have acknowledged that the Toyota management system, or lean, has enabled the company to achieve world class quality and efficiency, but few have been able to successfully emulate their practices. Many articles and books describe the tools commonly found within the Toyota production system. These tools alone, though, do not address the culture of structured problem solving that enables the organization to continuously learn and improve. This type of learning cannot be imitated since it is, as Weick suggested, context specific (Spear, 1999).

Spear (1999) outlines five "rules-in-use" that have enabled Toyota to achieve both world class efficiency and quality. In his observations of Toyota, he explains that these design guidelines "existed in the design, performance, and improvement of individual activities and in the design, operation, and improvement of system activities. The patterns were so strong, it appeared as if people were using rules to guide their decision making even though the rules themselves were never actually articulated" (Spear, 1999). These rules-in-use that define the essence of the Toyota production system are as follows:

- *Rule 1* – Design and perform every activity so that it is structured and self-diagnostic.
- *Rule 2* – Design and operate the connection between every person who or every machine that supplies a good, service, or information and the customer who receives the specific item so that the connection is direct, binary, and self-diagnostic.

- *Rule 3* – Each good, service, and piece of information must have a simple, pre-specified, self diagnostic flow-path over which it will travel as it takes form.
- *Rule 4* – Design and do all improvement activities so that they are experiments – structured, self-diagnostic (hypothesis-testing) activities.
- *Rule 5* – Resolve connection and flow-path problems that affect a customer-supplier pair in the smallest group that includes the affected individuals.

These rules-in-use represent the ideal state which offers guidelines for behavior. While Spear notes that the rules are rarely followed exactly, they provide an implicit goal towards which to strive. It is through these design guides that the organization can identify deviations and problem solve to keep errors small. These rules complement Weick's work on High Reliability Organizations (HROs) by adding clear design guidelines, particularly Rule 3, for systems composed of modular and interdependent entities. In this rule, Spear states three key characteristics of effective customer/supplier flow paths: pre-specified, simple, and self-diagnostic. Spear defines these characteristics as follows: Pre-specified flow paths require each product, service, or information to have one and only one flow path throughout the value stream, or series of processes and activities required to create or deliver a product or service. Simple flow paths must not have loops or intertwined branches. A self-diagnostic flow path is one that generates a binary signal when the good, service, or information deviates from the expected path.

Integrating the Two Perspectives

While the aspects of high reliability organizations and Toyota's 'rules in use' can help guide organizations to identify and respond to errors, and problem solve to continuously improve the system, they vary in their degree to which variety and/or complexity is accepted. The healthcare organization is an example of a complex, adaptive system that has multiple potential flow paths that are dependent on each patient's individual needs. The manufacturing parallel to healthcare's complexity would be a job shop where each individual part requires a unique machine sequence. It is hard to argue that the healthcare organization, or the job shop, should simplify operations to the extent that all flow paths are pre-specified, simple, and self-diagnostic. Instead, incorporating the requisite variety necessary for each organization with these ideal goals in mind can help the complex organization be mindful and problem solve when necessary. Incorporating these concepts and guidelines from high reliability theory and lean, as shown in Figure 1, provides an opportunity for organizations to reduce errors throughout the complex, non-linear value stream.

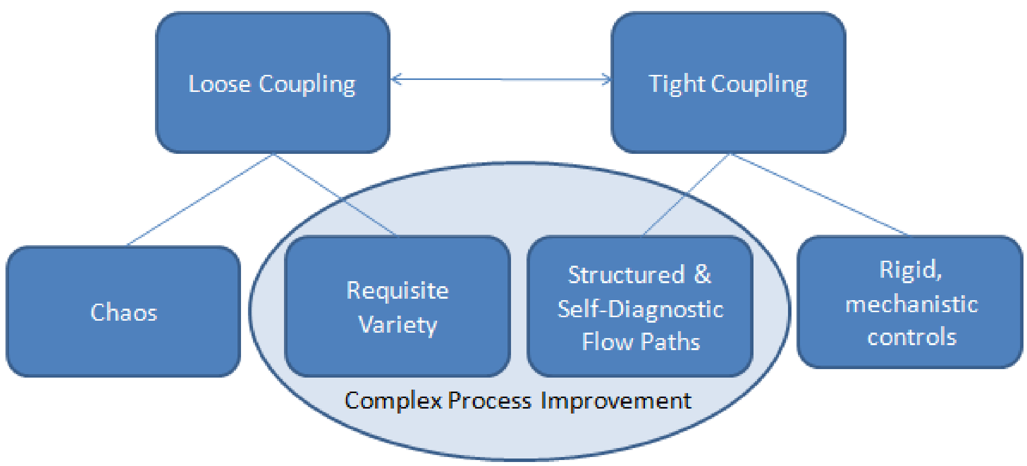


Figure 1: Coordination Continuum

By incorporating aspects from both ideals, the complex organization can focus on coordination between various internal customers and suppliers that most adequately meets the needs of each organization. The integration of these two approaches follows with the moderate coupling perspective forwarded by Simon (Simon, 1973) and Brown and Eisenhardt (Brown & Eisenhardt, 1998). In order to determine both requisite variety and the clarity of flow-paths, each organization must first understand its value stream, regardless of complexity.

EXTENDING THE VALUE STREAM MAP TO THE COMPLEX, NON-LINEAR SYSTEM

The value stream can be defined as the sequence of actions required to design, produce, or provide a product or service to the customer. Mapping the value stream is a process that has been used for decades within Toyota to depict current and future or "ideal" states in the process of continuous improvement. When mapping the value stream, practitioners move away from optimization of component parts and are better equipped to improve whole system functioning. At Toyota, the term "Material and Information Flow Mapping" (Rother & Shook, 2003) is commonly used to describe what lean practitioners now call "Value Stream Mapping" since both material and information paths are critical to providing the right product or service, in the right amount, at the right time.

The value stream map is useful at many levels within and across organizations. The value stream can vary greatly in scope and, in healthcare, can range from a single outpatient visit to long-term care which is coordinated across multiple care givers and organizations. In order to identify the appropriate scope, Rother and Shook suggest that one of the first steps in the mapping process requires selecting a product family. A product family is a group of products or services that pass through a series of similar processes. The concept of product families can be readily translated to service lines such as orthopedics, emergency medicine, general medicine, etc.

The value stream map is vital in understanding the current state of the system and identifying waste to be eliminated. Toyota's process for problem solving, and therefore waste reduction, is depicted in the "Waste Reduction Model" (Figure 2) (Liker & Meier, 2006). A clear understanding of the current state value stream is necessary to begin and maintain this cycle of continuous improvement.

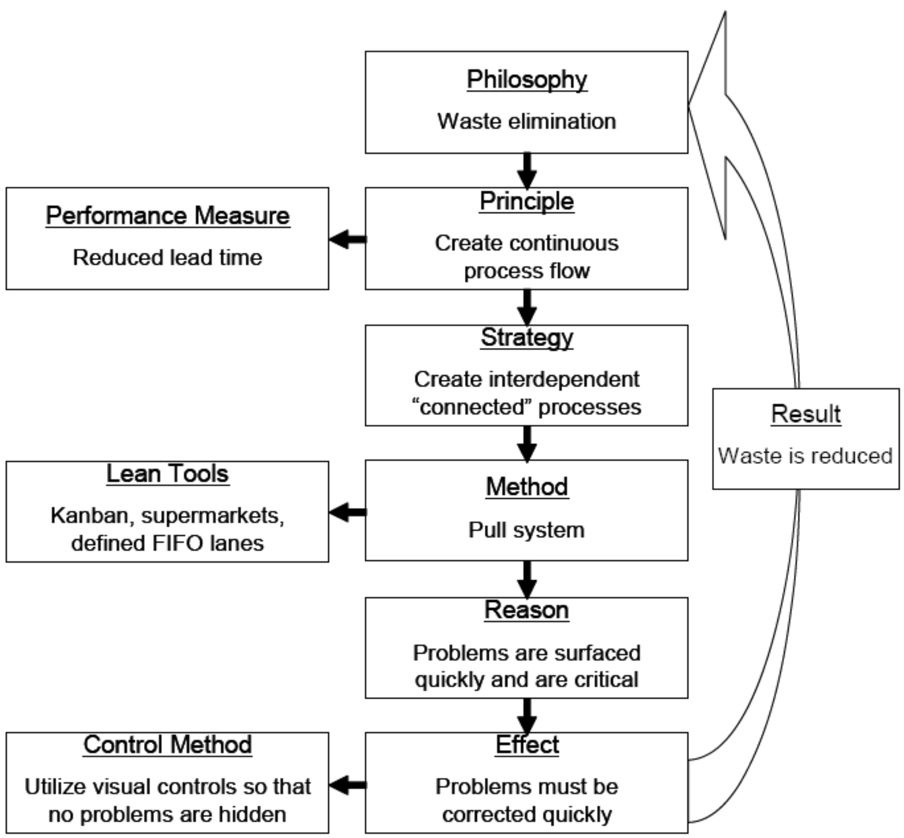


Figure 2: Waste Reduction Model (Liker and Meier, 2006)

The overarching philosophy of the "Waste Reduction Model" is waste elimination which focuses on elimination of non-value added process and activities in the value stream. The waste reduction model lays the foundation for system-wide process improvement and specifically for this research, error reduction. While the principle and ideal state that guides waste reduction is continuous flow, this is not always possible to achieve. Where continuous flow is not possible, the value stream must be comprised of interdependent "connected" process. This concept is the foundation for the lean adage, "flow where you can, pull where you must" (Womack et al., 1991). These processes are connected through clearly defined pull systems that link each customer and supplier through structured channels. These system characteristics make deviations obvious and enable timely problem solving and continuous waste reduction. This model of waste reduction follows with the Spear's 'Rules-in-Use.'

Both the "Waste Reduction Model" and the "Rules-in-use" express the significance of clear and consistent communication and flow paths between the connected processes within a value stream. Many manufacturing examples of value stream maps depict these clearly defined flow paths through linear, sequential map of process steps… Process 1 feeds Process 2, which feeds Process 3, which are all guided by information generated from a centralized source. While this is often the introductory example to learn the concept of value stream mapping, it is also commonly the form that we see the value stream exercise take, regardless of system intricacies. Yet attempts to fit the existing value stream within these constraints does one of two things: it reduces the scope of analysis to a singular department or basic process, or it presents an oversimplification of the system that does not capture true complexity. Toyota's method of process improvement has been so successful because it is fundamentally problem-solving based learning that is frequent, structured, and context specific. Therefore, what worked in one department or process may not work in another. Instead, what practitioners tend to do is apply similar tools in a completely different setting and expect similar results.

Since the value stream map is one of the first steps in taking a systems perspective to process improvement and moving through the waste reduction cycle, the following section provides an extension to the value stream map for the complex system. While the real challenge lies in adapting these philosophies, principles, and tools to fit each individual system, the following methodology presents a different perspective, particularly for use in healthcare, to account for both the requisite variety and clarity of connections necessary to tie error reduction efforts across interdependent, yet semiautonomous, units to enable system-wide improvement.

The Network Alignment Model

The complex, non-linear value stream must be able to balance both the requisite variety of flow paths while clearly identifying the connections between processes and/or departments. Following with the Rules-in-Use, the customers and suppliers throughout the value stream should be connected by clearly defined, overlapping request/response channels. Clarity of these connections help make deviations, or weak signals of system failures, obvious and enable immediate and effective problem solving.

To provide context, we present the value stream of admitted medical patients entering through the Emergency Department. Medical patients who enter through the Emergency Department (ED) tend to utilize similar processes and can therefore be considered the product or service family. This group of medical patients differ from direct admission medical patients since they utilize a similar set of services prior to the Emergency Department physician's decision to admit.

While there are many potential flow paths of admitted medical patients, we will only present the ancillary services provided by Radiology or Laboratory Services for explanatory purposes. Once the attending physician makes a decision to admit the patient to the hospital for further care, bed coordination is notified and attempts to place the patient on the most appropriate unit. The patient may require critical care services provided by the Medical Intensive Care Unit (MICU) or standard medical care provided by a general medical unit. When general medical beds are not available, many healthcare organizations will place medical patients on surgical floors. These patients are considered off-service and may be moved to a medical floor as medical beds become available or they may reside on the surgical floor for the duration of their stay in the hospital. Patients who required MICU care upon admission may later transfer to a medical unit once their condition has stabilized. Conversely, if a patient's condition worsens during the stay, the patient may have to move from a general medical unit into an MICU. At any point during the patient's hospitalization, additional testing performed by either Radiology or Laboratory Services may be required.

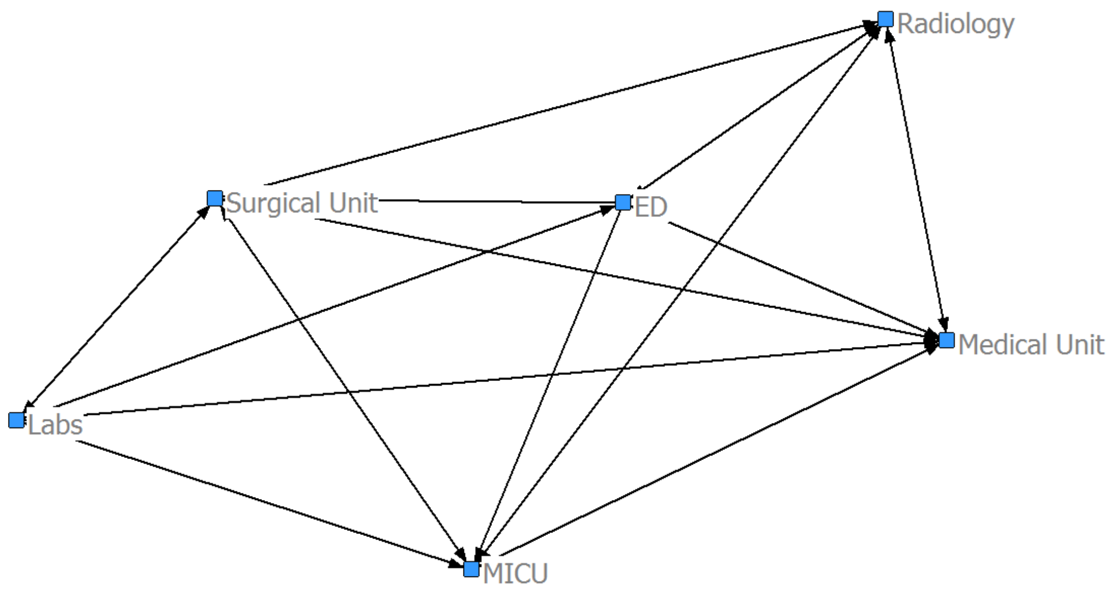


Figure 3: Admitted Medical Patient Technical Flow Network

Even in this high-level, basic healthcare example (shown in Figure 3), the inherent complexity in patient flow becomes apparent. The resulting value stream is both complex and non-linear. Even this basic example violates the third Rule-in-Use since it is neither pre-specified nor simple. There is an opportunity, though, for these connections to be self-diagnostic. Even though this value stream can vary depending on individual patient needs, the various flow paths are utilized frequently enough to suggest there should be clearly defined request/response channels between the internal customers and suppliers that are capable of recognizing potentially harmful deviations. Yet what often results in these semiautonomous and coupled systems is a lack of clarity regarding which patient is moving to what unit, at what time, and with what information. The daily ambiguity that spawns in these systems creates both complacency with deviations and mistrust between departments resulting in the inability of the system to respond to early signals of failure and problem solve across boundaries.

The value stream mapping exercise also encourages practitioners to go to where the work is being done, observe, and strive to understand what is really happening throughout the system – not just within the component processes or departments. During this process, the value stream map in Figure 3 begins to resemble a network as the requisite variety of flow paths is incorporated to effectively treat and manage the care for the admitted medical patient population. This network, in its current form, is not all that different from a simple process map. Beyond simple process maps, a major contribution of the value stream mapping exercise is the focus on the interdependence on the twin flows of material and information. Material and information flow must both be included for value stream thinking to be extended into the complex, non-linear system.

The Technical Flow Network

The first step in understanding the complex, non-linear value stream is to identify all the potential customers and suppliers within the value stream. Understanding each department's role within the larger system alone is an eye-opening experience, especially in an organization that has not historically pieced together individual contributions within this paradigm. Additionally, visually depicting the non-linearity and requisite variety of flow paths can be comforting to those doing the work and experiencing the chaos but can also provide a clear picture of the connections necessary to provide timely and accurate care for each patient. Therefore, the first step lies in establishing the network shown in Figure 3 where each node represents a unit and each dyad represents an interdependent system connection between two units.

- *The Technical Flow Network* – a network which establishes directional interdependence between the various units within a system.

While this flow has historically represented material flow in manufacturing, we refer to Figure 3 as an example of the technical flow network since the directed connections between internal customers and suppliers represent all of the potential technical flow paths required to bring either a product or service to fruition. The technical flow network, though, only represents one aspect of the value creation process. To understand how a product or service is transformed, one must also understand the flow of information between the various units or processes.

The Safety Control Network

The communication and coordination that accompanies the technical flow described in Figure 3 is extremely important to the quality of care. In order to be able to identify potentially dangerous deviations, each unit should establish clear expectations, as the respective customers and suppliers, regarding how technical work should flow between the units. Furthermore, as shown in Figure 4 this communication should allow for open feedback between units or individuals when communication is inadequate or the process does not happen as expected. This clarity in both clinical and process communication helps to create self-diagnostic flow paths that are both mindful and capable of problem solving when deviations occur. Therefore, instead of simply referring to this aspect of the value stream as information flow, we will use the term safety control network since the effectiveness of communication along these flow paths is critical to catching errors before they become failures and problem solving to continuously improve throughout the system.

- *The Safety Control Network* – a network which assesses organizational coordination or each area's ability to function as both a customer and supplier within the network.

The successful unit will have a clear understanding of customer requirements and will effectively resolve problems with suppliers to ensure they do not happen in the future.

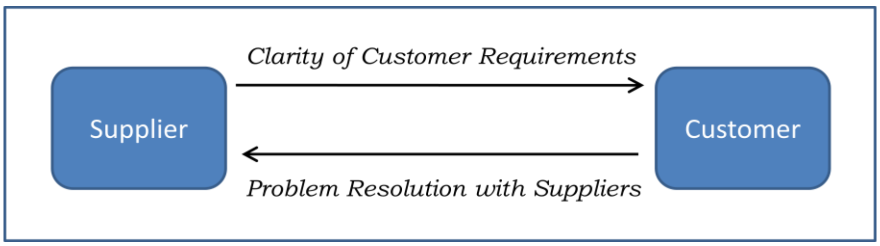


Figure 4: Cross-unit Coordination

While communication regarding technical flow usually follows the technical flow paths, intermediaries and centralized information systems can generate additional flow paths within an already complex system. For instance, in the admitted medical patient example, as soon as a patient is admitted, bed coordination will be notified electronically and will begin the search for the most appropriate bed given the clinical information found within the electronic medical record. Bed coordination is often used to facilitate patient moves between the Emergency Department (ED), medical units, surgical units, and intensive care units. In many cases, if a patient requires intensive care services and an MICU bed is available, the decision to move the patient will occur directly between the ED and the MICU. If a bed is not available and there is a patient in the ED in immediate need of MICU level care, bed coordinators must be notified of the priority to find a general medical bed for the most stable patient currently within the MICU. In this case, the timeliness of care for the critical patient in the ED rests on the ability of the system to effectively communicate and adjust to provide quality care to each patient. Any misunderstanding or delay in communication in the safety control network shown in Figure 5 will jeopardize patient safety and is increasingly considered by governmental agencies such as the IOM to be a preventable medical error.

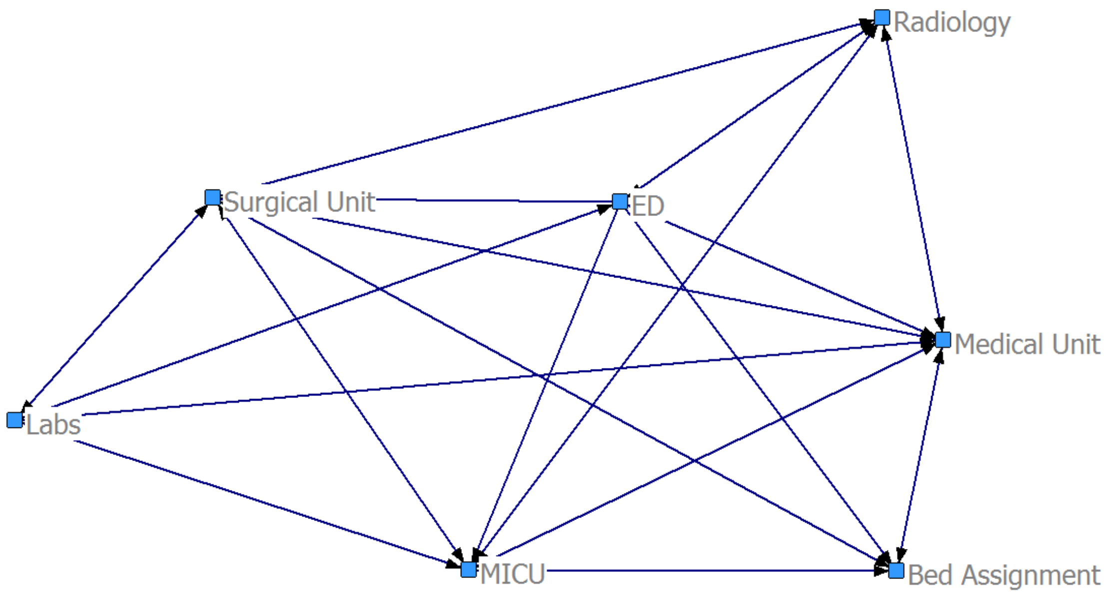


Figure 5: Admitted Medical Patient Safety Control Network

While the safety control network identifies the flow of important communication regarding technical flow, it must be paired with the technical flow network to truly understand how value is created throughout the system. Therefore, wherever there is technical flow there should also be clear communication regarding expectations and problem solving when deviations occur. It is alignment of these two networks that will support practitioners in the process of tying error reduction efforts across units to enable system-wide improvement.

Aligning the Technical Flow and Safety Control Networks

While the first step in mapping the complex, non-linear value stream requires an understanding of all of the directed relationships (denoting each internal customer and supplier) the second step requires analysis of the alignment between the technical flow network and the safety control network. By aligning these networks, practitioners can begin to understand where gaps exist between the semiautonomous yet interdependent units throughout the system.

