Lean Six Sigma Approaches in Manufacturing, Services, and Production

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Business Science Reference
An Imprint of IGI Global

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Published in the United States of America by
Business Science Reference (an imprint of IGI Global)
701 E. Chocolate Avenue
Hershey PA 17033
Tel: 717-533-8845
Fax: 717-533-8661
E-mail: cust@igi-global.com
Web site: http://www.igi-global.com

Library of Congress Cataloging-in-Publication Data

Lean six sigma approaches in manufacturing, services, and production / Edem Gerard Tetteh and Benedict M. Uzochukwu, editors.
pages cm
Includes bibliographical references and index.
Summary: “This book presents emerging research-based trends in the area of global quality lean six sigma networks and analysis through an interdisciplinary approach focusing on research, cases, and emerging technologies”-- Provided by publisher.
ISBN 978-1-4666-7320-5 (hardcover : alk. paper) -- ISBN 978-1-4666-7321-2 (ebook) -- ISBN 978-1-4666-7323-6 (print & perpetual access) 1. Six sigma (Quality control standard) 2. Lean manufacturing. I. Tetteh, Edem Gerard, 1972- editor. II. Uzochukwu, Benedict M., 1962- editor.

TS156.17.S59L43 2015
658.4’013--dc23

2014036390

British Cataloguing in Publication Data
A Cataloguing in Publication record for this book is available from the British