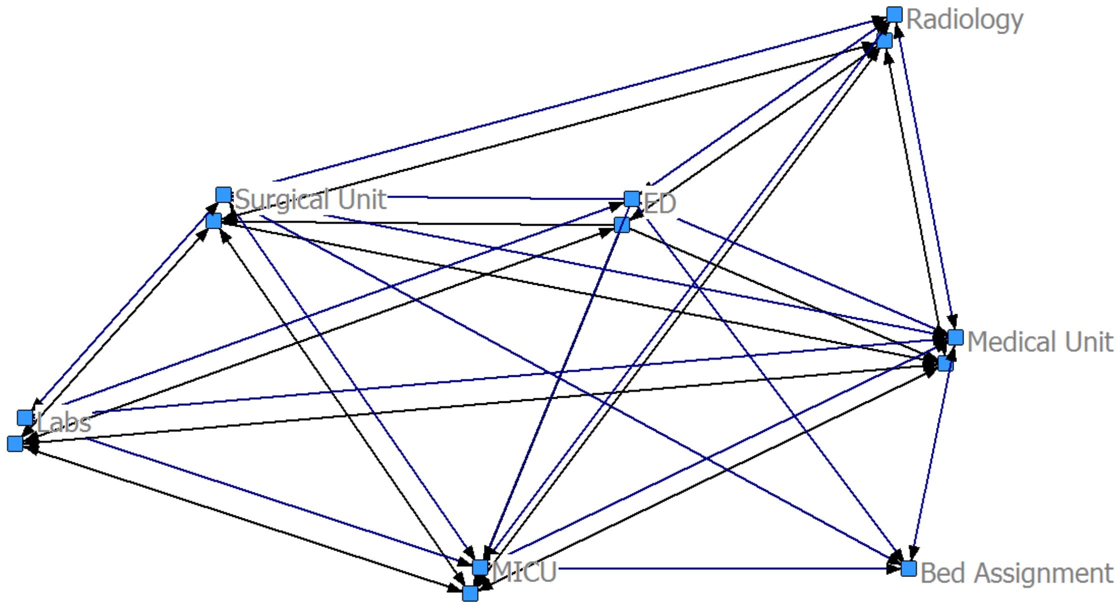


Figure 6: Network Alignment Approach

While networks have been historically used to model organization structures and human relations, they have only recently been used to identify alignment of organizational structures and technical communication networks (Sosa, Eppinger, & Rowles, 2004). This research was expanded in a 2007 study on the impact of product architecture and organizational structure on efficiency and quality in complex product development projects. To analyze the degree of alignment, the researchers defined a metric called a coordination deficit, which measures the extent to which organizational coordination falls short of product connectivity in complex product development (Gokpinar, Hopp, & Iravani, 2010). This same concept can be applied to the complex value stream mapping process.

The proposed model aligns the technical flow of a product or service, *the technical flow network*, with the ability to clearly define customer requirements and problem solve with suppliers, *the safety control network*. Aligning both the product (technical flow) and information (safety control) streams as shown in Figure 6 has implications for architectural simplification, information clarity, and problem identification (Spear, 1999). This type of alignment should reduce the risk of the supplier receiving multiple, possibly conflicting requests, which ultimately reduces errors throughout the entire delivery process. To use this tool as a way to incorporate the requisite variety of flow paths in complex systems, while creating "connected" interdependent processes that enable waste reduction and continuous improvement, one must understand where the gaps exist.

NETWORK ALIGNMENT APPROACHES: IDENTIFYING THE GAPS

One of the most valuable aspects of the value stream mapping exercise is the process of going to where the work is being done to observe and understanding how value is created throughout the system. Once the practitioner or team has gone to the floor to map the technical flow and safety control networks, there are two ways to analyze the alignment and identify gaps.

Detailed Analytic Approach

The first approach to understanding where the gaps exist throughout the system employs detailed analysis with quantitative weights for the dyads in each network. While the ideal system would have clear, self-diagnostic communication channels between every interdependent unit, it may not be feasible to do so all at once. To understand the extent of each gap for prioritization, the detailed analytic approach quantitatively determines the extent to which each dyad's technical flow (or interdependence) is aligned with that same connection's ability to function as both a customer and supplier within the system.

In a simplified case of the admitted medical patient flow example, gaps between the technical flow of a patient and communication between the various internal customers and suppliers are calculated by aligning the two networks as shown in Figure 7. The links, referred to as dyads, in the technical flow network are assigned weights based on the percentage of patient specimens that travel along a given path. For example, if 90% of all patients travel between Radiology and the ED, the dyad connecting these two areas is given a weight of .90. Since a patient may come and go from a given unit several times, the outgoing flow weights can exceed 1.0.

The links regarding technical communication form the safety control network, which can be based on survey responses to the clarity of customer requirements and feedback/problem resolution. If all the employees in Radiology agree that there is complete clarity in the Emergency Department's customer requirements and if all the employees within the Emergency Department agree that process deviations from Radiology are tracked and promptly resolved, this dyad in the safety control network would receive 100%, or 1.0.

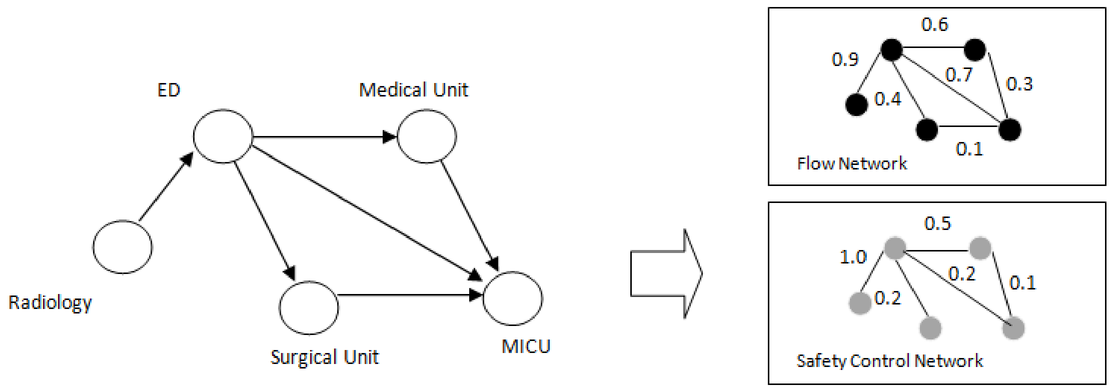


Figure 7: Detailed Analytic Alignment

Once weights for all dyads in both the technical flow and safety control networks have been established, the coordination assessment for each unit can be calculated as described in Figure 8. The coordination assessment represents the extent to which the flow network is aligned with the safety control network for each node or unit within the system and is calculated by summing the product of all aligning technical flow and safety control dyads. Once all products are summed, the average is taken to represent each unit's ability to function as both a customer and supplier within the system. While the intent of the network alignment approach is to identify dyadic gaps between units, each unit must first understand the role it plays within the greater system. For example, as shown in Figure 7, the coordination assessment for the ED is the product of the weights in the technical flow network and the safety control network.

- This yields a coordination assessment for the ED as a customer of (0.9*1.0) = 0.9

- This yields a coordination assessment for the ED as a supplier of (0.6*0.5) + (0.7*0.2) + (0.4*0.2) = 0.3 + 0.14 + 0.08 = 0.52
- Therefore, the ability of the ED to function as both a customer and a supplier within the system is denoted by an overall coordination assessment of (0.9 + 0.52)/2 = 0.71

Since each unit will have varying degrees of technical flow into and out of their unit, there is not a baseline coordination assessment to denote either good or poor coordination within the system. Instead, the coordination assessment is a metric that is unique to each individual unit. Therefore, the coordination assessment should be continuously evaluated to identify opportunities for improvement. Once all units have their coordination assessments calculated, each unit can determine the weakest area of alignment within all of their connections. In the above example, at first glance it appears that coordination between the ED and the surgical units is lowest (a product of 0.08). When we look at the ideal for each connection though, the coordination between the ED and the MICU has the most opportunity for improvement (currently at 0.14 with an ideal potential score of 0.7). In this respect, the ability of the ED to function as a supplier to the MICU should be of high priority. By comparing the current state of coordination to the ideal, each unit can identify those connections that are most likely to either generate or miss errors as they propagate throughout the system. By continuously improving upon each unit's coordination assessment, the complex system can begin to tie error reduction efforts across the multiple interdependent, yet semiautonomous, units to enable system-wide improvement.

The Coordination Assessment

- *The Coordination Assessment* – a metric which measures the extent to which the technical flow network is aligned with the safety control network.

If we let W^F and W^S represent the technical flow network and safety control networks, respectively, where $W^K = [W_{ij}^K]$, and W_{ij}^K represents the weight of the link between nodes *i* and *j* in the directed network *k*,*k* = F, S. We then define:

- $F_{ij} = W_{ij}^F/(\sum_i W_{ij}^F)$ so that F_{ij} (and F_{ji}) represents the weight of interdependence (proportion of technical flow) between unit *i* and unit *j* (and *j* to *i*) in the technical flow network,
- $S_{ij} = W_{ij}^S$ as area *i*'s assessment of the clarity of j's requirements, and
- $S_{ji} = W_{ji}^S$ as area *i*'s assessment of problem resolution with *j*.

Finally, we define β_i as the Coordination Assessment (CA) for node (unit) *i* as:

- $\beta_i = (\sum_j (F_{ij}\, S_{ij}) + \sum_j (F_{ji}\, S_{ji}))/2$

Figure 8: Calculating the Coordination Assessment

Once each unit's gaps are identified, each unit should work with the appropriate adjacent unit to understand how and why they scored poorly on a certain aspect and strive to improve each aspect, one at a time, following the scientific method. This approach utilizes each unit's inherent modularity, or semiautonomous nature, to design, test, and improve upon the weaknesses identified within the greater system.

Visual Management Approach

The path to alignment between the complex technical flow and safety control network does not have to involve detailed, quantitative analysis. As previously mentioned, a major contribution of the VSM as a tool is the process of going where the work is being performed and physically seeing how value is created. It is through this process that waste becomes apparent.

Instead of assigning quantitative weights to the dyads in each network, a cross-functional team (composed of all the represented units in the two networks) can also assign qualitative weights such as low, medium, or high. In the case of the simplified admitted medical patient flow in Figure 7, Radiology would have high technical interdependence with the ED and strong safety control mechanisms (clarity of customer requirements and problem resolution with suppliers).

While determining the weights of technical interdependence may be more straight forward (based upon simple frequency of flow between units), agreeing upon the weights of the safety control network may be more difficult. In order to guide the team towards consensus on the effectiveness of communication across each connection, a simple set of questions can be developed by each team to determine each unit's ability to act as both a customer and supplier to all other adjacent units within the network. To be most effective, these questions should be tailored to the context of the work being performed, but a general set of questions to be answered by the appropriate parties relative to each unit may include:

Clarity of Customer Requirements (to be answered by the suppliers):

1. Is every member in our unit (on all shifts) aware of our customers' needs regarding accuracy and timeliness of service?
2. Are the customers' requirements documented and/or easy to locate?
3. Are the customers' requirements consistent across the individuals within their department?

Problem Resolution with Suppliers (to be answered by the customers):

1. Is there a clearly identifiable and available representative within the unit that any team member can contact in the event of an error or question?
2. Does the upstream (supplying) unit respond quickly and thoroughly to resolve potential issues and problem solve with the downstream (customer) unit?
3. Are process changes that will affect the product or service to the downstream unit communicated appropriately?

As the team identifies the most appropriate questions to ask of each customer and supplier relationship, the team can also lay the groundwork for evaluating the effectiveness of these relationships. For example, if a unit were to score well on only one question within each set, they would likely receive a low weight along that particular dyad in the safety control network.

Once the dyads are weighted, the group can begin to evaluate the difference between the current state and the ideal for each potential connection based on the qualitative assessments. As is the case for the detailed analytic approach, having each unit take responsibility for their weakest system connection will build upon the inherent modularity in these systems to ensure that those that do the value adding work are also those that design and improve the work locally.

DISCUSSION AND CONCLUSIONS

Complex systems such as healthcare have a vast array of loosely coupled yet interdependent units that must work together to provide timely and accurate care for each patient. The complexity inherent to these systems often engenders silos and fragmentation which can make coordination and system-wide improvement difficult. While loose coupling reduces coordination between units, it does not imply poor coordination. This work aims to answer the question, “How can complex systems tie error reduction efforts across interdependent, yet semiautonomous, units to enable system-wide improvement?” By taking cues from high reliability organizations and lean such as requisite variety and the ‘rules-in-use,’ the complex system can problem solve and continuously improve without making simplifying assumptions just to make an approach or tool fit.

Since each unit has multiple potential interdependencies, it is important to clearly identify each unit’s internal customers and suppliers. Each unit must also understand to whom they are a customer and/or a supplier. In order to define the current state and visualize these relationships, we extend the value stream map (VSM) to the complex system. The value stream map is a powerful tool for understanding the current state, identifying opportunities, and continuously improving towards an ideal, but it is rarely modified for use beyond linear, sequential processes. A modification to the traditional

VSM is presented to help healthcare practitioners improve problem solving, and ultimately reduce errors, beyond departmental boundaries in the complex, nonlinear value stream. While this approach can be adopted by other complex systems that struggle with problem solving and process improvement across non-linear and loosely coupled units, this work fundamentally presents the importance of establishing contextual needs when determining the appropriate approach to error reduction and process improvement. The Detailed Analytic Approach and the Visual Management Approach to managing the complex, nonlinear value stream each offer a method for identification of internal customer and supplier relationships with a gap between the current ability to coordinate and the ideal. Both approaches utilize the inherent semiautonomous nature, or modularity, of units to own and improve upon their weakest connections for greater fit within the organization. In doing so, the system can reap the benefits of both loose and tight coupling and can move error reduction efforts beyond departmental boundaries. It is through this process that the whole system reliability is improved.

The inherent modularity of complex systems can make coordination and system-wide improvement difficult. This work presented a methodology for analyzing the cross-unit connections, or dyads, that tie the system together. By utilizing either the Detailed Analytic or Visual Management Approach, practitioners can begin to understand the interconnectedness of operations. Additionally, these approaches will help to identify where problems, or gaps between the current state and the ideal, exist.

Identifying gaps is only the first step in tying patient safety efforts across the complex system. These gaps become the motivation for system-wide continuous improvement. The ability to improve those connections requires a new way of thinking about the way problems are identified and continuously improved across organizational boundaries. While this work presents methodologies to identify where gaps exist, in the next chapter we will better understand how cross-unit coordination, along with other organizational factors, influence safety culture and overall quality within a system. The role of leadership becomes vital to creating a culture where structured and frequent problem solving across organizational boundaries becomes habit. This is where system-wide improvement across the complex system becomes difficult.

CHAPTER III: CROSS-UNIT COORDINATION: METHODS AND IMPLICATIONS

INTRODUCTION

The modern integrated health system has a multitude of hospitals, offices, clinics, and departments that work together to provide comprehensive and seamless patient care (Plsek, 2000). The past two decades have seen an increase in the integrated nature of the U.S. health system (Crosson, 2009). While organizational and financial structures continue towards the integrated model, many fail to develop processes to link the components within the system (Burns & Pauly, 2002). While interdependent, many units within the integrated health system function with little control or refinement of the inputs and outputs to each unit. Instead, patient care is often focused within the boundaries of a singular unit (de Souza & Pidd, 2009; Hillman, Braithwaite, & Chen, 2011). While formally organized within an integrated model, the coordination between components is often unchanged. This lack of coordination between units can be referred to as gaps in patient care (Cook et al., 2000).

There is little research on the identification of organizational gaps between units and the gaps' impact on patient safety. Instead, previous literature has focused on ways to bridge all connections through standardized handoffs under the assumption that gaps in care influence safety (Haig, Sutton, & Whittington, 2006; Manser, Foster, Gisin, Jaeckel,

& Ummenhofer, 2010). While leaders may strive to achieve local-level goals, efforts are largely focused within their span-of-control. These silo improvement efforts are therefore rarely capable of achieving widespread improvement.

In contrast to previous literature, in this paper we direct our attention to the strategic identification of gaps across organizational boundaries. In this study we test the impact that gaps in cross-unit coordination have the unit's safety culture, or the attitudes, beliefs, perceptions, and values that employees share in relation to safety. We study cross-unit coordination in detail by investigating the transfer of patient specimens and information across several laboratory units within a large, academic health system. Associations found between cross-unit coordination and safety culture, quality, and process improvement support the ongoing identification of gaps for system-wide improvement.

This chapter contributes to the research body concerned with patient safety and process improvement in large, complex systems such as healthcare by (1) establishing the importance of cross-unit coordination and its role in systemic improvement, (2) forwarding the coordination assessment as a metric for gap identification, and (3) emphasizing the importance of problem solving across organizational boundaries for increased patient safety. The findings of this work suggest that clearly defined customer (downstream unit) expectations are significantly associated with safety culture, which in turn is significantly correlated to perceptions of quality. This work also suggests that the ability to problem solve across organizational boundaries has potentially important implications for patient safety but does not appear to be practiced widely or consistently within the complex health system.

The remainder of this paper is organized as follows. In the next section, we review the literature on safety culture, organizational boundaries, and process improvement. We also review the methods forwarded in the previous paper for gap identification. In section three we develop our hypotheses, and in section four we discuss the industry setting, data, and methods utilized to test the hypotheses. Section five presents the results, and section six concludes the paper with a discussion of the implication for research and management.

THEORETICAL BACKGROUND

Complex organizations have a vast network of interdependent departments and people that work together to provide a product or service to the customer. In the case of healthcare, each patient has unique needs. Each patient's unique needs may require the expertise of several teams of care givers. The multidisciplinary nature of healthcare often requires coordination between several departments or individuals to both diagnose and treat the patient. The connections between units may be utilized to physically transfer a patient or their specimen. In addition to the physical transfer of the patient or their lab work, cross-unit connections are also extremely valuable in knowledge transfer. This work examines if and how the coordinated strength of a cross-unit connection impacts safety culture, and ultimately system-wide quality.

Safety Culture

The concept of safety culture and its implications on quality and patient safety have been a focus within the patient safety literature (Shojania, Duncan, McDonald, Wachter, & Markowitz, 2001; Nieva & Sorra, 2003; Singer, Gaba, Geppert, Sinaiko, Howard, & Park, 2003). The concept of safety culture originated after the 1986 Chernobyl disaster (Pidgeon, 1991). The post-accident review used the term to describe the characteristics and attitudes within the organization that are required to give potentially disastrous safety issues the attention they deserve. The term safety culture has since been utilized in several high reliability organizations to understand and analyze organizational safety beliefs, values, and attitudes of groups and/or individuals.

Research surrounding safety culture has grown in the past decade, especially within healthcare (Colla, Bracken, Kinney, & Weeks, 2005). The Agency for Healthcare Research and Quality (AHRQ) outlines the key components to a culture of safety by acknowledgement of the high-risk nature of the work and a commitment to safety, a blame-free environment where individuals can openly report errors or near-misses, collaboration across ranks and disciplines to resolve patient safety problems, and an organizational commitment to address safety concerns. To measure the safety culture, the AHRQ provides validated surveys for various provider levels and departments within healthcare. These surveys have been widely utilized to monitor and improve the safety culture within healthcare (Nieva & Sorra, 2003; Singla, Kitch, Weissman, & Campbell, 2006).

Pidgeon and O'Leary suggest four factors that support a 'good' safety culture (Pidgeon & O'Leary, 1994). These factors include senior management commitment to safety, shared care and concern for hazards and their impacts, realistic and flexible norms and rules about hazards, and continual reflection upon practice through monitoring, analysis, and feedback systems (organizational learning). The last factor suggests that as problem solving improves, the organization learns and the safety culture improves. Due to the organic nature of these factors, the safety culture of an organization evolves over time and develops as a result of history, environment, health and safety practices, and leadership (Reason, 1998).

There is little debate over the importance of safety culture and the impact the concept has on adverse events within organizations (Yule, 2003; Vogus & Sutcliffe, 2007). While the importance of safety culture is not debated, few authors have gone beyond face validity and supported their claims by reporting predictive validity (Guldenmund, 2000). Furthermore, there is a need to refine the concept and create a better understanding of organizational contributors to safety culture that will become a basis for culture-enhancing practices (Reason, 1998).

Organizational Boundaries and Patient Safety

Cross-unit gaps are one factor discussed in the literature that is often associated with patient safety (Cook et al., 2000; Nemeth, Hollnagel, & Dekker, 2009). Gaps that occur across organizational boundaries can be defined as system discontinuities. Cook, Render, and Woods (2000) note that the opportunity for failures as a result of gaps is large, but the incidence of failure is low due to the ability of practitioners to identify and bridge gaps. Similarly, Tushman noted the importance of subunit communication on the organization's ability to deal with uncertainty (Tushman, 1979). To address the issue of coordination across organizational boundaries, several researchers have focused attention on taxonomies of coordination (Adler, 1995), how organizational structure impacts communication across organizational boundaries, and aspects of successful coordination (Heath & Staudenmayer, 2000).

The cross-unit transfer of the patient and their information is commonly referred to as a ‘hand off’ in healthcare. The passing of information between units is an area of focus in healthcare and patient safety research. A spike in this research occurred in 2007, shortly after the Joint Commission published a new requirement in their 2006 National Patient Safety Goals. The 2006 requirement reads: “Implement a standard approach to ‘hand off’ communications, including an opportunity to ask and respond to questions.” The justification for this new requirement was included in the following 2008 Joint Commission handbook: “The primary objective of a ‘hand off’ is to provide accurate information about a [patient’s] care, treatment, and services, current condition and any recent or anticipated changes. The information communicated during a hand off must be accurate in order to meet [patient] safety goals.”

Petersen et al (Petersen, Brennan, O'Neil, Cook, & Lee, 1994) showed the impact of physician cross-coverage, or the transfer of care to a physician outside the patient’s assigned care team, with an increased incidence of preventable adverse events. The study, though, was focused on cross-coverage and not the exchange of information or “handoff.” In a retrospective study of adverse events and their “root causes” the Joint Commission identified “communication problems” as the leading cause of sentinel events in all categories in 2005. Handoffs happen frequently throughout a patient’s care (Dracup & Morris, 2008) and are a critical channel in the exchange of patient information. It is therefore reasonable to assume that they are also a critical point for loss of information and risk to patient safety. While there are a number of articles that assume an association between “hand offs” and patient safety, there are few empirical studies which support this assumption (Riesenberg, Leitzsch, Massucci, Jaeger, Rosenfeld, Patow, Padmore, & Karpovich, 2009; Cohen & Hilligoss, 2010; Patterson & Wears, 2010; Riesenberg, Leisch, & Cunningham, 2010).

Hand off is not the only term associated with the transfer of knowledge, patient care, and lab work. 'Hand over,' 'nursing report,' 'report,' and 'sign-out' are other terms commonly used in various healthcare settings. These terms are often used in slightly different contexts, "such as 'sign-out' with its suggestion of a temporary delegation of formal authority for decisions and of legal responsibility for consequences, as might occur at a shift change to overnight care" (Cohen & Hilligoss, 2010). The transfer of knowledge that is required at sign-out is similar to the communication required when a patient or their lab work is physically moved to a new department within the system. While the terms are similar, there are distinct challenges that arise in coordinating patient care across organizational boundaries.

The Joint Commission defines the objective of a 'hand off' around the transfer of accurate patient information. In this work, we are not only concerned with the transfer of information but with the ability of organizations to tie process improvements across units for system-wide improvement in patient safety. Therefore, we focus on the ability of interdependent units to problem solve and improve. Because this work investigates the ability of interdependent units to coordinate across organizational boundaries, we forward the term 'cross-unit coordination' to focus the discussion. While the term cross-unit coordination has been utilized by organizational theorists to describe lateral coordination across organizational boundaries (Daft, 2004) it has not been formally defined. Therefore, we define 'cross-unit coordination' as the ability to effectively communicate and problem solve across an organizational boundary between one sending (upstream) unit and one receiving (downstream) unit. By refining the scope of the ‘hand off’ discussion common to healthcare literature, this paper establishes a new focus on cross-unit coordination and investigates its impact on safety culture, and ultimately patient safety.

Problem Solving across Organizational Boundaries

Cross-unit coordination is a concept that applies when two distinct and interdependent units coordinate to provide a product or service. This separation and coordination is often referred to as modularity in organizational design (Ro, Liker, & Fixson, 2007). Modularity is a general set of principles utilized to manage complexity within any type of system. By breaking up a complex system into manageable components, an organization can increase both flexibility and expertise (Sanchez, 1996; Baldwin & Clark, 2000; Langlois, 2002). Certain organizations choose to become more or less modular, while others are naturally organized in interdependent groups due to inherent complexity and specialization. While there are many benefits to the move towards modularization, there are also potential disadvantages to this type of organizational design. Modularity may require independence and “loose coupling” between units, and may not be effective when there is either tight coupling or interactive complexity (Bierly, Gallagher, & Spender, 2008). This independence can inhibit problem solving efforts when work is dispersed across organizational boundaries (Gomes & Joglekar, 2008).

Problem solving between units enables coordination necessary to identify errors and establish processes that prevent future errors. In order for the organization to collectively learn, its members must learn to become something larger than the individual or subunit, connecting to one another in ways that create new meaning and system-wide improvement (Senge, 1993).

Several researchers highlight the importance of lateral coordination and communication across the organization. Womack, Jones, and Roos highlight the importance of clear communication and expectations between upstream and downstream units in improving the value stream, or all the actions needed to bring a product to a customer (Womack et al., 1991). In research in complex organizations, Spear identifies gaps between units and workarounds that are created in the absence of problem solving (Spear & Schmidhofer, 2005). What sets the operations of organizations like Toyota and others apart, is the way they couple the process of doing work with the process of learning to do it better as its being done (Spear, 2005). This aspect of Toyota is an integrated part of the culture that both fosters process improvement and is a result of process improvement. A culture of continuous improvement is the differentiating factor between organizations that implement process improvement tools superficially and those that continuously identify problems, create countermeasures, test, and adjust the process until goals are achieved (Liker & Franz, 2011). Spear highlighted Toyota's unique ability to utilize connections across the organization for problem solving and continuous improvement to enable true system-wide improvement. (Spear, 1999).

The Coordination Assessment

The previous paper forwarded the concept of the Network Alignment Approach as a method to visually map the connectedness of units in a complex system and identify the gaps that may prevent system-wide improvement. There are two methods practitioners can utilize to identify organizational gaps. The first method, the Detailed

Analytic Approach, is more quantitative in nature and requires volume and survey data to assess the existence and severity of gaps between interdependent units within a system. The second method, The Visual Management Approach, is targeted towards team-based exercises between multidisciplinary leaders and team members to identify areas for opportunity. Since this work is focused on understanding the implications of cross-unit coordination on patient safety and system-wide improvement, we utilize the Detailed Analytic Approach to empirically test our hypotheses.

In order to quantitatively assess cross-unit coordination, the network of interdependencies must first be mapped to display all the potential connections between units required to deliver a product or service to the customer. The network diagram is then duplicated to depict two aspects of the system. In one network, the technical coupling is depicted by assigning weights to the connections, or dyads, between units based upon the volume of work that is passed from one unit to another. This network is referred to as the Technical Flow Network. In the second network, coordination is assessed along each connection, or dyad, based upon the units' ability to clearly define downstream requirements and problem solve upstream when deviations occur. The ability of the two units to coordinate can be determined through survey data. The network is referred to as the Safety Control Network and the weights assigned to each connection represent the extent to which there is explicit communication about downstream requirements and problem solving with upstream suppliers.

Within the Detailed Analytic Approach, the Coordination Assessment is forwarded as a metric which represents the extent to which the Technical Flow Network is aligned with the Safety Control Network within a system (see Figure 8 in Chapter 2).

In other words, one would expect that units that are tightly coupled within a system have clear process standards and are able to problem solve when deviations occur. Conversely, if two units are tightly coupled but cross-unit coordination is weak, then those connections would instead be considered gaps and become a focus for process improvement and patient safety efforts. The Coordination Assessment therefore becomes a metric to quantitatively assess the effectiveness of cross-unit coordination between two interdependent, yet semiautonomous units.

HYPOTHESES DEVELOPMENT

The Network Alignment approach provides a methodology to proactively identify gaps across complex systems. In addition to cross-unit gaps, process improvement efforts, error tracking, and clearly documented processes all have the potential to impact a system's safety culture. All else being equal, a strong safety culture, where team members proactively identify and solve problems, should contribute to improved quality across the system. In this section we formulate hypotheses on how several factors might influence safety culture, and in turn, how that safety culture impacts quality.

Cross-Unit Coordination

Several studies have suggested underlying factors or components of safety culture. Two common factors found within this body of research include the proactive identification and resolution of problems as well as leadership commitment to safety. In this study, we focus closely on one important aspect of safety culture: continual reflection upon practice through monitoring, analysis, and feedback systems (Pidgeon, 1991).

Since this study is focused on cross-unit coordination and system-wide improvement, we focus on the reflection of practice across organizational boundaries. Since the ability to identify and resolve problems has been a focal point within the safety culture literature, one could suspect that the ability to problem solve and improve processes between interdependent units, or strength of cross-unit coordination, will improve the overall safety culture of these units which leads us to our first hypothesis: *Cross-unit coordination, as measured by the Coordination Assessment, is positively associated with safety culture.* More specifically, when we consider the Coordination Assessment as being comprised of two components, we formulate two hypotheses:

H1a: Problem Solving with Suppliers is positively associated with safety culture.

H1b: Clarity of Customer Requirements is positively associated with safety culture.

Process Improvement Efforts

Spear (Spear, 1999) highlighted Toyota's unique ability to utilize clear request and response channels across organizational boundaries to quickly identify deviations and problem solve. When improvements across connections span multiple units or departments, localized improvement efforts evolve into system-wide organizational improvement. While process improvement efforts and safety culture theoretically appear to have a cyclical relationship (improvement efforts create a stronger safety culture and vice versa), we specifically test the former hypothesis which suggests that units that place greater value on process improvement will also have a stronger safety culture. One could expect that as problem identification and problem-solving efforts become engrained into the culture, team members will feel more comfortable and confident in the proactive identification of potentially harmful errors. This leads to our second hypothesis:

H2: The strength of process improvement efforts is positively associated with safety culture.

Error Documentation

The under reporting of medical errors, adverse events, and near misses has been an issue in healthcare for as long as errors have been tracked. The reasons for underreporting include loss of reputation, fear of losing their job, loss of market share, loss of accreditation, and liability concerns (Dragseth, 2001). Since we focus on organizational contributors to safety culture, we hypothesize that departments or units that report errors openly and without blame as a part of daily operations would also have a stronger safety culture:

H3: Error documentation is positively associated with safety culture.

Standard Work

While problem solving is an inherently flexible and adaptive task, it is also most effective when there are clear and visible process expectations. These standards allow for deviations from the process, and likely errors, to become increasingly salient. By establishing clear and visible guidelines for a process, deviations from the standard should be identified more easily and openly within a unit.

H4: Availability of standard work is positively associated with safety culture.

Safety Culture and Quality

A strong safety culture is often assessed by the extent of a blame-free environment where team members are able to report errors or near misses without fear of reprimand or punishment. An underlying assumption made within the safety culture literature is that if the safety culture improves, errors will be identified, the organizational will learn from the errors, which will enable prevention against future errors. As team members become more informed about the numerous factors that have an impact on safety systems, safety culture will improve and become the "engine that drives the system towards the goal of sustaining the maximum resistance towards its operational hazards" (Reason, 1998). Thus, we hypothesize that as safety culture improves, quality also improves:

H5: Safety culture is positively associated with quality.

DATA AND METHODS

We explore the above formulated hypotheses in the context of a laboratory setting in a large, academic health system. In the following section we describe the processes and interdependent units that comprise the case setting as well as the data and methods utilized to test our hypotheses.

Industry Setting: Anatomic Pathology

Anatomic Pathology is the study of structural changes that occur in organs and tissues as a result of disease. There are several areas of specialization within Anatomic Pathology. While some are more common than others, large, academic health systems often have representation and expertise in each of these specialties which offer a larger array of studies that can be utilized to diagnose disease. As a result, these larger health systems often provide consultations to patients with primary care in other, smaller health systems. While Anatomic Pathology specialties are not necessarily different units, they often require different processing techniques which are often organized as separate units within Anatomic Pathology. Given the complexity of the diagnosis process, patient specimens can be routed and re-routed between processing units at the pathologists' discretion. The following section describes the case of one Anatomic Pathology department.

The department of Anatomic Pathology (AP) at one large, academic health system receives anywhere from 300 to 1,000 patient tissue samples to be processed daily to test for a variety of cancers. This AP department houses over eight smaller processing laboratories which interact with technicians, pathologists, the hospital, and each other on a daily basis. In total, the case under analysis is comprised of 18 interdependent, yet semiautonomous units within the overarching Anatomic Pathology system. The individual labs within Anatomic Pathology are dependent on one another for processing and evaluating tissue samples. Both the physical sample and patient paperwork travel between labs within AP. While many of the labs are dependent on one another, there few standards conveying expectations about how or when patient samples and paperwork should arrive.

This research began by observing all of the possible specimen flow paths within the Anatomic Pathology department. Specimens, in the form of tissue samples, can originate within the overarching health system (i.e. within operating room), in client hospitals (the health system under study is comprised of 3 main hospitals, 40 health centers, and 120 outpatient clinics), or at an outpatient clinical laboratory. From their point of origin, specimens can be sent directly to the dermatopathology suite, faculty suites (primarily for consultations), the main hospital mail room, central distribution, or surgical pathology accessioning. A lack of a standard submittal process and variability in specimen needs results in variability in specimen arrival to the department.

Once patient specimens are accessioned into the information system, they are sent to a grossing station depending on how the specimen is categorized (breast, dermatopathology, endocrine, gastrointestinal, head and neck, neuropathology, renal, and ophthalmic pathology). The technician (pathologist, pathologists' assistant, or resident) grosses the tissue by visually inspecting the sample and dictating diagnostic information into the medical record system. Once the specimen is grossed, the grossing technician places sections of the tissue sample into plastic blocks. The blocks of tissue are then sent to the histology lab to be chemically treated, embedded in paraffin, and cut into thin layers which are placed onto a glass microscope slide. There may be as few as one or as many as fifty slides containing cross-sections from one tissue sample. These slides can be sent directly to a pathologist or to one or more of the other processing labs (Immunohistochemistry "IPOX," Cytopathology, Special Stains, Clinical Pathology "CP," Autopsy, Hematopathology, and Electron Microscopy). These labs provide a number of different diagnostic tests for different variants of cancer and non-cancerous diseases.

Since dozens of slides can be cut from one tissue sample, a pathologist can call for several different processes. Each stain (technique utilized to highlight various aspects of the tissue) or process is then performed on a different microscope slide to be examined by the pathologist. These tests can be requested prior to accessioning or in response to questions raised by the pathologist during processing. This aspect of clinical testing adds to the overall complexity of the system by introducing non-linear flow paths. A visual example of all the potential specimen flow paths can be seen in Figure 9. Each unit, or node, is color coded based upon its overall function within the Anatomic Pathology system. Green nodes represent a point of origin into the system, dark blue nodes sort and register specimens, light blue nodes cut and modify the tissue for examination, black nodes represent units that process the tissue within Anatomic Pathology, red nodes represent units that process the tissue within Clinical Pathology, and purple represent diagnosis and storage units. This diagram highlights the vast number of path permutations and interdependencies found within an Anatomic Pathology department.

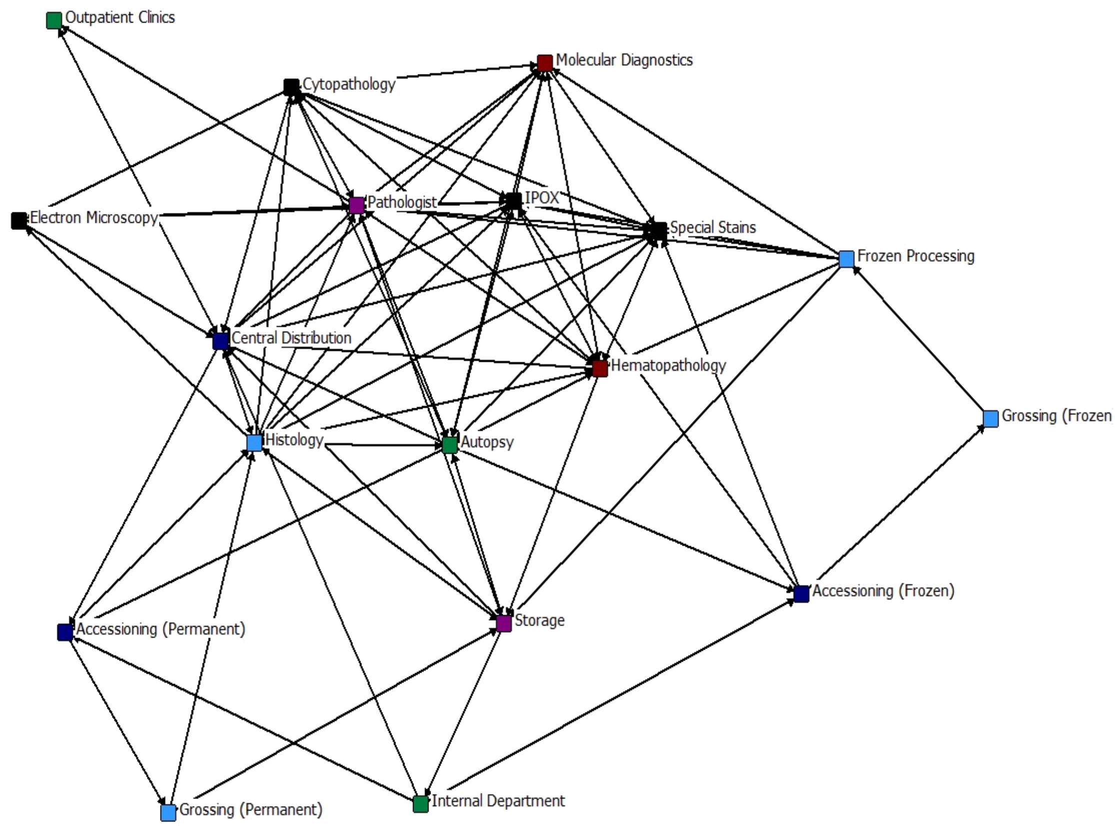


Figure 9: Anatomic Pathology Flow Network

This research will focus on how cross-unit coordination between the internal units impacts the overall safety culture within the Anatomic Pathology system. Furthermore, we investigate how additional factors contribute to safety culture and if safety culture, or other organizational factors, impact quality within the lab. This approach will attempt to understand the extent to which direct, clearly defined, overlapping request and response channels between units reduces the risk that the pathologist receives a slide that misrepresents the sampled tissue, misrepresents the patient, or is not prepared according to industry standards. Additionally, this work demonstrates how this coordination can impact the ability of a system to identify and solve problems for improved patient safety.

Unit of Analysis

While we are primarily interested in understanding the implications of cross-unit coordination in improving system-wide patient safety, our study utilizes individual perceptions of quality, safety culture, and engagement in process improvement efforts. Therefore, our unit of analysis is the individual team member who is located in one of the units, or nodes, within the system. Since we place an emphasis on cross-unit coordination, the team member also assesses the alignment of specimen flow and coordination between all upstream and downstream units. While team member assessments within units may vary, this approach utilizes a consistent unit of analysis and helps us to avoid both ecological and exception errors in reasoning. In other words, we respectively avoid generalizations about certain units based upon averages and we also avoid conclusions about a particular unit based upon a particular individual. Instead, we are able to understand how perceptions of connectedness and coordination are associated with safety culture.

Methodology

This work will utilize an embedded, case study design that incorporates statistical surveys to empirically test our hypotheses as well as open-ended questions and direct observations to provide context to the quantitative analysis. Triangulation of the data through case study provides a more holistic understanding of the results (Jick, 1979). The case study is an appropriate method for understanding the complex, health care system (Yin, 1999). This is in large part because the case study is best utilized in "situations where the number of variables far outstrip the number of data points" (Yin, 1994). Furthermore, by using multiple sources of evidence the complexity of the case will be addressed by the collection of converging evidence that triangulates over a given fact or hypothesis.

Variable Operationalization

Prior to the start of the study, the following variables were expressly defined along with the method utilized for data collection. These variables and methods comprise the basis for quantitative evaluation of the proposed hypotheses.

We first utilize cross-unit coordination to analyze the ability of interdependent units to clearly define expectations and problem solve when deviations arise. We utilize the *Coordination Assessment*, as previously described, as our metric for cross-unit coordination. Since our unit of analysis is the individual, we assess both upstream and downstream flow and coordination from each participant's perspective. The first step in this process is to identify all interdependent units that may send or receive a product or information. The interdependencies in this study were evaluated in advance of the data collection and are shown in Figure 9.

To evaluate the *Coordination Assessment* at the individual level, each participant was asked a series of survey questions that were tailored to the unit in which they work. For example, if a participant worked in the Accessioning area within Anatomic Pathology, we tailored the survey to generate questions regarding technical volume (see Appendix A and Table 1) and coordination between all of Accessioning's interdependent units. First, the participant was asked to estimate the percentage of specimens received from all sending units. The technical volume, or coupling between units, is then multiplied by the participant's perceived ability to problem solve with the upstream supplier. All of the upstream connections are added for a total measure of *Problem Solving with Suppliers*.

Next, the participant was asked to estimate the percentage of specimens sent to all downstream units. The participant was also asked about the perceived ability of these downstream units to clearly define and communicate process expectations. The technical volume along each dyad was then multiplied by the participant's perceived ability to establish and understand the customer's requirements. All of the downstream connections are added for a total measure of *Clarity of Customer Requirements*.

This overall approach measures the alignment between technical flow and cross-unit coordination and relies on individual perceptions to quantify the connections, or dyads, shown below. This approach places greater weight on coordination across organizational boundaries that have tighter coupling within the system. To assess overall coordination, weighted by interdependence, the *Coordination Assessment* is calculated by averaging the measures of *Problem Solving with Suppliers* and *Clarity of Customer Requirements*. This metric represents the perceived ability of each unit in the system to clearly communicate and problem solve with other units as they send and receive specimens (calculations shown in Figure 8 and visual representation shown in Figure 10).

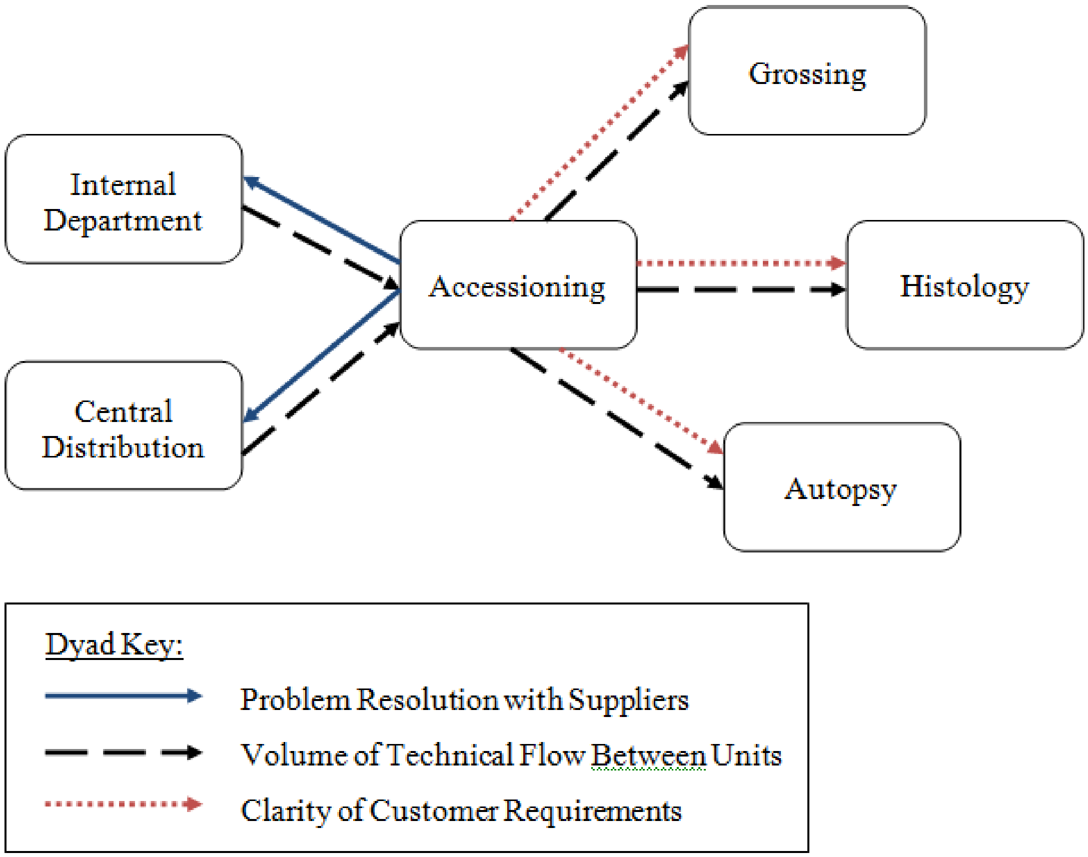


Figure 10: Coordination Assessment Example in AP

While the questions regarding volume and coordination were asked with respect to all interdependent units, we also asked some basic documentation questions to gauge if errors received from any sending units are documented, noted as the variable *Errors Documented*. Furthermore, we attempt to understand if the downstream unit's requirements are documented and easily accessible, which is noted as the variable *Standard Work Easily Accessible*. These questions (Table 2) were included since they may potentially impact the ability of a given unit to coordinate with upstream and downstream units, but they are not necessarily specific to each sending or receiving unit.

Safety culture and quality are assessed by the individual participant through survey. The safety culture represents the beliefs, attitudes, and values team members share about patient safety within the workplace. Safety culture in our study is assessed upon a few common, validated questions within the Safety Attitudes Questionnaire. These questions focus on team member training, comfort with problem identification and leadership commitment to safety (Table 4) and are identified as the variable *Total Safety Culture Assessment*.

Quality, while best defined by the stakeholder, is generally a measure of excellence or a state of being free from defects or significant variations (Harvey & Green, 1993). In healthcare, patient safety refers to the prevention of medical error that leads to adverse healthcare events (Shojania et al., 2001). The Institute of Medicine (IOM) considers patient safety "indistinguishable from the delivery of healthcare." Therefore, the term *quality* in this study is used interchangeably with patient safety and is primarily measured by the participant's perception of frequency of errors in information and/or specimen preparation (Table 3). This variable is noted as *Frequency of Errors*.

Finally, process improvement (PI) efforts are assumed to be an independent variable which directly impacts safety culture. Process improvement efforts in this study are defined as the engagement of team members in problem solving within the work unit. While the effectiveness of these efforts can vary greatly, the involvement of front-line team members in problem identification and problem solving is considered, for purposes of this study, to be an important and significant indicator of process improvement. This variable is assessed by the individual and is based upon team member involvement in problem solving efforts (Table 5) and is referred to as *Strength of PI Initiative*.

Table 1: Summary of Supplier and Customer-Specific Questions

		Questionnaire Item	Scale (5 point)
Supplier and Customer Specific Questions	**Problem Solving with Suppliers**	If I receive an error** from each of the following areas, I would know whom to contact to resolve the issue, how to contact them, and I would expect an immediate response. (**e.g. paperwork and label discrepancy, incomplete patient information, missing specimen, poor specimen preparation, etc.)	1 = Strongly Agree to 5 = Strongly Disagree
	Clarity of Customer Requirements	I have access to information** that states exactly how a specimen should be prepared for each of the following areas. (** e.g. Labeling requirements, required nuclear detail, label placement, how and when to transport, etc.)	1 = Strongly Agree to 5 = Strongly Disagree
	Clarity of Customer Requirements	My area has open and effective communication with each of area below regarding how a specimen should be prepared and when it should arrive.	1 = Strongly Agree to 5 = Strongly Disagree

Table 2: Summary of Non Unit-Specific Questions

		Questionnaire Item	Scale (5 point)
Documentation and Standardization	**Errors Documented**	Errors that are passed to my area are carefully documented so that there is a clear record of where the error originated, type of error, and whether or not it was resolved.	1 = Strongly Agree to 5 = Strongly Disagree
	Standard Work Easily Accessible	Documentation stating how to prepare a specimen is easy to locate.** (**e.g. Visible from your workstation or immediately accessible within your workstation.	1 = Strongly Agree to 5 = Strongly Disagree

Table 3: Summary of Quality Questions

		Questionnaire Item	Scale (5-6 point)
Quality	**Error Frequency**	I receive a specimen that has incomplete or incorrect paperwork or labeling with the following frequency:	Once Per: 1 = Hour, 2 = Day, 3 = Week, 4 = Month, 5 = Year, 6 = Never
		I receive a specimen that is prepared incorrectly with the following frequency:	1 = Very Likely to 5 = Very Unlikely

Table 4: Summary of Safety Culture Questions

	Questionnaire Item		Scale (5 point)
Safety Culture	**Provided Necessary Information**	I am consistently provided with all the necessary information to perform my job.	1 = Strongly Agree to 5 = Strongly Disagree
	Encouraged to Report Safety Concerns	I am encouraged by management to report any patient safety concerns I may have.	1 = Strongly Agree to 5 = Strongly Disagree
	Difficulty Asking Questions	It is difficult for employees to ask questions when there is something that they do not understand.	1 = Strongly Agree to 5 = Strongly Disagree
	Safety Concerns Given Immediate Attention	Every safety concern is given immediate attention.	1 = Strongly Agree to 5 = Strongly Disagree

Table 5: Summary of Process Improvement Questions

	Questionnaire Item		Scale (5 point)
Process Improvement Efforts	**Employee Involvement**	Involving everyone in continuous improvement is a priority within our workplace.	1 = Strongly Agree to 5 = Strongly Disagree
	I Have Been Actively Involved	I have played an important role on a team whose goal is to improve our process.	1 = Strongly Agree to 5 = Strongly Disagree

Surveys were distributed to all team members working within the Anatomic Pathology department. While perceptions of units generating and sending specimens were evaluated from a problem solving perspective, these individuals were not included within the survey. In total, surveys were sent to 249 technicians, residents, and pathologists located within 16 separate units within Anatomic Pathology. We received a total of 96 responses for a 39% response rate.

In addition to quantitative survey data, qualitative data was also collected to provide greater insight on the implications of cross-unit coordination across organizational boundaries. To provide this context, direct observation was utilized by the researcher to gather information about the networks within Anatomic Pathology. Furthermore, open-ended questions were included in the survey (Appendix A). Triangulation of the data using the aforementioned methods will deepen our ability to understand associations between cross-unit coordination, process improvement efforts, safety culture, and quality.

RESULTS

We organize the results in the following sections around the aforementioned hypotheses. We first present the quantitative results and follow with qualitative observations and comments.

Quantitative Results

The descriptive statistics and correlations for the variables in the study are presented in Table 6. As shown in Table 6, there are significant correlations among all variables and safety culture, with the exception of problem solving with suppliers. The rest of the positive correlations stress the importance of estimating the direct effects of organization factors (problem solving with suppliers, clarity of customer requirements, error documentation, availability of standard work, and process improvement efforts) on safety culture.

Table 7 presents the results of the regression analysis. Model 1 shows the effect of several organizational factors on safety culture. The model explains about a third (29.5%) of the variation in our sample and the p-value of the F test indicates a good model fit.

Table 6: Correlations

CORRELATIONS, MEANS, AND STANDARD DEVIATIONS FOR VARIABLES IN THE STUDY

		1	2	3	4	5	6	7	8
1	Coordination Assessment								
2	Problem Solving with Suppliers	0.848 0.000 96							
3	Clarity of Customer Requirements	0.837 0.000 96	0.458 0.000 96						
4	Errors Documented	0.134 0.226 96	0.095 0.394 96	0.135 0.225 96					
5	Standard Work Easily Accessible	0.403 ***0.000 96	0.261 *0.017 96	0.429 ***0.000 96	0.249 *0.023 96				
6	Total Frequency of Errors	-0.148 0.180 96	-0.047 0.674 96	-0.208 0.059 98	-0.014 0.901 96	-0.037 0.740 96			
7	Total Safety Culture Assessment	0.357 ***0.001 96	0.175 0.113 96	0.437 ***0.000 96	0.240 *0.029 96	0.239 *0.030 96	-0.301 **0.006 96		
8	Strength of PI Initiative	0.171 0.122 96	0.101 0.364 96	0.192 0.081 96	0.404 ***0.000 96	0.309 **0.005 96	-0.056 0.616 96	0.455 ***0.000 96	
Mean		1.989	1.856	2.122	2.510	2.698	7.000	2.182	2.203
Standard Deviation		0.569	0.686	0.664	1.076	1.162	2.031	0.625	0.773

– Pearson Correlation — *p < 0.05

– P-value — **p < 0.01

– N — *** p < 0.001

Table 7: Regression Results

REGRESSION RESULTS OF DIRECT EFFECTS			
	Variable	*Model 1* Safety Culture	*Model 2* Quality
1	Problem Solving with Suppliers	-0.0325	0.1336
2	Clarity of Customer Requirements	0.3675***	-0.4136
3	Errors Documented	0.0295	0.0565
4	Standard Work Easily Accessible	-0.0272	0.0909
5	Strength of PI Initiative	0.3093***	0.2013
6	Total Safety Culture Assessment		-0.9826**
	Adjusted R^2	29.5%	4.1%
	F	7.86***	1.58

Standardized regression coefficients
* p < 0.05
**p < 0.01
***p < 0.001

Table 7 also contains the coefficient estimates of the regression. Two variables have coefficients significant at the 0.1% level, clarity of customer requirements and strength of process improvement initiative. These results support hypotheses 1b and 2. While two variables, errors documented and standard work easily accessible, fall just outside 5% significance level, the values are insufficient to support hypotheses 3 and 4. Problem solving with suppliers is not close to being significant and the coefficient shows a negative sign, indicating that safety culture is weakened with active problem solving.

This result disconfirms our hypothesis 1a. We will return to a possible explanation for this result in the discussion section.

To test for the influence of safety culture, and other organizational factors, on quality, we reran the regression including safety culture. In this regression, Model 2 in Table 7, the dependent variable is quality. The model is a poor fit, explaining only 4% of the variation in our sample. While five of six variables are insignificant, safety culture is significant at the 1% level, which supports hypothesis 5. We know that all the other variables, except problem solving with suppliers, are associated with safety culture. These insignificant variables likely become intervening variables in the model and show their impact on quality through the safety culture variable. While safety culture is significantly associated with quality in this study, the overall model is not significant. While the model is likely lacking important variables, we explore other explanations for the poor model fit in the discussion section.

Qualitative Feedback

Table 8 highlights responses to the open-ended questions in the survey. Open-ended feedback was not required, but at least one open-ended response was received in 81% of the surveys. While all responses were not included, feedback from each unit was reviewed for common themes and the more common responses per unit were included in Table 8. Question numbers refer to the open-ended questions listed in Appendix A.

What is striking about the qualitative feedback is the difference in responses between units, particularly in the case of Cytopathology. Cytopathology had separately been working on a number of process improvement efforts. There were a total of ten responses from the Cytopathology group and they, on average, responded with a $\mu=1.38$

($\sigma = 0.42$) score for *Strength of PI Effort* (on the 5-point Likert scale noted in Table 5). This is compared to the remainder of the responses ($n = 86$) which responded with a $\mu=2.29$ ($\sigma = 0.75$) score for *Strength of PI Effort*.

For example, in response to the question "Does Error Documentation Prevent Future Errors?" a team member in Cytology noted the following: "*Sometimes. It depends on the type of error and if solutions are able to be implemented by staff within Cytopathology. [I] don't feel able to affect changes outside Cytopathology*." The following comments were also made by Cytopathology participants: "*We are using lean methods to determine root cause and take action to prevent in future*," and "*Standardizing work flow will eliminate errors*." This type of qualitative feedback provides insights beyond quantitative survey responses and helps us to make sense of the data and results in a more meaningful way. By examining the open ended responses, we can begin to understand the variability in problem solving ability, clarity of customer requirements, process improvement efforts, and safety culture throughout the Anatomic Pathology department.

Table 8: Open-Ended Question Responses

Question	Unit (Node)	Response
#5	Cyto-pathology	*"Yes, we have an opportunity board to help us label problems we have in our lab, and we come up with conclusions on how to fix them."*
#8	Pathologist	*"Many things seem like they have a standard policy but it is difficult if not impossible to figure it out (like, for example, how to send a specimen to molecular diagnostics for a FISH test)."*
#18	Cyto-pathology	*"Increased focus on quality and errors over the last several years has helped to improve quality, but there is always a need for continuous improvement. Staff still seem to be very reluctant to talk about errors and bring them to the surface. They still seem to worry about repercussions and how they will be perceived."*
#5	Histology	*"If errors are addressed, there's seldom any follow-up between the supervisors and the person(s) who originally documented and/or committed the error. Hence, the same errors keep happening."*
#5	Pathologist	*"No, we typically encounter the same labeling errors on GI biopsies from [unit X] on a daily basis."*
#5	Histology	*"I have not seen consistent changes made in an effort to prevent certain errors from happening. Almost every day errors are made due to lack of communication of expectations to the techs, leading to repeated work and longer turn-around times."*
#3	IPOX	*"In almost all cases, there are multiple players involved with a case. Often it is hard to know whether to contact a resident, fellow or Pathologist in charge for any specific case. It usually takes at least two phone calls (often more) to resolve a question."*
#24	Histology	*"There tends to be a disconnect between what the employees understand and what management understands. I have pointed out what I thought were primary issues to be told it is a symptom of a bigger problem that will be dealt with later. Given that, and not a fuller explanation, I leave off pointing out any more problems since I don't understand the bigger picture."*
#3	Central Distribution	*"It can be difficult to resolve a problem when you are going from person to person trying to figure it out and each person gives you a different place to try or just says it's not theirs."*
#30	Hemato-pathology	*"Improvement processes should involve everyone. We are a team, but only the team leaders decide."*

DISCUSSION AND CONCLUSIONS

Interpretation of Results

While the regression analysis in Model 1 confirmed a reasonably good fit, the results for problem solving with suppliers warrant further scrutiny. We believe the reason why the coefficient for this variable does not exhibit stronger significance lies in the truncation of the data. Either the question utilized to gauge problem solving ability was misleading or a lack of problem solving across organizational boundaries impaired participant's ability to accurately answer the question.

The qualitative responses, particularly within Cytopathology, help us to understand the quantitative results. While Cytopathology had a number of responses that suggested that they utilize structured problem solving within their unit, there were several comments to suggest that coordinating and problem solving with other units was difficult. These comments were present in open-ended questions throughout the study and were also apparent in direct observations of the laboratory. Cytopathology team members were more likely to note weaker problem solving capability across boundaries. Other units responded to the problem solving question positively but made comments that suggested there is ineffective problem solving between units. We list a few of these contradictory responses in Table 9. A problem solving value of 1 denotes that the respondent strongly agreed that they knew who to contact at each supplier in the event of an error, and the respondent could also expect an immediate response. For each respondent we list both the problem solving value, calculated as an average for all suppliers, and one of their open-ended responses.

Table 9: Respondent Problem Solving Values and Associated Comments

Respondent Unit (Node)	Problem Solving Value	Comment
Pathologist	1	*“We typically encounter the same labeling errors on GI biopsies from [Unit X] on a daily basis.*
Hemato-pathology	2	*“I am not, nor are my coworkers, completely clear on what to do if there is a problem.”*
Histology	1	*“If errors are addressed, there’s seldom any follow-up between the supervisors and the person who documented or committed the error. Hence, the same errors keep happening.”*
Histology	1.3	*“I have not seen consistent changes made in an effort to prevent certain errors from happening.”*
Pathologist	1.4	*“Errors are discussed during meetings, and then lab policy is changed to prevent future occurrences.”*
Hemato-pathology	2	*“I have never been informed who the contact person is if I receive an error from [Unit X] or [Unit Y]. Contact information should be readily available.”*

The results in Table 9 suggest that the problem solving variable was truncated and therefore skewed our ability to accurately determine its impact on safety culture and quality. It is apparent that either the question regarding problem solving capability was misleading or our respondents overestimated their ability to problem solve with suppliers. In either case, the open-ended comments suggest that there is an inability to problem solve with suppliers and implement countermeasures. While one would suspect that problem solving with suppliers would contribute to safety culture and quality, the current study showcases the difficulty in effectively capturing problem solving ability, and its implications, in healthcare. While problem solving with suppliers did not prove to be a significant variable in our study, Model 1 did prove to be a good fit when predicting safety culture. While organizational factors such as error documentation and availability of standard work fell just outside the 5% significance level, clarity of customer requirements and process improvement efforts significantly contributed to a unit's overall safety culture.

While we believe that the truncation of the problem solving variable impaired its contribution to both models, the lack of contribution from the other variables on quality may be explained by their intervening impact on safety culture. Furthermore, their overall affect may be lessened by the way quality was calculated. Quality, in this study, was calculated as the perceived frequency of paperwork and specimen errors. This variable is therefore perceptions of quality and not actual quality, or frequency of error. Variables such as error documentation and process improvement efforts may actually make the respondent more aware of errors that are otherwise overlooked or quickly passed along to a supervisor. In this case, perception of error may actually increase with error documentation and process improvement efforts. The lack of fit within Model 2 suggests that our methods for estimating error frequency may have impacted our understanding of organizational contributors to quality. Additionally, while there are likely several variables missing that contribute to quality, problem solving with suppliers, when captured appropriately, should theoretically improve both safety culture and quality. While Model 2 was not a good fit when predicting quality, we were able to confirm the association between safety culture and quality.

Managerial Implications

While our analysis is based on one case study within an Anatomic Pathology department, we believe it allows for certain generalizations, especially within healthcare, but potentially to other complex environments such as advanced product development and research and design. First, the significance of clear customer requirements on safety culture suggests there is value in the approach of aligning technical flow with cross-unit coordination (or the safety control network). The inability of the problem solving component to associate with any other variable suggests that either there is truly no correlation with safety culture, or participants in the study were unfamiliar with effective problem solving and had difficulty answering the questions in a meaningful way. Based on the literature review, direct observation, and open-ended comments we believe the issue was the latter. Second, the study supports a relationship between safety culture and quality.

In addition to the importance of clarity of customer requirements, safety culture is significantly impacted by process improvement efforts. Based on these findings, we better understand the importance of coordination and process improvement within and across organizational boundaries. Leadership must work to foster this type of culture within departmental boundaries and with leadership outside of the department. By calculating the coordination assessment, leadership can begin to understand how each department can improve as both a customer and supplier. All the variables in the study, work together to create more aware and responsive units that are capable of identifying problems and testing countermeasures that will improve safety culture and quality throughout the system. Each variable in the study requires leadership that can enable structured problem solving and process improvement by all team members. Model 1 shows that improvement of several organizational factors can improve safety culture. Furthermore, Model 2 shows the impact of safety culture on quality. By improving upon these variables within each unit, and coordinating across organizational boundaries for improved error identification and problem solving, leaders can simultaneously improve both safety culture and quality within the organization.

Limitations and Future Work

The largest limitations in this study stem from the availability of data. While utilizing the individual as the unit of analysis allowed us to avoid ecological and exception errors in reasoning and was necessary given the data, it is also the largest limitation of the study. Ideally, the unit of analysis would be the dyad, as the aim of the study is to determine the effectiveness of coordination efforts along these connections and their implications on quality throughout the system. If the unit of analysis were the dyad, though, we would have to find some way to capture error frequency across these connections. This data is not available at a unit-level, let alone the dyad-level. Variability in error reporting and collection within healthcare makes it difficult to assess associations using actual quality data. Given the propositions within this study, we believe that accurate collection of quality data will be difficult without cross-unit coordination, which is the very association we are looking to test. This is an area of opportunity for future research.

This study also highlighted the difficulty in assessing problem-solving capabilities with upstream suppliers. This may be due to cultural difficulties in error disclosure in healthcare or it may be due to varied perceptions of what effective problem solving means. There is a need in this area of research to construct a study that is able to both document errors and test for problem-solving ability across boundaries within healthcare.

The last, and arguably most important, aspect of this research for further examination is the ability of leaders and healthcare practitioners to apply these findings within their departments and health systems to enable problem solving and system-wide improvement. The next paper will describe one health system's efforts to utilize iterative, cross-unit improvements to improve patient safety.

CHAPTER IV: TRANSFORMING COMPLEX VALUE STREAMS IN HEALTHCARE: AN ORGANIC APPROACH TO SYSTEM-WIDE PATIENT SAFETY

INTRODUCTION

As news regarding errors and quality in healthcare continues to grow, many healthcare organizations have started some type of formal process improvement program to proactively address mounting patient safety concerns. Depending on the unique situation, these process improvement efforts may be initiated by those who do the work, by hospital administration, or by the government (Vincent, 2003; Iedema, Jorm, Long, Braithwaite, Travaglia, & Westbrook, 2006). If hospital administration believes that a process has the potential for preventable medical errors, they may initiate a process improvement effort from the top-down. In this case, the individuals who deliver the care may or may not understand the motivation for initiating the process improvement. If a reportable medical error occurs, government agencies such as The Joint Commission may initiate the improvement effort from the outside-in by requiring a standard root-cause analysis with a corresponding action plan for preventing similar errors from occurring in the future. Depending on how the error is communicated, who is included, and how the root cause analysis is performed, the care givers involved may have varying degrees of engagement in the highly formalized process improvement effort (Wald & Shojania, 2001). With mounting evidence that the causes of preventable errors are pervasive and need to be worked on daily through continuous improvement, more progressive hospitals have worked to create a culture of process improvement from the bottom-up by engaging all team members throughout the system (Liker & Franz, 2011). In this case, the individuals who are closest to the work are trained and led by their group leaders to systematically identify and solve problems that can lead to errors.

The way in which a process improvement effort is initiated can impact the way in which leadership and team members engage in the initiative and can subsequently impact the long-term sustainability of the process improvement effort (Frankel, Leonard, & Denham, 2006). While some patient safety improvement efforts occur within the boundaries of one segment of an organization and fall under one leader's span of control, the complexity of the healthcare delivery process often requires participation from interdependent yet semiautonomous departments to adequately address the patient safety concern. Therefore, the way team members engage in process improvement efforts in one department does not necessarily correspond with engagement in other departments. It is in this respect that improving patient safety across the complex healthcare organization becomes extremely challenging, particularly if limited to bottom-up efforts within units.

This chapter will seek to understand how multiple units collectively engage in a system-wide patient safety initiative. Unlike patient safety initiatives that can be addressed and improved within a singular unit, this case study will examine the ability to quickly transfer patients requiring intensive care into the Intensive Care Unit (ICU). While this is not a metric regularly monitored in health care, the speed or lead-time with which patients in need of intensive care receive ICU-level care has been shown to directly impact patient mortality. One study showed that patients who were transferred from an inpatient unit to the ICU more than four hours after a marker of clinical instability was noted, had a nearly five-fold higher adjusted risk of death than patients transferred earlier (Young, Gooder, McBride, James, & Fisher, 2003). Similarly, a study of delays in transfer from the Emergency Department (ED) to the ICU found that patients who waited more than six hours in the ED had significantly increased hospital length of stays, higher intensive care unit mortality, and higher hospital mortality (Chalfin, Trzeciak, Likourezos, Baumann, & Dellinger, 2007). While additional studies have noted the time-critical nature of ICU care for acutely ill patients (Rapoport, Teres, Lemeshow, & Harris, 1990; Duke, Green, & Briedis, 2004), even more have identified the increase in mortality and error associated with holding these patients in the ED (Trzeciak & Rivers, 2003; Cowan & Trzeciak, 2004; Richardson, 2006; Liu, Thomas, Gordon, Hamedani, & Weissman, 2009). According to Kaboli & Rosenthal (2003):

> "While the importance of eliminating delays in transporting patients to the hospital for certain conditions has received a great deal of public attention, it is perhaps ironic that little attention has focused on delays in transferring patients already in the hospital to an ICU that may be just down the hall."

Patient movement to the ICU requires coordination between the sending department and the ICU. If there aren't any ICU beds available, additional departments may be utilized to board the most stable ICU patients, making room for higher acuity patients. In these cases, several departments are required to coordinate multiple patient moves to get the clinically unstable patient critical care as soon as possible. The case study presented in this chapter will analyze one approach to engaging departments across the system in an effort to reduce the time from patient admission in the ED to arrival in the ICU.

The patient safety effort under study began in earnest after an unfortunate, and likely preventable, adverse event occurred. Leadership of the ED and the ICU departments decided something had to change and subsequently initiated a process improvement effort to prevent similar events from occurring in the future. This case study will examine their organic, team member-driven effort to improve patient safety. Their effort initially focused on the process for patient transfer between their two units and was later iteratively extended across the system to improve overall coordination and responsiveness to patient needs. While organic and mechanistic approaches to organization-wide process improvement have been studied at a macro-level in other industries (Kucner, 2008), this chapter will seek to understand how these approaches to process improvement impact a system-wide patient safety effort that spans several interdependent, yet semiautonomous departments.

Specifically, we look to understand how the approach to improvement is translated across organizational boundaries. Coordination across these boundaries will be defined by the ability to perform frequent and structured problem solving while maintaining the flexibility to quickly adapt to patient needs. Cross-departmental coordination is examined as the patient safety improvement effort is extended across the system. Perceptions regarding the ability to coordinate care and problem solve to achieve a shared patient safety goal are captured through periodic, semi-structured interviews with leaders throughout the organization. The research methods include interviews and participant observation longitudinally in a real intervention to reduce patient transfer time.

Approaches to Improvement: Mechanistic vs. Organic

The terms mechanistic and organic were first described in 1961 (Burns & Stalker, 1994) in a study contrasting how different organizational structures fit within varying external environments. In a mechanistic structure, tasks and responsibilities are rigid and well-defined. In an organic structure, tasks are continuously refined and responsibilities are often shared and established in teams. In mechanistic organizations, communication tends to be vertical, whereas in organic organizations there is more lateral communication through informal networks. According to Burns and Stalker, mechanistic structures are better suited to a stable operating environment while organic structures are better suited to a dynamic or uncertain environment. The term mechanistic implies that the organizational structure and underlying processes are like a machine, in which each part plays a specific role and a given input will produce an expected output. The term organic, on the other hand, implies that the organizational structure is much like an organism which is able to adapt and learn in response to a changing environment. In their studies, Burns and Stalker used these terms to refer to the overarching organizational structure. Over time, this theory has been extended to describe more localized department structures (Daft, 2004) and more recently varying approaches to the deployment of lean management systems (Kucner, 2008). In this paper, we further extend these concepts to understand how a hybrid mechanistic and organic approach to a singular process improvement effort impacts coordination and improvement across the organization.

While the mechanistic and organic concepts represent almost opposing approaches to organizing, Burn's and Stalker's work noted that there wasn't one best approach. Instead, these approaches lie on a continuum and the best approach will be unique to each organization and will be contingent on both internal and external environmental factors which may change over time. This concept of contingency theory emerged in several areas of organizational theory in the late 1960s as organizations became increasingly viewed as open systems that strive for a goodness of fit between internal needs and the external environment (Morgan, 2006). There are advantages, depending on the situation, to both mechanistic and organic approaches to process improvement. For example, the structure of mechanistic approaches can provide a better infrastructure for long-term sustainability of the initiative whereas an organic approach allows for adaptation and learning throughout the improvement process (Kucner, 2008). While there can be advantages to each approach, there is often a best fit that combines elements of each that meets the needs of the environment and organizational goals. Adler (Adler & Borys, 1996) observed a Toyota run manufacturing plant and found a hybrid that he called enabling bureaucracy, as opposed to coercive bureaucracy. A coercive bureaucracy will create fixed routines and procedures that in turn create rigid and static processes. On the other hand, an enabling bureaucracy will utilize meta-routines (routines for changing routines) to continuously improve and adapt processes to meet changing needs. The Toyota Production System exemplifies enabling bureaucracy (Adler, Goldoftas, & Levine, 1999) and is the model for lean management.

Approach to Improvement and Organizational Learning

Often the approach to an organization's strategy, a new initiative, or even a small improvement, is a result of the motivation for change and the organization's culture and is less often a formal plan by leadership. Ideally, leadership would tailor the approach to process improvement to achieve a goodness of fit between the organization's needs and the external environment. The first step in this process, which is fundamental but easily taken for granted, is to clearly define the goal. People are more often motivated by a positive vision than by a localized objective with no apparent purpose (Liker & Franz, 2011). The way in which this goal is established may influence leadership, and ultimately team member engagement in the initiative. The approach to improvement utilized by leadership can shape the problem solving and learning experience for those closest to the work. Unless the people in the process are supported to learn a new way of thinking and are taught skills to enable them to improve the process themselves, it will be a short-lived improvement to the process (Liker & Franz, 2011).

Toyota is an example of an organization that has continually practiced problem solving at all levels to enable learning and system-wide improvement. Problem solving occurs throughout Toyota through the use of PDCA, or plan-do-check-adjust.[1] PDCA is the basis of problem solving taught by Walter Shewhart at Bell Laboratories which utilizes a methodical approach to defining, understanding, and solving problems. While the concept was adopted by many organizations, few have been as successful as Toyota in fully utilizing the power of PDCA. While subtle, there are important differences in

[1] This is more often referred to as plan-do-check-ACT. Liker and Franz (2011) prefer "adjust" because it implies a more dynamic learning process based on the check step.

approach that differentiate high performing organizations from the others. A mechanistic approach to utilizing PDCA for problem solving would follow rigid steps which may include data collection, statistical analysis, and creation of countermeasures based on the data. If the process did not achieve the desired result, adjustments may be made, but another full cycle of PDCA would be unlikely. This type of problem solving does not foster the culture necessary to become a learning organization. An improvement would be made and the team would move on to a completely new issue. An organic approach to PDCA, on the other hand, would be continually performed by those doing the work in a sincere effort to both improve and learn. Problem solving in the organic case becomes a way of thinking and eventually becomes a habit that is extended across all levels of the organization. This process requires a great deal of time and patience from leadership with a focus on long-term goals for organizational learning and people development.

As problem solving occurs organically, new ideas and processes are translated willingly throughout the organization. When driven by mechanistic means, problem solving that occurs in one area is directed by management to be replicated in other areas of the organization. This mechanistic sharing of learning is often referred to as "sharing best practice" or identifying pre-existing solutions for quick wins. The process that worked well in one department or organization is expected to be adopted in other areas with little to no regard for the goodness of fit with the unique external environment and internal needs. The Japanese refer to the organic sharing of learning across the system as *yokoten*, which means that the environment must be considered before adopting a new practice, or the idea is not likely to succeed (Liker & Franz, 2011). The ability to tie improvement efforts across fundamentally different departments or units, therefore, requires a great deal of thoughtfulness, testing, and adjustment to iteratively move towards systemic improvement.

Design Elements for Iterative Improvement

When processes require the coordination of many interdependent units, problem solving and learning across organizational boundaries is necessary to tie improvements across an organization. *Yokoten*, therefore, requires contextual considerations and problem solving from not just one department but by both departments coordinating to improve the delivery of a service or product. For example, Figure 11 below represents four interdependent units within a system. In order to improve the overall delivery of a service or product, improvements must be made both within and across organizational boundaries. If Unit A and Unit B utilize PDCA cycles to improve coordination across connection #1, Unit C and Unit D may be able to utilize learning from A and B to improve connection # 4. Though, in order to achieve a goodness of fit, the unique needs of Departments C and D must be considered. Therefore, Units C and D must be able to perform structured problem solving and adjustment to understand how to best improve coordination between their units.

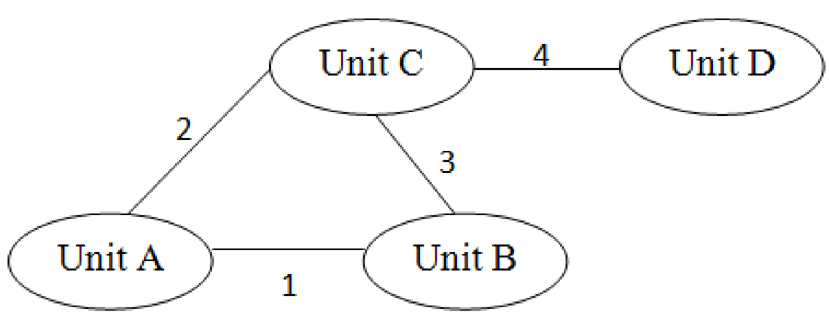


Figure 11: Interdependence and Cross-Unit Connections

The ability of a system to coordinate, learn, and improve across multiple, interdependent units can improve both flexibility and whole-system functioning. When the complex value stream is mapped and the interdependencies between units are understood by leadership, the team can determine together where problems exist throughout the system. Problems, in the PDCA way of thinking, are gaps between the ideal and actual condition. Once these connections are mapped and understood by the team, leadership can utilize their vision of the improved state to determine where the gaps exist. The thoughtful analysis of each connection in the system can be a good starting place for *yokoten*. Starting improvement efforts on connections furthest from the ideal is a good way to utilize vision and organic motivation to engage leadership and team members in continuous problem solving with a purpose. As these connections improve, learning is shared with other leaders as a basis for problem solving and iterative and cross-unit improvement.

Requisite Variety

In complex systems like healthcare, flexibility is critical to meeting unexpected demands while maintaining quality and patient safety. While some leaders may think that reducing interdependencies would improve clarity and overall coordination across a system, it can drastically reduce resilience and the flexibility necessary to respond to urgent, unforeseen patient needs. Resilience is the ability of systems to quickly and effectively respond to unforeseen, unpredicted, and unexpected demands and to resume or continue normal operations (Nemeth, Wears, Woods, Hollnagel, & Cook). In complex systems such as healthcare delivery, the challenge lies in improving coordination and problem solving across all of the interdependent connections necessary to bring a product or service to fruition. Process variety and flexibility allows the organization to discover adaptive responses, which become another avenue for organizational learning. Weick suggests that there is a requisite amount of variety that complex organizations must maintain to respond to disruptions with the appropriate degree of sensitivity (Weick, 2001). Like an organism, the organization must adapt to its environment and evolve in order to survive.

Process complexity and interdependencies have the ability to improve adaptability and flexibility across the entire system. Process variety and interdependencies, though, are only advantageous when the system can adequately coordinate and improve these connections over time.

Structured and Self-Diagnostic Communication

From a problem solving perspective, one positive aspect of a mechanistic organizational structure is the clarity of processes and tasks. A certain input will generally produce a certain output. This consistency and clarity can help to facilitate problem solving since deviations are more easily identified. The metaphor of organizations as machines is largely based on the concept that departments within an organization, like parts within a machine, can be structurally modified to produce a different result. However, many products and services today are far too complex for any one individual to understand and improve from a systematic level. Therefore, one individual or team can't simply modify one component of a system to significantly change the output.

Due to the complexity of the system, it is the structured and self-diagnostic nature of the connections between units that improves problem solving and, ultimately, system-wide improvement. The clarity of requirements and ability to problem solve between internal customers and suppliers lays the foundation for incremental and systematic organizational improvements. These structural qualities of the system improve the ability of team members within the organization to perform scientific experiments and continuously improve. Spear (1999) observed that these principles and design elements were common across functional roles and hierarchical levels within areas of Toyota that were governed by the Toyota Production System (TPS). He termed these principles the "Rules-in-Use" which allow organizations and workers to problem solve and continually improve. TPS-managed organizations design the connections among people and activities to be "specified-in-their-design, tested-with-their-every-use, and improved close in time, place, and person to the occurrence of every problem" (Johnston & Spear, 2001). Structured and self-diagnostic connections improve the ability of the organization to learn through broad-based, frequent problem solving.

In this work we will examine both the advantages and disadvantages of the approach taken by leadership in one patient safety effort, how this approach changed as the initiative grew, and how the approach was perceived by various departments as improvement efforts were iteratively extended across the system. Furthermore, we will examine how approach to improvement affects the ability of the system to spread problem solving and process improvement across the interdependent, yet semiautonomous departments within a complex system. Specifically, we examine the ability of departments to utilize inherent complexity to improve responsiveness to urgent and unpredictable patient needs by problem solving across multiple organizational boundaries through structured and self-diagnostic communication.

DATA AND METHODS

This chapter will utilize an embedded, single case study design to examine how an organic approach to process improvement utilized structured problem solving and requisite variety to iteratively tie patient safety efforts across the system. Using an interpretive perspective, we analyze how leadership's approach to process improvement across organizational boundaries influences the ability to coordinate patient safety efforts across the complex health system.

Research Methods

The embedded, single case study design was utilized to follow one health system's effort to reduce the time it takes to get a critical patient appropriate medical care. The patient safety initiative was monitored over the course of ten months. A case study approach is ideal for a longitudinal study of change (Yin, 2009), and the embedded design allowed for deeper analysis within and between departments as the initiative was iteratively extended across the health system. The unit of analysis in this study is the cross-unit connection, or dyad, between departments. Findings from these connections are triangulated with multiple sources of data including interviews, participant observation, and quantitative process data to improve the credibility of data interpretation (Hansen, 2006). In addition to the multiple sources of data, the longitudinal, embedded case provides a unique opportunity to present a rich description of an organizational change nuanced by both time and contextual factors (Pettigrew, Woodman, & Cameron, 2001). This rich data set provided the context necessary to study how improvement efforts are extended across the complex organization.

Interviews

Eighteen semi-structured interviews were conducted over the course of five months, from May to September 2010. The open semi-structured format allows for a focused, yet exploratory conversation. While a questionnaire framework was prepared in advance (Appendix B), the majority of the questions were adapted during the interview, allowing the conversation to naturally probe for additional details and deeper understanding. The interviews focused on three main areas: understanding of the process for moving ICU patients to or from each unit, communication between the various units during patient movement, and problem identification and resolution. Interviews averaged about thirty minutes, and each was recorded and subsequently transcribed with the consent of the participant. Interview participants included physicians, nurse leaders, and nurses from across the system. Interviews were conducted with individuals from the Emergency Department, each ICU, bed coordination, the Department of Medicine, and the inpatient nursing units.

Participant Observation

Throughout this initiative, I was employed at the health system under study with primary focus on patient flow and throughput across the system. While I worked closely with the leaders who were spearheading the initiative, I was not providing direct support or guidance throughout the initiative. This unique perspective allowed me to closely follow the progress of the initiative without being biased by personal goals or setbacks throughout the process. Observations were documented as field notes. In addition to personal field notes, weekly meeting minutes were collected to track the team's discussion of the effort over the course of the study.

Process Metrics

Quantitative process metrics were captured throughout the initiative to monitor patient delays to the ICU. Since the effort was initiated by the Emergency Department (ED) and the Medical Intensive Care Unit (MICU), the first metric collected was the total time between hospital admission in the ED to the time the patient was transferred to the MICU. As additional ICUs were incorporated into the initiative, similar metrics were tracked as patients were transferred to each unit from the ED. In each case, baseline data was collected and transfer times were tracked daily over the course of ten months.

RESEARCH SETTING AND BACKGROUND

The process for getting an ICU patient into a critical care setting can be difficult. Depending on the severity of the patient, the ability of the system to coordinate adaptive responses between departments is extremely time sensitive and critical to patient outcomes. The first step in the process is identifying that a patient requires ICU-level care. While certain patient needs are immediately obvious, others may not be. The clinical parameters that signal a need for more intensive medical care may or may not be immediately visible.

Once a provider has identified that a patient requires the ICU, the provider or care giver must notify the appropriate ICU of the patient's condition and needs. Some health systems have one ICU while others have several specialized ICUs. The hospital under study has Medical Intensive Care Unit (MICU), a Surgical Intensive Care Unit (SICU), a Cardio-Thoracic Intensive Care Unit (CTICU), and a step-down (less intensive) ICU referred to as Medical Assessment and Treatment (MAT).

Depending on critical care demand and ICU capacity, there may or may not be a bed available in the appropriate ICU. If a bed is available, the sending provider must contact the appropriate receiving provider as soon as possible to perform a safe and timely handoff of patient information. If a bed is not available, a series of patient moves must be coordinated to get the acutely ill patient immediate critical care. While patient transfers are usually managed by a centralized "bed coordination" unit, the patient movement from the ED to the ICU and between ICUs is coordinated between physicians and nursing based on patient severity. Due to capacity constraints, care givers in the ICU want to ensure the patient is appropriate for ICU-level care. Additionally, understanding patient severity and specific needs will help care givers in the ICUs determine which unit is appropriate. Depending on the individual needs of the patient, the severity of the other ICU patients, and overall hospital census, care givers in the ICU may have to engage several departments, as shown in Figure 12, in an attempt to coordinate patient moves to best meet the needs of all patients.

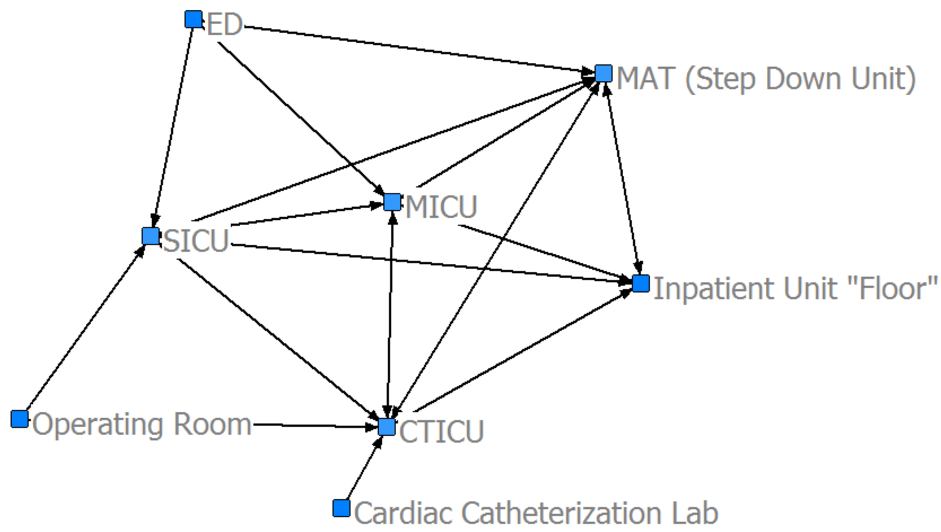


Figure 12: ICU Patient Flow Network

Aside from capacity constraints and logistical complexity, patient moves can be a difficult task to accomplish for several other reasons. In the following section, excerpts from interviews will provide background on some of the underlying cultural barriers to coordinating critical patient moves between the ED, ICUs, and inpatient units.

Cultural Barriers to Coordinating Critical Care

Each department within the health system is like a microcosm. While operating within the same organization, each unit has its own norms and expectations for patient care. *"Patients that come up here [from another unit] don't seem to be given the same sort of care that we would provide." [ICU Nurse]* Over time, these differences in expectations can create cultural barriers between departments within the same organization. These differences combined with the urgency of patient moves and the pressure of capacity constraints can create tension between departments. *"It's medicine* *versus surgery versus the ICU. I've never seen such a turf war before over beds." [ED Nurse Manager]*

Historic problems between units, both real and perceived, can diminish trust across organizational boundaries. *"We've had some communication issues with charge nurse calling every ten, twenty minutes, almost accusatory, like we're not moving the patients fast enough. Where I think, we've been moving as fast as we can." [ICU Nurse]* These problems can occasionally manifest in contemptuous responses to requests for patient moves. *"It's always difficult to get anybody to answer you on the floor. It's frustrating, but it's also something we've come to expect." [ICU Nurse]* These tensions between units can make problem solving and process improvement difficult. *"The nurse managers can be very defensive about their nurses. We don't take our nurses being criticized too easily and we become very defensive and we can't have open communication." [Inpatient Unit Nurse Manager]*

In addition to the tension between units, providers may have patient safety concerns with taking a patient off their clinical specialty. Certain physicians may refuse that their patient be transferred into an off-service (or off-specialty) ICU. Additionally, certain physicians may have varying expectations on what type of patients they are willing to accept in their ICUs. When these requirements are not explicit, tension can arise when trying to coordinate patient moves. *"It's not written anywhere that I know of. But we don't want to take anyone that is on any kind of precautions. We only have four isolation rooms in our unit. So, we won't take anyone, because our patients are fresh post-op, that's on precautions or an unexplained elevated white count or temperature." [ICU Nurse]*

Finally, it can be difficult to determine how to best coordinate patients when you are unsure of what type of patient will need care next. Furthermore, no one unit has the whole-system perspective. *"I think it's a system issue. The only way that you can have space in your ICU to accept a patient from the ED or from the floor is by having space somewhere else in the hospital to move your patient to." [Hospitalist]* Without real-time, system-wide metrics that every department is seeing, it is difficult to prioritize patient moves and decisions. *"For the longest time, the squeaky wheel was the ED. And the ED would always get the beds first, even if it didn't make sense." [ICU Nurse]*

Historic cultural barriers between units can make timely transfer of critical care patients difficult. Each department or unit works largely within a silo. These interdependent, yet semiautonomous units strive to provide the best care for their patients, without necessarily understanding the needs of patients in other units. *"Everybody thinks their unit has the right answers. Everybody has this ethnocentric kind of thing going on where they can't appreciate the bigger picture." [ICU Nurse]* In the case of critical care, delays have direct and negative implications for patient safety. The impact of delays on patient safety became apparent to the health system under study when two sentinel events occurred within the same month as a result of delayed critical care. These events became the motivation for change.

Motivation and Approach to Change

In the same month, two sentinel events occurred as patients waited to receive critical care. One patient decompensated while on an inpatient medical floor, but all ICU beds were occupied and the necessary patient moves were not accomplished in the time needed to open a bed for the critical patient. In the other case, a patient waited in the Emergency Department for a medical ICU bed to become available. In this case, the ideal ICU bed was not available, but there was availability in another, off-service ICU. The urgency of the situation and overall bed occupancy was not fully understood by leadership in all areas and the move was not coordinated quickly enough for the patient to receive the necessary critical care. The motivation for change came from the leaders in the Medical ICU (MICU) and the Emergency Department (ED). Their deep desire to change both the process and culture to prevent similar events from happening in the future became the catalyst for organic, widespread improvements for patient safety.

Phase I: The Burning Platform (May - June 2010)

The leaders began their effort to reduce delays to critical care by evaluating the cross-unit connections between departments. The most utilized connection for ICU patient flow is between the Emergency Department (ED) and the Medical Intensive Care Unit (MICU). This was a logical starting point for the improvement effort due to the volume of patient transfers between the ED and MICU and a lack of communication and coordination. In this respect, the current state of the process for patient movement was furthest from the ideal. Furthermore, it required the coordination of both leaders actively engaged in leading the initiative.

Data was collected to determine the current effectiveness of the process for patient movement between the ED and the MICU. Prior to establishing a new process, the average time from admission in the ED to arrival in the MICU was 270 minutes. The average lead time took four and a half hours for the sickest and most acutely ill patients in the hospital to get to the Intensive Care Unit after admission in the ED.

The leaders started the improvement initiative by engaging team members in each area to develop a standard process for ED providers and nurses to communicate the need for a patient move into the MICU. The team's goal was to create a process that was capable of transferring a patient to the ICU within 100 minutes of admission in the ED. All team members agreed that the variety of processes for communication between the ED and the MICU made timely transfer difficult. The team focused on creating a singular, standard line of communication. The first call from the ED provider would go to the Department of Medicine, since the hospitalist would be assuming care of the patient. A singular number was created that one hospitalist carried at all times. Once the hospitalist was contacted, they would review the patient's information to determine the most appropriate unit for transfer. They could downgrade the patient if they felt the patient was stable enough to move to an inpatient nursing unit ("floor"), they could send the patient to the Medical Assessment and Treatment Unit (MAT) if the patient needed moderately intensive critical care, or they could send the patient to the MICU if immediate intensive care was required. If the patient required the MAT or the MICU, the hospitalist would contact a singular critical care nurse to coordinate the logistics of the patient move. This critical care nurse is referred to as the "ENIT" nurse, which stands for Emergency Nursing Intervention Team. If a bed is available, the ENIT nurse would physically go to the ED to move the patient into the MAT or MICU. If a bed is not available, the ENIT nurse would convey that information to the hospitalist and would then attempt to coordinate moving another, more stable, patient to another ICU or inpatient floor.

The process was implemented and had moderate success in the first few weeks. Transfer times were improving but were not meeting the goal established by the team. The team uncovered multiple issues throughout the process. As issues arose, countermeasures were established, and the process was tested again to see if they were effective. Throughout this phase the team adopted the use of logbooks to log the time either the hospitalist or ENIT nurse were contacted. When the patient was transferred to the ICU, leaders could check to see if they met their goal. If they did not meet their goal because of a preventable delay in the process, the reason for delay was documented, and the issue would be escalated to senior leadership for support and problem solving if necessary.

By the end of this phase, the time to transfer a patient between the ED and the MICU and MAT had dropped to an average of 120 minutes. This was a 55% reduction in lead time, but it still did not meet the goal set by the team. Throughout these first few months, the MICU was often at full capacity and several patient moves were being coordinated in order to move one patient into the unit. The team decided that they would try to keep one bed available at all times to reduce the delays for the most critically ill. In order to keep one bed available, providers had to be more proactive in identifying stable patients that could be moved to either the MAT or the inpatient floor. While this helped, there were often no good candidates to transfer off the unit, and it was not a standard practice that could be easily monitored. While the process for patient movement between the ED and the MICU had drastically improved, leaders knew that in order to improve further, additional connections throughout the system had to be improved as well.

Phase II: Cross-Unit Collaboration and Process Improvement (June - September 2010)

After a few months of refining the process between the ED and the MICU, the lessons learned were extended to the SICU. The SICU is the second largest and most widely utilized ICU. The nurse manager for the area became heavily involved in the process improvement efforts and became a champion for achieving similar success. The multidisciplinary team reevaluated the connections in the ICU patient flow network to determine the next step. In the first few months of the effort it was clear that the MICU consistently had a higher occupancy than the SICU. It was determined that there were a few patient diagnoses, primarily trauma and non-trauma neurology (stroke) patients, who could be sent to either the MICU or the SICU. Leadership in the SICU decided to take these patients directly from the ED in an effort to level occupancy between the MICU and SICU and reduce last-minute patient moves between departments. While the volume between the ED and the SICU was previously minimal, the process improvement strengthened this connection in order to improve whole-system functioning. This connection became the second dyad for improvement in the process.

While there was previously little direct volume between the ED and the SICU, the plan to have the SICU take all stroke cases meant there would be a significant volume increase along this connection. Leadership took the lessons learned between ED and the MICU and applied the same thinking to the cross-unit connection between the ED and the

SICU. The SICU, though, did not utilize an ENIT nurse and did not feel as though that process would work for their area. In keeping with a singular, direct connection between departments, leadership decided that all urgent calls for patient transfer would be directed to one midlevel provider in the SICU.

Baseline data had already been collected on the time from admission to arrival in the SICU. This data was monitored on a daily basis, and the SICU midlevel adopted the use of a logbook similar to the hospitalist and the MICU ENIT nurse. Within the first month, transfer times had dropped significantly to all units: the MAT, MICU, and SICU.

While transfer times continued to drop across the board, it was apparent that coordination of moves between the ICU units was still taking too long. Leadership felt that while coordination between the ED and the units had improved remarkably, cultural barriers to coordinating patient moves between ICUs still delayed patient movement when the overall system census was high. The connection between the MICU and the MAT, though highly utilized, regularly communicated patient moves and was not felt to be a high priority for improvement. This is largely due to the fact that both units fall under the umbrella of the Department of Medicine, have the same leadership, and share nursing and physician staff. The connection between the MICU and the SICU, on the other hand, was felt to be the next most logical area for improvement.

In order to improve the connection between the MICU, MAT, and SICU, leadership felt as though there needed to be a daily communication between the clinical leaders in each area. This effort was extended to include the CTICU and bed coordination to ensure that all areas had a similar understanding of overall occupancy and patient severity in each unit. Each leader would utilize a standard template so that all units were providing similar information. The items on the template included overall unit occupancy, expected operating room transfers to the SICU and CTICU, and number of potentially stable patients. Bed coordination was included since it is responsible for coordinating any patient movement from the ICUs to the inpatient floors. The daily, multidisciplinary huddle occurred at the beginning of each day shift and lasted less than ten minutes. If any patient moves had to be coordinated between units throughout the day, the nurse leaders involved in the daily huddle would contact each other directly.

While the daily huddle became an integral part of preparing for each day in the MAT, MICU, SICU, and even with bed coordination, it did not become a habit for the CTICU. As the connections between the ED and SICU and the MAT/MICU and SICU were strengthened, the overall time from admission to arrival in the ICU continued to drop. While the team had not been able to consistently meet the 100 minute goal, the patient safety initiative was being recognized by executive and senior leadership in numerous venues across the organization and the team's efforts continued to evolve and improve as problems arose.

Phase III: System-Wide Improvement (September - November 2010)

At this point in the process improvement effort there were two connections that had not been addressed and were far from ideal: the MICU/SICU and CTICU connection and the ICU and Inpatient Floor connections. Leadership felt that it would be too difficult to engage the CTICU in further collaboration due to the numerous restrictions that had been placed on what type of patients could utilize CTICU beds. Furthermore, it was not a connection that had been highly utilized in the past. All team members felt that the next major area for improvement was between the ICUs and the floors. The biggest barrier for the ICUs to move patients out of their unit to make room was the time it took to get a floor nurse on the phone to facilitate the handoff report. This issue had been present for years and many were not optimistic in the ability to improve the timeliness of handoffs between the ICUs and all fourteen inpatient floors across the organization.

The effort to engage the floors in an efficient and effective process for patient movement was the final and most difficult step in the system-wide improvement initiative. The chief nursing officer supported the effort and challenged each floor's nurse manager to reduce the time between first contact for handoff and the time the handoff actually occurred. ICU nursing began to track the time they would place a call to the floor for a patient move and the time the request was answered by the receiving nurse. While senior leadership supported improving this longstanding issue, the nurse managers closest to the process were not thoroughly engaged and had a difficult time problem solving. The adversarial relationships that had been established throughout the years between units made open and honest communication about opportunities for improvement difficult. Additionally, instead of focusing on improving one connection at a time in an iterative fashion, all connections between the ICUs and medical and surgical floors were being monitored on the same metric with little to no problem solving and adjustment. While the ability to quickly transfer patients into the ICU is often dependent on the ability of the floors to quickly move stable ICU patients onto their floors, the connections between the ICUs and the floors continued to be a struggle for the team and for the system as a whole. While the overall time from admission to ICU had dramatically improved over the course of ten months, the lack of engagement from leaders on the inpatient floors made it difficult to achieve the goal the team established in the wake of the two sentinel events.

After the first six months of improvement the connections between the ED, MICU, MAT, and SICU were well-established, but the process continued to evolve. Maintaining the process became especially challenging during the busy winter months. The team, though, had started to utilize problem solving between units to continually refine and improve the process. While there were a few relapses in the process, most noticeably between the ED and the MAT the team was able to utilize the *plan, do, check, adjust* cycle to continually improve both the process and their overall ability to coordinate and adapt to unexpected and urgent patient needs.

EVIDENCE OVER TIME

The following tables chronicle the system-wide patient safety initiative described in the previous chapter. Excerpts are provided from the semi-structured interviews conducted during the first five months of study to provide context throughout the improvement effort as it was extended across the organization. Additionally, transfer times between the ED and the ICUs show the longitudinal impact of the effort on timely care for critical patients.

Qualitative Evidence

The following tables highlight comments that provide insight to the ability of cross-unit teams to improve both the structure and self-diagnostic nature of each connection over time. The cross-unit connections are first grouped by their ability (or inability) to utilize structured and self-diagnostic connections to problem solve and continually improve. Structure refers to the ability of each dyad to clearly define a process with expected outcomes. As cross-unit expectations are established, deviations become increasingly salient and provide a basis for problem solving. The self-diagnostic nature of each connection refers to the ability of the units to collectively respond to those deviations and problem solve for continual process improvement.

The following tables showcase how cross-unit connections evolved over time to create a clearly defined, structured process capable of problem solving for system-wide improvement to critical care patient safety. These tables provide context to the quantitative assessment of 'ED to ICU Time' as the initiative evolved. For example, Table 10 captures comments regarding the evolution of structure between the ED and the ICU while Table 11 captures comments regarding the evolution of problem solving, or the self-diagnostic capability, between the ED and the ICU. Within these tables, comments are coded by the unit in which the commenting team member works. For example, in Table 10, to get all perspectives on the evolution of the improvement efforts, we interviewed leaders, physicians, and nurses within the ED, MICU/SICU, and Bed Coordination. While Bed Coordination is not a physical unit that patients visit, the Bed Coordinators help to facilitate movement between the ED and the MICU and therefore have very valuable insights regarding issues and improvements to the coordination along this dyad.

The open format of the interviews allowed interviewees to reflect on communication and problem solving before the initiative as well as the current evolution and improvements to the various connections. Multiple individuals were interviewed from each unit. Interviews were transcribed and provide the case study with a body of longitudinal dialogue rich in context.

The first column in each table shows comments from team members before the improvement effort began for each cross-unit connections. The second column in each table notes team member comments taken during the initial stages of the process improvement effort for each dyad, or cross-unit connection. The final column highlights comments that were captured after several iterations of the improvement effort along each dyad. These three columns are then categorized, as shown along the bottom of each table, to show the progressive effectiveness of each cross-unit connection to establish structured or self-diagnostic connections in the system-wide effort to improve ICU patient safety.

Table 10: Comments over Time Regarding Structure between the ED and ICU

Dyad	Node	Before	During	After
		ED to ICU: Organic Improvement to Cross-Unit Structure		
ED to ICU	ED	"The process was manipulated by different people to suit their needs. It was haphazard. You can't talk to the charge nurse, but you could talk to the MAT nurse. It wasn't clear at all."	"The ED provider calls another provider. They accept the patient. They need to notify the charge nurse or ENIT nurse in the MICU and say, we have a patient in the ED."	"Once we make -- the ED provider makes the decision that a person needs to go to the ICU, he calls the [hospitalist]. The [hospitalist] attending then talks to the ENIT. It's dramatic; I mean there's no comparison."
	Bed Coord.	"Bed coordination, as an afterthought, was told 'we're moving this patient from this unit or floor to this floor.' So we were double booking beds."	"[Previously] we were just concerned with the patient coming out of the ED and finding them a bed. Now, it's more of a system-wide perspective where I look at the entire value stream, from the time the admission happens to the time a patient is discharged and all the interfaces in-between."	"The next step was, okay, let's put standard work in place, standards in place that says, okay, this is the process. This is step one, step two, step three. And instead of being just an ICU department process, it was more of a flow process."
	ICU	"There's a lack of communication at times. Providers that just aren't ready to call the ENIT nurse or get the ball rolling with getting the patient somewhere or just aren't familiar with the process and sit on people. "	"[With the new process] if there's a patient crashing on the floor, the ENIT gets a call, if there's a patient that needs to come up from the ED, the ENIT gets a call."	"A lot of the problem with flow, months ago, was when you were getting different calls from different places. We weren't always getting the patients to the right place in a timely fashion. So, instead of having two people try to orchestrate this, one person is [the contact] and that's their sole responsibility."
		[Low Structure]	***[Medium Structure]***	***[High Structure]***

Table 11: Comments over Time Regarding Problem Solving between the ED and ICU

Dyad	Node	Before	During	After
		ED to ICU: Organic Improvement to Cross-Unit Problem Solving		
ED to ICU	ED	"You finally contact the charge nurse upstairs and [they say] "we never heard about this patient." We'll have two, three ICU patients down here for sixteen hours or eight hours that nobody knows about."	"Right now, things have changed a little; I pick up the hospitalist phone, since we have this kind of direct line to get a hold of the hospitalist. So, I'll pick it up and say, hey, what's going."	"The hospitalists still find the feedback that the patient didn't move appropriately or quickly enough very threatening. I mean, a lot of times their feeling is that they're being singled out. And I have to just keep telling them, this isn't about you. We're looking for your input."
	Bed Coord.	"There were no metrics or measurements put in place, [and therefore] there were no escalations [when the process didn't work]."	"We [realized] how important it was for the leaders to be involved in the feedback and escalation process, which they all didn't understand at first."	"It didn't work right off the bat. What needed to happen, is there needed to be monitoring on a daily, hourly basis by individuals. And when it didn't work, correct it right then. And if there were issues right then, it escalated. That probably took four to six weeks."
	ICU	"We hear about [problems] after the fact, that there's somebody that's looking into it. But usually we have to bear the brunt of being at fault, whether justified or not."	"If a patient has been identified as needing an ICU and they're sitting there and nobody has moved them yet, then it escalates to the off-shift director."	"Things happen and we found out where the barriers are and what the glitches are [and we adjust our process accordingly]."
		[No Problem Solving]	***[Infrequent Problem Solving]***	***[Frequent Problem Solving]***

Table 12: Comments over Time Regarding Structure between ICUs

Dyad	Node	ICU to ICU: Organic Improvement to Cross-Unit Structure		
		Before	**During**	**After**
ICU to ICU	MICU/MAT	"I mean, when you're talking to one of these nurses and they're giving you a hard time, it's like they don't even realize that you're not doing this by choice. You don't want to give up this patient to take an admission that's even sicker. But they just don't seem to understand that."	"CTICU is still a problem. I don't know for sure, but I believe they still have empty beds. Or, like I said, beds filled with non-critically ill patients just to fill the beds."	"Now we have a very good understanding of where we're at to start the day [because of the critical care morning huddle]."
	SICU	"I think it's just a global ownership thing. I think a lot of times there are just too many parties involved."	"But now with the evolution [we're taking] the stroke admissions. And that was an attempt to unload the MICU I think of beds and to utilize where we had openings."	"I think [clearly defining] the people that are involved in communication makes a difference. And the other big thing that I think we need to continue to improve upon is having a more collaborative critical care environment where we actually coordinate these things together."
	CTICU	"It's not written anywhere that I know of, but we don't want to take anyone that is on any kind of precautions. We only have four isolation rooms in our unit. So, we won't take anyone that's on precautions or has an unexplained elevated white count or temperature."	"And I didn't realize this, but I guess apparently the bed coordinators don't use our beds as boarding beds."	"In the process, the barriers end up being the communication. Because, you know, what is really going on -- what is real to me might not be real to you. So that it's much more difficult to classify patients by acuity and to, you know, really figure out who can stay and who can go."
		[Low Structure]	***[Low Structure]***	***[Medium Structure]***

Table 13: Comments over Time Regarding Problem Solving between ICUs

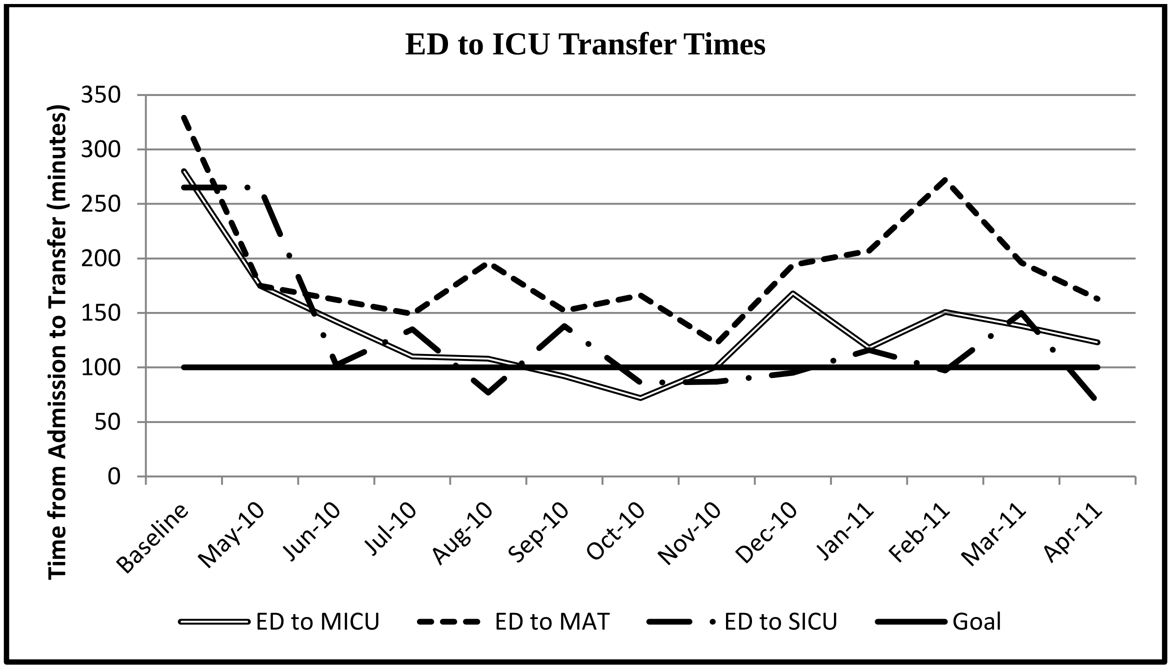
Dyad	Node	ICU to ICU: Mechanistic attempt to Improve Cross-Unit Problem Solving		
		Before	**During**	**After**
ICU to ICU	MICU/MAT	"In terms of safety [metrics], I don't know specific ones, like errors we may have made. That's not something that we've shared amongst the whole group."	"Root cause seems to happen a lot. You know, just communication with emails, everybody checking their log sheets. It's a lot of emailing he said/she said stuff. And I don't think that's effective at all right now. It's only adding to the issues."	"We look at the information every day. And if there was an outlier, then we will pull out the record and we will try to calmly figure out what didn't work and then as a whole explain to everybody this is why the process didn't work and this is what should have happened."
	SICU	"I think a lot of it is he said/she said. You don't really have hard data. So, it's hard to, you know, sort of comment or troubleshoot when you say, oh, there's this delay in transfer. And then people say, 'what do you mean there's a delay in transfer?'"	"I think right now we're in the process of working on figuring a way to collect that data, what time the [SICU] midlevel was contacted. From that period of time, what time was the patient in the door, and what time did we close out."	"We have to correct our problems and have goals that are set. And if we don't meet those goals, then we have to look at the ways that we need to make changes to improve upon them."
	CTICU	"Most of the times I have patients myself. So, sometimes, you know, someone is waiting on the phone for me for a few minutes or I have to wait for that other charge nurse for a few minutes on the phone. But I don't know that that's -- I mean, that's just expected."	"From the CT standpoint, everybody's discharge instructions are written by seven o'clock. But on the medical side, when the providers don't see the patients until three or four o'clock in the afternoon, they're being discharged at seven o'clock at night, that's not a nursing problem."	"When [problems] have been pointed out to me I've really tried to look at the whole situation and see whether there really was an open bed, whether anybody really explored the use of the CTICU beds, which is certainly a barrier."
		[No Problem Solving]	***[No Problem Solving]***	***[Infrequent Problem Solving]***

Table 14: Comments over Time Regarding Structure & Problem Solving between the ICUs and Floor Units

Dyad	Node	ICU to Floor: Mechanistic Attempt to Improve Cross-Unit Structure and Problem Solving		
		Before	**During**	**After**
ICU to Floor	ICU	"The residents take a long time getting transfer orders written. You got to keep calling any time you change your shift."	"It's also been good that we have taken ownership of who we want moved. And we, meaning us, the hospitalist, saying that this is a patient we feel is a better inpatient."	"But now what we're doing is, the nurses who are covering for the one that may be at lunch takes report and we can still get the patient into the other [floor]. I haven't heard that they're at lunch because they know that's not acceptable anymore."
	Floor	"So, just knowing who to contact and who to communicate with, you know, can be a barrier. I think the EMR (Electronic Medical Record) will solve some, but it's not the answer to everything. I mean, people need to communicate."	"Now, we have the docs involved, we have the ENIT involved, the nurse manager from ICU is being charged to get the patients out within an hour. I finally said, what the heck is this? You know, you're wasting my time because I'm talking to too many people."	"We [now] document when we call the ENIT nurse. And then the ENIT nurse is supposed to put in the progress notes that she came, saw the patient, what her feelings were, and that she talked to the doctors and feels that the patient needs to go to intensive care."
		[Low Structure]	***[Low Structure]***	***[Medium Structure]***
	ICU	"It's always difficult to get anybody to answer you on the floor. It's frustrating, but it's also something we've come to expect. So, I almost always start with a charge nurse."	"We can't give report… even though we are all under the same motto that we take report and move our patients in thirty minutes. It's an ongoing battle. Even escalating to the nurse managers isn't always effective."	"A lot of times you call to give report and you're left on hold for a number of minutes until we give up and hang up and then call back. Finding the nurses that are going to be accepting the patient is very time consuming."
	Floor	"Trust is a barrier because if you do it wrong for so long, no one is ever going to trust that you finally could get it right."	"Honestly, the nurse managers can be very defensive about their nurses. And we find, we don't take our nurses being criticized too easily and we become very defensive and we can't have open communication."	"I think the biggest issue is that we don't have enough collaboration between staff. We have partial collaboration between managers, which is good if they're not trying to protect their little chicks."
		[No Problem Solving]	***[No Problem Solving]***	***[No Problem Solving]***

Quantitative Evidence

The time, in minutes, from admission in the ED to transfer to the ICU was measured for the MICU, MAT, and the SICU. This data was collected and reviewed daily and was tracked over time as shown below in Figure 13.



13: ED to ICU Transfer Times

The first few months of the initiative had the largest impact on transfer time to the ICU. During this time, the connections between the ED and the MICU/MAT/SICU had become structured and frequent problem solving was utilized to continually improve. The small improvements from July to August correspond to the increased structure and coordination between the MICU, MAT, and SICU. Overall coordination between the ICUs moved from low to medium structure, and from no problem solving to infrequent problem solving. The final phase (after September) corresponds to the little, if any, coordination improvements made between the ICUs and the floors. Furthermore, the final months showcase the difficulty in maintaining and improving the process during the higher volume months of January and February. Without the cooperation of the floors to quickly move stable patients out of the ICUs, meeting and sustaining the 100 minute goal was difficult. Despite the minimal improvement of these remaining connections, the team was able to adjust over time to achieve a lead time of 120 minutes between admission in the ED and arrival to the ICU.

DISCUSSION

In this study, semi-structured interviews, which focus on cross-unit coordination, provide the context for understanding how process improvement initiatives are iteratively extended across an organization. The following themes emerged from triangulation of the interviews, quantitative data, and participant observation.

Organic vs. Mechanistic Approaches to Improvement

The approach to process improvement can change as an initiative is extended throughout the interdependent units of a complex system. While the initial approach to improvement was organically driven by leaders who were sincerely motivated by ill-fated delays in patient care, the final phase of the effort became increasingly mechanistic. When leadership was sincerely engaged in the effort, a culture of problem solving was established as historic barriers between units were replaced by coordination and continuous improvement towards a common goal of improved patient safety. Creating an environment where problems are openly identified can be difficult for team members and requires the consistent support and attention from leadership. Instead of fostering a new way of thinking, the final phase of the effort was mechanistically dictated to leaders on the inpatient floors and continuous problem solving declined.

The team knew that in order to meet the goal established by the team, the inpatient floors would have to quickly respond to move stable patients out of the ICUs to make room for the urgent transfer of critical patients into the ICUs. As the initiative gained the attention of senior leadership, the engagement of leaders on the inpatient floors was top-down instead of bottom-up. Instead of mechanistically dictating next steps towards the end of an already successful initiative, senior leaders could have utilized the advantages of a mechanistic approach to help sustain previous achievements through standardization and encouraged future improvements through leadership support and recognition.

Furthermore, the once iterative approach to improvement moved to one large attempt at creating a "best practice" across all ICU to inpatient floor connections. While senior leadership had the good intentions of further improving patient safety, departmental leaders were not engaged in the same natural, organic way as leaders in the ED and ICUs. Instead of utilizing a top-down, mechanistic approach to engage all other units, senior leaders could have supported the iterative extension of the process to other units by engaging new leaders one-by-one to utilize PDCA and standardization to both improve and maintain the gains. While the difference in approach was not a conscious decision, it did have a significant impact on the ability to problem solve and continuously improve the connections from the ICUs to the inpatient floors. Without the sincere and thoughtful engagement of these leaders as well as senior leader support to standardize and maintain improvements, downstream cross-unit coordination did not improve and the overall initiative struggled to achieve its goal. On the other hand, when leaders were sincerely engaged, countermeasures were created, tested, and continuously refined in a combined effort to improve patient safety.

Structured and Self-Diagnostic Connections

Complex interdependencies can make system-wide improvement difficult, but when multiple components work together to iteratively improve towards a common goal, the collective improvement efforts are often greater than the sum of individual improvements. Additionally, the increased ability to coordinate and adjust allows for a more resilient and responsive organization. In order to capitalize on the benefits of inherent complexity, the connections must be able to clearly define internal customer and supplier expectations. This cross-unit process structure is the first step in making deviations immediately visible and is the basis for frequent problem solving. Additionally, structured connections minimize the impact that cultural differences may have on overall coordination by clearly establishing needs and expectations. The tension associated with perception between units is replaced by a binary signal of whether or not the defined expectations were met: yes or no (Spear, 1999). If the answer is no, the team can investigate potential root causes, develop new countermeasures, and test to evaluate if they are effective.

Structured dyads become the basis for self-diagnostic connections. As connections become increasingly structured and self-diagnostic, they become the basis for both significant and sustained improvements. More importantly, the ability to create structured and self-diagnostic connections becomes the basis for continuous organizational learning.

CONCLUSIONS

When goals require the coordination of several interdependent yet semiautonomous units, organic engagement across the system can be difficult. The motivation created by a positive vision is vital for system-wide process improvement. The sincere engagement of leadership towards an effort provides the foundation for creating a culture that embraces continual problem solving as a habitual way of thinking. Once a vision is established, internal interdependencies can be evaluated by leadership one-by-one to determine the gap between the coordination required for the vision and the current state. The case study presented utilized an organic version of the Visual Management approach as detailed in Chapter II. This approach enabled leaders to understand interdependencies and identify the largest cross-unit gaps that were preventing the system from achieving its ICU patient safety goals. The identification of these gaps provided a starting place and roadmap for system-wide improvement.

As dyads are identified for improvement, units must coordinate to establish structured connections across these dyads to form the basis for continual problem identification and solving utilizing the *plan, do, check, adjust* cycle. As improvements are made and the effort is iteratively extended across the system, lessons can be shared across the system and customized to meet the needs of each interdependent pair of units. This is what Toyota has referred to as *yokoten* and is witnessed in the early phases of the

ICU case study. In order for the lessons learned to be organically disseminated and not mechanistically dictated to the next dyad for improvement, they should be thoughtfully adapted by leadership and team members to fit each area's unique operating environment. This learning does not attempt to reduce complexity within the system, rather it embraces the requisite variety required to bring a product or service to the customer and focuses on improving the effectiveness of each unique connection across the system.

This work highlights the importance of the leader's role in establishing a vision, understanding interdependencies, identifying gaps, supporting problem solving, and organically engaging other leaders, dyad-by-dyad, for system wide process improvement. As improvement efforts are organically extended across the complex system, the organization becomes increasingly able to adapt and respond to changing and unforeseen patient needs. The ability of leadership to utilize both organic and mechanistic approaches to improvement in the appropriate place, at the appropriate time are shown within this case study to be a critical factor in the creation of structured and self-diagnostic cross-unit connections. When organizations choose to a breadth-focused, or mechanistic, approach to improvement the strength of front-line leaders becomes increasingly important. Specifically, these leaders should be experienced in problem solving as well as identifying and testing countermeasures. When an organization does not have a group of leaders experienced in process improvement, a depth-based, or organic approach is more appropriate. This type of approach to process improvement naturally engages both leaders and team members in the problem identification and solving. With time, these types of organic improvement efforts will help grow leaders and enable the organization to utilize a more mechanistic approach for widespread process improvement. This evolution in the approach to process improvement helps leaders, and their team members, become more experienced in structured problem solving. As these efforts are increasingly coordinated across organizational boundaries, the system as a whole is better able to identify errors and problem solve for improved functioning, patient safety, and organizational learning.

CHAPTER V: CONCLUSIONS

SUMMARY AND IMPLICATIONS

The complexity inherent to healthcare systems can make coordinated problem solving and improvement difficult across organizational boundaries. Furthermore, this research presents a socio-technical based methodology for the identification of gaps in cross-unit coordination by overlaying the technical flow network (which depicts coupling between units within a system) with the safety control network (which highlights the ability to clearly define customer requirements and problem solve with suppliers). By aligning these networks, practitioners can begin to identify where gaps in the system exist. This methodology prioritizes improvements to cross-unit coordination by focusing first on the most tightly coupled units. Two methods are offered to aid practitioners in the proactive identification of gaps for widespread improvement: the Detailed Analytic Approach and the Visual Management Approach. The Detailed Analytic method is utilized to test the implications of cross-unit coordination, as measured by the Coordination Assessment, in Chapter III and the results suggest that this cross-unit coordination has implications for quality, safety culture, and process improvement.   The case study in Chapter IV utilized the Visual Management Approach to attempt a system-wide patient safety initiative. The advantages and disadvantages of organic and mechanistic approaches to the iterative improvement of cross-unit connections are reviewed and analyzed through both qualitative and quantitative data. The longitudinal analysis presented in Chapter IV highlights the importance of cross-unit connections, contingency theory, and leadership support in the successful extension of improvement across a complex system.

These composite cases help to answer our three main research questions. The first question that was posed was: *How can complex systems tie patient safety efforts across interdependent, yet semiautonomous, units to enable system-wide improvement*? To answer this question, we first showed the importance of clearly identifying each unit's internal customers and suppliers. In order to understand the system's interconnectedness and the effectiveness of each connection, the value stream map was extended to the complex system through the Network Alignment approach. The Detailed Analytic Approach and the Visual Management Approach to managing the complex, nonlinear value stream each offer a method for identification of internal customers and suppliers as well as the gaps that arise due to a discrepancy between the current ability to coordinate and the ideal. By identifying and improving these gaps between units, organizations can begin to extend process improvement efforts beyond organizational boundaries for true system-wide improvement.

The second research question posed was: *How can practitioners utilize the network alignment approach for cross-unit gap identification and how do these gaps impact safety culture and quality?* In Chapter III, the Anatomic Pathology case study shows an example of one approach to gap identification using the Detailed Analytic Approach. Connections, or dyads, with larger values (given the survey structure) were able to highlight areas of strong interdependence, or coupling, and weak coordination.

This approach not only allows leaders to prioritize improvement efforts on the largest gaps, but by including questions regarding cross-unit coordination, documentation, and process improvement we were able to understand how various organizational factors influence safety culture, and ultimately quality. All variables, with the exception of problem solving with suppliers, were associated with safety culture as shown in Table 7. Furthermore, safety culture was shown to be significantly associated with quality. These results suggest that there are tangible areas of focus for leadership and team members looking to improve patient safety. Clarity of customer requirements, which is only one component of the Coordination Assessment, was shown to be significantly correlated with quality, safety culture, and process improvement efforts. The other half of the Coordination Assessment, problem solving with suppliers, was not significantly correlated with safety culture or quality, but is likely due to unfamiliarity with problem solving. While certain care givers are becoming more open to raising concerns, there may not be well-identified channels for problem solving with team members outside organizational boundaries. Based on literature and qualitative responses, we believe that problem solving with suppliers will be equally correlated, if not more, with quality, safety culture, and process improvement and deserves attention and refinement in future work. The case study in Chapter III provides an example of one approach to gap identification as well as the impact these gaps and other organizational factors have on safety culture, and ultimately quality.

The third, and final, research question stated in this work was: *How does the approach to system-wide improvement impact problem solving and process improvement across the interdependent, yet semiautonomous departments within a complex system?*

The case study presented in Chapter IV utilized an organic version of the Visual Management Approach to network alignment and highlights the importance of organic engagement of front-line leaders in the iterative extension of improvement efforts and the role of senior leadership in supporting the initiative and helping to standardize the iterative improvements that are made. This organic-mechanistic hybrid approach utilizes the benefits of both approaches to improvement. This hybrid approach is both contingent on the environment and is likely to change throughout the evolution of a system-wide improvement initiative. The case study displays the importance of leadership engagement in the overall ability of the improvement effort to iteratively establish structured and self-diagnostic cross-unit connections throughout a complex system. The case utilized longitudinal qualitative data to monitor the progression of cross-unit connections throughout the system to become structured, with clearly defined process expectations, and self-diagnostic, so that deviations are quickly identified and resolved. This data was also paired with quantitative data regarding the overall time it took for an ICU patient to receive the required critical care. The case highlights the effectiveness of the Visual Management approach for iterative cross-unit improvements, the advantages and disadvantages of both organic and mechanistic leadership approaches to the extension of improvement efforts, and the association between structured, self-diagnostic cross-unit connections and system-wide improvement.

Each research question complements the previous question for a holistic approach to the identification and improvement of cross-unit gaps for system-wide improvement. The ability of leadership to utilize these findings to create structured and self-diagnostic connections throughout the complex system will impact the effectiveness of system-wide problem solving which, in turn, becomes the basis for continuous organizational learning and improvement.

LIMITATIONS AND FUTURE WORK

The case studies presented in Chapters III and IV were both based on data of singular, embedded case studies in healthcare environments. While both of these cases utilized multiple forms of data to provide a more complete picture, the findings in each chapter would be stronger if data was collected from multiple systems or organizations for comparison to enhance external validity. This could also be accomplished by building upon these cases in future research. Furthermore, it would be ideal to compare cross-unit coordination and quality in a complex system at Toyota to the cross-unit coordination and quality in a similarly complex system within healthcare. While different applications, leadership engagement and the establishment of structured and self-diagnostic connections between units in each organization would likely provide additional insight into the creation and improvement of these connections as well as implications for quality and system-wide process improvement.

Another option for enhancing external validity would be to extend this work to other high reliability or complex applications such as nuclear energy, aviation, complex product development, or research and design. This work builds on lean management principles as well as resilience engineering and safety culture research to contribute to the developing knowledge of system-wide improvement and error reduction in complex systems. The next step of this work should focus on better explaining and understanding how and when problem solving occurs across organizational boundaries in complex systems. This may, or may not, be different in certain applications. For example, the difficulties noted in Chapter III regarding statistical associations with problem solving with suppliers may not be present in other industries where problem identification is encouraged.   Future work could expand these research questions and methodologies to other settings and more rigorously examine the relationships between cross-unit problem solving and quality, safety culture, and system-wide improvement efforts.

APPENDICIES

APPENDIX A: ANATOMIC PATHOLOGY SURVEY

1) Please select one of the following units that most closely represents your area of work.
    a. UM Outpatient Clinics
    b. UM Internal Department
    c. Central Distribution
    d. Accessioning (Rm1)
    e. Accessioning (Rm2)
    f. Grossing (Rm1)
    g. Grossing (Rm2)
    h. Histology
    i. Rm1
    j. IPOX
    k. Cytopathology
    l. Special Stains
    m. Autopsy
    n. Hematopathology
    o. Molecular Diagnostics
    p. Electron Microscopy
    q. Pathologist
    r. Storage

<u>Problem Solving with Suppliers</u>

2) If I receive an error from each of the following areas, I would know whom to contact to resolve the issue, how to contact them, and I would expect an immediate response. (Answer for each Supplier)
    1. Strongly Agree
    2. Agree
    3. Neutral

4. Disagree
5. Strongly Disagree
6. Not Applicable

3) If any of your responses to the above question contained the word disagree, explain why is it difficult to communicate and resolve problems with that particular area. What could be done to improve the current communication process?
4) Errors that are passed to my area are carefully documented so that there is a clear record of where the error originated, type of error, and whether or not it was resolved.
    1. Strongly Agree
    2. Agree
    3. Neutral
    4. Disagree
    5. Strongly Disagree
5) If your area documents errors, does the documentation lead to changes that prevent errors from happening in the future? Please explain.
6) Please estimate the percentage of specimens that are sent to your area from each of the following:
    1. 0-10%
    2. 11-20%
    3. 21-30%
    4. 41-50%
    5. 51-60%
    6. 61-70%
    7. 71-80%
    8. 81-90%
    9. 91-100%
    10. N/A

<u>Clarity of Customer Requirements</u>

7) I have access to information that states exactly how a specimen should be prepared for the following areas: (Answer for each Customer)
    1. Strongly Agree
    2. Agree
    3. Neutral
    4. Disagree
    5. Strongly Disagree

6. Not Applicable

8) If you do know exactly what information is required when passing on a specimen, how did you learn what was necessary (training, experience, verbal reminders, standard operating procedures, etc.)? If requirements are unclear, what could be done to improve the current situation?
9) My area has open and effective communication with the areas below regarding how a specimen should be prepared and when it should arrive. (Answer for each Customer)
    1. Strongly Agree
    2. Agree
    3. Neutral
    4. Disagree
    5. Strongly Disagree
    6. Not Applicable
10) If any of your responses to the above question contained the word disagree, please explain the problem. What could be done to improve upon the current situation?
11) Documentation stating how to prepare a specimen is easy to locate.
    1. Strongly Agree
    2. Agree
    3. Neutral
    4. Disagree
    5. Strongly Disagree
    6. Not Applicable
12) It is common for different personnel within each of the following areas to have different preferences regarding specimen preparation. (Answer for each Customer)
    1. Strongly Agree
    2. Agree
    3. Neutral
    4. Disagree
    5. Strongly Disagree
    6. Not Applicable
13) Estimate the percentage of specimens that are sent from your area to the following areas:
    1. 0-10%
    2. 11-20%
    3. 21-30%
    4. 41-50%
    5. 51-60%
    6. 61-70%

7. 71-80%
8. 81-90%
9. 91-100%
10. N/A

<u>Individual Quality Perceptions</u>

14) I receive a specimen that has incomplete or incorrect paperwork or labeling with the following frequency:
    1. Once per Hour
    2. Once per Day
    3. Once per Week
    4. Once per Month
    5. Once per Year
    6. Never
15) What is the likelihood that paperwork errors affect the accuracy of the patient's diagnosis?
    1. Very Likely
    2. Likely
    3. Possible
    4. Unlikely
    5. Very Unlikely
16) I receive a specimen that is prepared incorrectly with the following frequency:
    1. Once per Hour
    2. Once per Day
    3. Once per Week
    4. Once per Month
    5. Once per Year
    6. Never
17) What is the likelihood that specimen preparation errors affect the accuracy of the patient's diagnosis?
    1. Very Likely
    2. Likely
    3. Possible
    4. Unlikely
    5. Very Unlikely
18) Do you believe that quality within the Anatomic Pathology department needs to be improved? Please explain.

<u>Individual Safety Culture Attitudes</u>

19) I am consistently provided with all the necessary information to perform my job.

1. Strongly Agree
2. Agree
3. Neutral
4. Disagree
5. Strongly Disagree

20) If your response to the above question contained the word disagree, please explain why.

21) I am encouraged by management to report any patient safety concerns I may have.
    1. Strongly Agree
    2. Agree
    3. Neutral
    4. Disagree
    5. Strongly Disagree

22) Could management be doing more to address quality and safety concerns within the lab? Please explain.

23) It is difficult for employees to ask questions when there is something that they do not understand.
    1. Strongly Agree
    2. Agree
    3. Neutral
    4. Disagree
    5. Strongly Disagree

24) If your response to the above question contained the word agree, please explain why it is difficult to ask questions.

25) Every safety concern is given immediate attention.
    1. Strongly Agree
    2. Agree
    3. Neutral
    4. Disagree
    5. Strongly Disagree

<u>Process Improvement Efforts</u>

26) Involving everyone in continuous improvement is a priority within our workplace.
    1. Strongly Agree
    2. Agree
    3. Neutral
    4. Disagree
    5. Strongly Disagree

27) Do you believe that process improvement programs will improve quality long term? Please explain.

28) I have played an important role on a team whose goal is to improve our process.

1. Strongly Agree
2. Agree
3. Neutral
4. Disagree
5. Strongly Disagree

29) Our area adopted a Process Improvement Program within the following time frame.

1. Over 5 Years Ago
2. 3-4 Years Ago
3. 1-2 Years Ago
4. Within the Past Year
5. Never (Not Applicable)

30) Any comments or feedback that you can add about communication, quality, or safety would be greatly appreciated. Please use the box below for your comments.

APPENDIX B: ICU PATIENT FLOW INTERVIEW GUIDE

Background Information

1. How many years have you worked in your current position?
2. How many years have you worked for the organization?
3. What is your current job title / job classification?
4. What specific goals and metrics does your unit track regarding patient safety?
5. How do you know if you are successful?

ICU Patient Movement – Process

1. What is the process to move ICU patients to or from your unit? Is this process documented anywhere?
2. Is this process similar across shifts and personnel?
3. What is the process for ICU patient placement if all the ICUs are full?

ICU Patient Movement – Communication

1. What type of communication occurs with the following areas during an ICU patient move? (Exclude respondent's own unit):
   Emergency Department; SICU; MICU; MAT; CTICU; Surgical Floor; Medical Floor; PACU; ENIT; Bed Coordination
2. Is communication between units clear, concise, and accurate? If not, can you give me an example?
3. What are the barriers to effective and efficient communication between these various units?

Problem Identification and Resolution

1. Can you give examples of common problems your unit encounters when trying to move patients?
2. What is the process for problem resolution between units? For example, if a patient waited in the ED (or ICU for floor respondents) for 3 hours while there was an open bed, how does your unit respond?
3. Can you sense when patient safety is more vulnerable? If so, what do you do to adjust the current situation to minimize risk to the patient?
4. Do you believe that ICU patient moves are a priority within the organization?
5. What do you think is RGH's biggest barrier to being able to move patients to or from the ICU in a timely fashion?
6. Do you believe ICU patient delays are attributable to one particular source, or is it a broader, systems problem?

REFERENCES

Safety Culture, accessed, [available at http://psnet.ahrq.gov/primer.aspx?primerID=5].

Adler, P. S. (1995). Interdepartmental interdependence and coordination: The case of the design/manufacturing interface. *Organization Science*, 147-167.

Adler, P. S., & Borys, B. (1996). Two types of bureaucracy: Enabling and coercive. *Administrative Science Quarterly*, 41(1), 61-89.

Adler, P. S., Goldoftas, B., & Levine, D. I. (1999). Flexibility versus efficiency? A case study of model changeovers in the Toyota production system. *Organization Science*, 43-68.

Altman, D. E., Clancy, C., & Blendon, R. J. (2004). Improving patient safety--five years after the IOM report. *N Engl J Med*, 351(20), 2041-3.

Ashby, W. R. (1958). Requisite variety and its implications for the control of complex systems. *Cybernetica*, 1(2), 1-17.

Baldwin, C. Y., & Clark, K. B. (2000). *Design rules: The power of modularity*: The MIT Press.

Barach, P. (2003). The end of the beginning: lessons learned from the patient safety movement. *J Leg Med*, 24(1), 7-27.

Begun, J. W., Dooley, K., & Zimmerman, B. (2003). Health care organizations as complex adaptive systems. *Advances in Health Care Organisation Theory*. *San Francisco: Jossey-Bass*.

Berwick, D. M. (1989). Continuous improvement as an ideal in health care. *The New England Journal of Medicine*, 320(1), 53.

Bierly, P. E., Gallagher, S., & Spender, J. C. (2008). Innovation and Learning in High-Reliability Organizations: A Case Study of United States and Russian Nuclear Attack Submarines, 1970–2000. *Engineering Management*, *IEEE Transactions on*, 55(3), 393-408.

Bleich, S. (2005). Medical errors: five years after the IOM report. *Issue Brief (Commonw Fund)*(830), 1-15.

Bogner, M. S. (1994). *Human error in medicine*: L. Erlbaum Associates.

Brown, S. L., & Eisenhardt, K. M. (1998). *Competing on the edge: Strategy as structured chaos*: Harvard Business Press.

Burns, L. R., & Pauly, M. V. (2002). Integrated delivery networks: a detour on the road to integrated health care? *Health affairs (Project Hope)*, 21(4), 128.

Burns, T., & Stalker, G. M. (1994). *The management of innovation*: Oxford University Press, USA.

Carroll, T., & Burton, R. M. (2000). Organizations and complexity: searching for the edge of chaos. *Computational & Mathematical Organization Theory*, 6(4), 319-337.

Cebul, R. D., Rebitzer, J. B., Taylor, L. J., & Votruba, M. E. (2008). Organizational Fragmentation and Care Quality in the US Healthcare System. *Journal of Economic Perspectives*, 22(4), 93-113.

Chalfin, D. B., Trzeciak, S., Likourezos, A., Baumann, B. M., & Dellinger, R. P. (2007). Impact of delayed transfer of critically ill patients from the emergency department to the intensive care unit*. *Critical care medicine*, 35(6), 1477.

Cohen, M. D., & Hilligoss, P. B. (2010). The published literature on handoffs in hospitals: deficiencies identified in an extensive review. *Quality and Safety in Health Care*, 19(6), 493.

Colla, J. B., Bracken, A. C., Kinney, L. M., & Weeks, W. B. (2005). Measuring patient safety climate: a review of surveys. *Quality and Safety in Health Care*, 14(5), 364.

Cook, R. I., Render, M., & Woods, D. D. (2000). Gaps in the continuity of care and progress on patient safety. *BMJ*, 320(7237), 791-4.

Cook, R. I., & Woods, D. D. (1994). Operating at the sharp end: the complexity of human error. *Human Error in Medicine*, 13, 225–310.

Corrigan, J. M., Donaldson, M. S., Kohn, L. T., Maguire, S. K., & Pike, K. C. (2001). Crossing the quality chasm: a new health system for the 21st century. *Washington, DC: The Institute of Medicine*.

Cowan, R. M., & Trzeciak, S. (2004). Clinical review: emergency department overcrowding and the potential impact on the critically ill. *Critical care*, 9(3), 291.

Crosson, F. J. (2009). 21st-century health care—the case for integrated delivery systems. *New England Journal of Medicine*, 361(14), 1324-1325.

Crowston, K., & Kammerer, E. E. (1998). Coordination and collective mind in software requirements development. *IBM Systems Journal*, 37(2), 227-245.

Daft, R. L. (2004). *Organization theory and design*. Mason, OH: SouthWestern.

de Souza, L. B., & Pidd, M. (2009). Exploring the barriers to lean health care implementation. *Public Money & Management*, 31(1), 59-66.

Deming, W. E. (1992). *Out of the crisis: quality, productivity and competitive position*: Cambridge University Press.

Dooley, K. J. (1997). A complex adaptive systems model of organization change. *Nonlinear Dynamics, Psychology, and Life Sciences*, 1(1), 69-97.

Dracup, K., & Morris, P. E. (2008). Passing the torch: the challenge of handoffs. *American Journal of Critical Care*, 17(2), 95.

Dragseth, D. (2001). There are many ways to make mistakes at work. *Bismark Tribune*.

Duke, G., Green, J., & Briedis, J. (2004). Survival of critically ill medical patients is time-critical. *Crit Care Resusc*, 6, 261-267.

Faraj, S., & Xiao, Y. (2006). Coordination in fast-response organizations. *Management Science*, 52(8), 1155.

Fisher, E. S., Staiger, D. O., Bynum, J. P. W., & Gottlieb, D. J. (2006). Creating accountable care organizations: the extended hospital medical staff. *Health Affairs*.

Frankel, A. S., Leonard, M. W., & Denham, C. R. (2006). Fair and just culture, team behavior, and leadership engagement: The tools to achieve high reliability. *Health Services Research*, 41(4p2), 1690-1709.

Galbraith, J. R. (1974). *Organizational design: An information processing view*: M. Wiener.

Gallagher, T. H., Waterman, A. D., Ebers, A. G., Fraser, V. J., & Levinson, W. (2003). Patients' and physicians' attitudes regarding the disclosure of medical errors. *JAMA*, 289(8), 1001.

Gittell, J. H. (2002). Coordinating mechanisms in care provider groups: Relational coordination as a mediator and input uncertainty as a moderator of performance effects. *Management Science*, 48(11), 1408-1426.

Gittell, J. H., Weinberg, D., Pfefferle, S., & Bishop, C. (2008). Impact of relational coordination on job satisfaction and quality outcomes: a study of nursing homes. *Human Resource Management Journal*, 18(2), 154-170.

Gittell, J. H., & Weiss, L. (2004). Coordination Networks Within and Across Organizations: A Multi level Framework*. *Journal of Management Studies*, 41(1), 127-153.

Gokpinar, B., Hopp, W. J., & Iravani, S. M. R. (2010). The Impact of misalignment of organization structure and product architecture on quality in complex product development. University College London, University of Michigan, Northwestern University, 1-35.

Gomes, P. J., & Joglekar, N. R. (2008). Linking modularity with problem solving and coordination efforts. *Managerial and Decision Economics*, 29(5), 443-457.

Grandori, A., & Soda, G. (1995). Inter.-Firm Networks: Antecedents, Mechanisms and Forms. *Studies*, 16(2), 183-214.

Guldenmund, F. W. (2000). The nature of safety culture: a review of theory and research. *Safety Science*, 34(1), 215-257.

Haig, K. M., Sutton, S., & Whittington, J. (2006). SBAR: a shared mental model for improving communication between clinicians. *Joint Commission Journal on Quality and Patient Safety*, 32(3), 167-175.

Hansen, H. (2006). The ethnonarrative approach. *Human Relations*, 59(8), 1049.

Harvey, L., & Green, D. (1993). Defining quality. *Assessment & Evaluation in Higher Education*, 18(1), 9-34.

Hasenfeld, Y. (1993). *Human services as complex organizations*: Sage Publications, Inc.

Health Grades, I. (2004). HealthGrades Quality Study: Patient Safety in American Hospitals.

Health Grades, I. (2008). HealthGrades Quality Study: Patient Safety in American Hospitals.

Heath, C., & Staudenmayer, N. (2000). Coordination neglect: How lay theories of organizing complicate coordination in organizations. *RESEARCH IN ORGANIZATIONAL BEHAVIOR*, 22, 153-192.

Helper, S., MacDuffie, J. P., & Sabel, C. (2000). Pragmatic collaborations: advancing knowledge while controlling opportunism. *Industrial and corporate change*, 9(3), 443.

Hillman, K., Braithwaite, J., & Chen, J. (Eds.) (2011). *Healthcare Systems and Their (Lack of) Integration*.

Holland, J. H. (1992). Complex adaptive systems. *Daedalus*, 17-30.

Hughes, C. M., Honig, P., Phillips, J., Woodcock, J., Anderson, R. E., McDonald, C. J., Weiner, M., & Hui, S. L. (2000). How Many Deaths Are Due to Medical Errors? *JAMA*, 284(17), 2187.

Iedema, R. A. M., Jorm, C., Long, D., Braithwaite, J., Travaglia, J., & Westbrook, M. (2006). Turning the medical gaze in upon itself: root cause analysis and the investigation of clinical error. *Social Science & Medicine*, 62(7), 1605-1615.

Ishikawa, K. (1985). *What is total quality control? The Japanese way*: Prentice-Hall.

Ishikawa, K., & Lu, D. J. (1985). *What is total quality control?: the Japanese way*: Prentice-Hall Englewood Cliffs, NJ.

Jenkins, D. P., Stanton, N. A., Walker, G. H., Salmon, P. M., & Young, M. S. (2006). Applying cognitive work analysis to the design of rapidly reconfigurable interfaces in complex networks. Uxbridge, Middlesex: Brunel University.

Jick, T. D. (1979). Mixing qualitative and quantitative methods: Triangulation in action. *Administrative Science Quarterly*, 24(4), 602-611.

Johnston, S. J., & Spear, S. (2001). How Toyota Turns Workers Into Problem Solvers. *Harvard Business Review Working Knowledge*.

Juran, J. M. (1988). *Juran on planning for quality*: Free press New York.

Kaboli, P. J., & Rosenthal, G. E. (2003). Delays in transfer to the ICU. *Journal of General Internal Medicine*, 18(2), 155-156.

Kohn, L. T., Corrigan, J., & Donaldson, M. S. (2000). *To err is human: Building a safer health system*. Washington, D.C.: National Academy Press.

Kucner, R. J. (2008). A Socio-Technical Study of Lean Manufacturing Deployment in the Remanufacturing Context.

Laffel, G., & Blumenthal, D. (1989). The case for using industrial quality management science in health care organizations. *JAMA: the journal of the American Medical Association*, 262(20), 2869.

Langlois, R. N. (2002). Modularity in technology and organization. *Journal of Economic Behavior & Organization*, 49(1), 19-37.

Laughlin, R. B., Curie, M., & are out while Jurassic, L. R. (2005). *A Different Universe: Remaking Physics from the Bottom Down*: Basic Books, New York.

Leape, L. L. (2000). Institute of Medicine medical error figures are not exaggerated. *JAMA*, 284(1), 95-7.

Leape, L. L. (2009). Errors in medicine. *Clinica Chimica Acta*, 404(1), 2-5.

Leape, L. L., & Berwick, D. M. (2005). Five years after To Err Is Human: What have we learned? *JAMA*, 293(19), 2384-90.

Leape, L. L., Berwick, D. M., & Bates, D. W. (2002). What practices will most improve safety? Evidence-based medicine meets patient safety. *JAMA*, 288(4), 501-7.

Leape, L. L., Brennan, T. A., Laird, N., Lawthers, A. G., Localio, A. R., Barnes, B. A., Hebert, L., Newhouse, J. P., Weiler, P. C., & Hiatt, H. (1991). The nature of adverse events in hospitalized patients. *New England Journal of Medicine*, 324(6), 377-384.

Leape, L. L., Lawthers, A. G., Brennan, T. A., & Johnson, W. G. (1993). Preventing medical injury. *QRB. Quality review bulletin*, 19(5), 144.

Leape, L. L., Woods, D. D., Hatlie, M. J., Kizer, K. W., Schroeder, S. A., & Lundberg, G. D. (1998). Promoting patient safety by preventing medical error. *JAMA*, 280(16), 1444.

Lebanon, N. H., & Hanover, N. H. (2000). How many deaths are due to medical error? Getting the number right. *Eff Clin Pract*, 6, 277-283.

Lee, T. H. (2002). A broader concept of medical errors. *New England Journal of Medicine*, 347(24), 1965.

Liker (2004). *The Toyota way: 14 management principles from the world's greatest manufacturer*. New York, NY: McGraw-Hill.

Liker, & Meier, D. (2006). *The Toyota Way Fieldbook: A Practical Guide for Implementing Toyota's 4Ps*: McGraw-Hill.

Liker, J., & Hoseus, M. (2008). *Toyota culture: The heart and soul of the Toyota way*. New York, NY: McGraw-Hill.

Liker, J. K., & Franz, J. K. (2011). *The Toyota Way to Continuous Improvement*: The Mc-Graw Hill Companies.

Liu, S. W., Thomas, S. H., Gordon, J. A., Hamedani, A. G., & Weissman, J. S. (2009). A pilot study examining undesirable events among emergency department-boarded patients awaiting inpatient beds. *Annals of emergency medicine*, 54(3), 381-385.

Lyons, P., & Walton, M. (2005). Australian Council for Safety and Quality in Health Care. National Patient Safety Education Framework bibliography. Canberra: Commonwealth of Australia, 2005.

Manser, T., Foster, S., Gisin, S., Jaeckel, D., & Ummenhofer, W. (2010). Assessing the quality of patient handoffs at care transitions. *Quality and Safety in Health Care*, 19(6), 1.

McDonald, C. J., Weiner, M., & Hui, S. L. (2000). Deaths due to medical errors are exaggerated in Institute of Medicine report. *JAMA*, 284(1), 93.

Miller, J. H., & Page, S. E. (2007). *Complex adaptive systems: An introduction to computational models of social life*: Princeton Univ Pr.

Moody, R. C., & Pesut, D. J. (2006). The motivation to care: Application and extension of motivation theory to professional nursing work. *Journal of Health Organization and Management*, 20(1), 15-48.

Morgan, G. (2006). *Images of organization*: Sage Publications Inc.

Nemeth, C., Wears, R., Woods, D., Hollnagel, E., & Cook, R. Minding the Gaps: Creating Resilience in Health Care. *Advances in Patient Safety: New Directions and Alternative Approaches. Washington, DC: Agency for Healthcare Research and Quality*.

Nemeth, C. P., Hollnagel, E., & Dekker, S. (2009). *Resilience engineering perspectives: Preparation and restoration*: Ashgate Publishing.

Nieva, V. F., & Sorra, J. (2003). Safety culture assessment: a tool for improving patient safety in healthcare organizations. *Quality and Safety in Health Care,* 12(suppl 2), ii17.

Patterson, E. S., Cook, R. I., Woods, D. D., & Render, M. L. Gaps and resilience. In M. S. Bogner (Ed.), *Human Error in Medicine, second edition*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Patterson, E. S., Roth, E. M., Woods, D. D., Chow, R., & Gomes, J. O. (2004). Handoff strategies in settings with high consequences for failure: Lessons for health care operations. *International Journal for Quality in Health Care*, 16(2), 125.

Patterson, E. S., & Wears, R. L. (2010). Patient handoffs: standardized and reliable measurement tools remain elusive. *Joint Commission Journal on Quality and Patient Safety*, 36(2), 52-61.

Perrow, C. (1984). *Normal accidents: Living with high risk systems*. New York: Basic Books.

Petersen, L. A., Brennan, T. A., O'Neil, A. C., Cook, E. F., & Lee, T. H. (1994). Does housestaff discontinuity of care increase the risk for preventable adverse events? *Annals of Internal Medicine*, 121(11), 866.

Pettigrew, A. M., Woodman, R. W., & Cameron, K. S. (2001). Studying organizational change and development: Challenges for future research. *The Academy of Management Journal*, 44(4), 697-713.

Pidgeon, N., & O'Leary, M. (1994). Organizational safety culture: Implications for aviation practice. *Aviation psychology in practice*, 21-43.

Pidgeon, N. F. (1991). Safety culture and risk management in organizations. *Journal of Cross-Cultural Psychology*, 22(1), 129.

Pinelle, D., & Gutwin, C. (2006). Loose coupling and healthcare organizations: Deployment strategies for groupware. *Computer Supported Cooperative Work (CSCW)*, 15(5), 537-572.

Plsek, P. (2000). Redesigning health care with insights from the science of complex adaptive systems. *Crossing the Quality Chasm: A New Heath System for the 21st Century: National Academy of Sciences*, 309-322.

Plsek, P. (2001). Redesigning health care with insights from the science of complex adaptive systems. *Crossing the quality chasm: A new health system for the 21st century*, 309-22.

Qureshi, Z. H. (2007). A review of accident modelling approaches for complex socio-technical systems: Australian Computer Society, Inc. 47-59.

Rapoport, J., Teres, D., Lemeshow, S., & Harris, D. (1990). Timing of intensive care unit admission in relation to ICU outcome. *Critical care medicine*, 18(11), 1231.

Rasmussen, J. (2000). The concept of human error: Is it useful for the design of safe systems in healthcare. *Safety in Medicine. Kiddington, Oxford, UK: Elsevier Science*.

Reason (1990). *Human error*: Cambridge University Press.

Reason, J. (1998). Achieving a safe culture: theory and practice. *Work and Stress*, 12, 293-306.

Reason, J. (2000). Human error: models and management. *British Medical Journal*, 320(7237), 768.

Reason, J. T. (1997). *Managing the risks of organizational accidents*: Ashgate Brookfield, Vt., USA.

Reid, P. P., Compton, W. D., Grossman, J. H., & Fanjiang, G. (2005a). Building a better delivery system. *Washington (DC): Institute of Medicine*.

Reid, P. P., Compton, W. D., Grossman, J. H., & Fanjiang, G. (2005b). Building a Better Delivery System: A New Engineering. *Health Care Partnership*.

Richardson, D. B. (2006). Increase in patient mortality at 10 days associated with emergency department overcrowding. *Medical Journal of Australia*, 184(5), 213.

Riesenberg, L. A., Leisch, J., & Cunningham, J. M. (2010). Nursing handoffs: a systematic review of the literature. *AJN The American Journal of Nursing*, 110(4), 24.

Riesenberg, L. A., Leitzsch, J., Massucci, J. L., Jaeger, J., Rosenfeld, J. C., Patow, C., Padmore, J. S., & Karpovich, K. P. (2009). Residents' and attending physicians' handoffs: a systematic review of the literature. *Academic Medicine*, 84(12), 1775.

Ro, Y. K., Liker, J. K., & Fixson, S. K. (2007). Modularity as a strategy for supply chain coordination: the case of US auto. *Engineering Management, IEEE Transactions on*, 54(1), 172-189.

Rother, M., & Shook, J. (2003). *Learning to see: value stream mapping to create value and eliminate muda*: Productivity Press.

Rouse, W. B. (2008). Health care as a complex adaptive system: Implications for design and management. *BRIDGE-WASHINGTON-NATIONAL ACADEMY OF ENGINEERING-*, 38(1), 17.

Runciman, B., & Walton, M. (2007). *Safety and ethics in healthcare: a guide to getting it right*: Ashgate Pub Co.

Sabel, C. F., & Zeitlin, J. (2004). Neither modularity nor relational contracting: Inter-firm collaboration in the new economy. *Enterprise & Society*, 5(3), 388-403.

Sanchez, R. (1996). Strategic product creation: managing new interactions of technology, markets, and organizations. *European Management Journal*, 14(2), 121-138.

Scott, R. D. (2009). The direct medical costs of healthcare-associated infections in US hospitals and the benefits of prevention. *Atlanta, GA: Division of Healthcare Quality Promotion National Center for Preparedness, Detection, and Control of Infectious Diseases Coordinating Center for Infectious Diseases Centers for Disease Control and Prevention*.

Senders, J. W., & Moray, N. (1991). *Human error: Cause, prediction, and reduction*: L. Erlbaum Associates.

Senge, P. M. (1993). The Fifth Discipline: The Art and Practice of the Learning Organization: Book review.

Senge, P. M. (1994). *The fifth discipline fieldbook: Strategies and tools for building a learning organization*: Random House, Inc.

Shojania, K. G., Duncan, B. W., McDonald, K. M., Wachter, R. M., & Markowitz, A. J. (2001). *Making health care safer: a critical analysis of patient safety practices*: Citeseer.

Shortell, S. M., Gillies, R. R., Anderson, D. A., Erickson, K. M., & Mitchell, J. B. (1996). Remaking health care in America. *Hospitals & health networks/AHA*, 70(6), 43.

Simon, H. A. (1973). The organization of complex systems. *Hierarchy theory: The challenge of complex systems*, 1-27.

Singer, S. J., Gaba, D. M., Geppert, J. J., Sinaiko, A. D., Howard, S. K., & Park, K. C. (2003). The culture of safety: results of an organization-wide survey in 15 California hospitals. *Quality and Safety in Health Care*, 12(2), 112.

Singla, A. K., Kitch, B. T., Weissman, J. S., & Campbell, E. G. (2006). Assessing patient safety culture: a review and synthesis of the measurement tools. *Journal of Patient Safety*, 2(3), 105.

Sosa, M. E., Eppinger, S. D., & Rowles, C. M. (2004). The misalignment of product architecture and organizational structure in complex product development. *Manage. Sci.*, 50(12), 1674-1689.

Spear, S., & Bowen, H. K. (1999). Decoding the DNA of the Toyota production system. *Harvard Business Review*, 77, 96-108.

Spear, S. J. (1999). *The Toyota production system: An example of managing complex social/technical systems*, Harvard University.

Spear, S. J. (2005). Fixing health care from the inside, today. *Harv Bus Rev*, 83(9), 78-91, 158.

Spear, S. J., & Schmidhofer, M. (2005). Ambiguity and workarounds as contributors to medical error. *Ann Intern Med*, 142(8), 627-30.

Stange, K. C. (2009). The problem of fragmentation and the need for integrative solutions. *Annals of Family Medicine*, 7(2), 100.

Thomas, E. J., Studdert, D. M., Runciman, W. B., Webb, R. K., Sexton, E. J., Wilson, R., Gibberd, R. W., Harrison, B. T., & Brennan, T. A. (2000). A comparison of iatrogenic injury studies in Australia and the USA I: context, methods, casemix, population, patient and hospital characteristics. *International Journal for Quality in Health Care*, 12(5), 371.

Thompson, J. D. (1967). *Organizations in action*: Transaction Publishers.

Thompson, J. D. (2003). *Organizations in Action: Social Science Bases of Administrative Theory*: Transaction Publishers.

Trist, E. (1981). The evolution of socio-technical systems. *Occasional Paper*, 2.

Trzeciak, S., & Rivers, E. P. (2003). Emergency department overcrowding in the United States: an emerging threat to patient safety and public health. *Emergency medicine journal*, 20(5), 402.

Turner, B. A., & Pidgeon, N. F. (1997). *Man-made disasters*: Butterworth-Heinemann, Oxford.

Tushman, M. L. (1979). Work characteristics and subunit communication structure: A contingency analysis. *Administrative Science Quarterly*, 82-98.

Tushman, M. L., & Nadler, D. A. (1978). Information processing as an integrating concept in organizational design. *Academy of Management Review*, 3(3), 613-624.

Van Cott, H. (1994). Human errors: Their causes and reduction. *Human Error in Medicine*, 53–65.

Vincent, C. (2003). Understanding and responding to adverse events. *New England Journal of Medicine*, 348(11), 1051.

Vogus, T. J., & Sutcliffe, K. M. (2007). The safety organizing scale: development and validation of a behavioral measure of safety culture in hospital nursing units. *Medical Care*, 45(1), 46.

Volpp, K. G. M., & Grande, D. (2003). Residents' suggestions for reducing errors in teaching hospitals. *New England Journal of Medicine*, 348(9), 851.

Wachter, R. M. (2004). The end of the beginning: patient safety five years after 'to err is human'. *Health Aff (Millwood)*, Suppl Web Exclusives, W4-534-45.

Wald, H., & Shojania, K. G. (2001). Root Cause Analysis. *Making health care safer: a critical analysis of patient safety practices*.

Weick, K. E. (1982). Management of organizational change among loosely coupled elements. *Change in organizations: New perspectives on theory, research and practice*, 375-408.

Weick, K. E. (2001). *Making sense of the organization*: Blackwell Publishers.

Weingart, S. N., Wilson, R. M. L., Gibberd, R. W., & Harrison, B. (2000). Epidemiology of medical error. *BMJ*, 320, 774-7.

Wilensky, G. R., Wolter, N., & Fischer, M. M. (2007). Gain Sharing: A Good Concept Getting a Bad Name? *Health Affairs*, 26(1), w58.

Womack, J. P., Jones, D. T., & Roos, D. (1991). *The machine that changed the world*: Harper Perennial New York.

Woods, D. D., Johannesen, L. J., Cook, R. I., & Sarter, N. B. (1994). *Behind human error: Cognitive systems, computers, and hindsight*: Crew Systems Ergonomics Information Analysis Center.

Yin, R. (1994). Case study research: Design and methods . Beverly Hills.

Yin, R. K. (1999). Enhancing the quality of case studies in health services research. *Health Services Research*, 34(5 Pt 2), 1209.

Yin, R. K. (2009). *Case study research: Design and methods*: Sage Publications, Inc.

Young, M. P., Gooder, V. J., McBride, K., James, B., & Fisher, E. S. (2003). Inpatient transfers to the intensive care unit. *Journal of General Internal Medicine*, 18(2), 77-83.

Yule, S. (2003). Safety culture and safety climate: A review of the literature. *Industrial Psychology Research Centre,* 1-26.

Zhan, C., & Miller, M. R. (2003). Excess length of stay, charges, and mortality attributable to medical injuries during hospitalization. *JAMA*, 290(14), 1868.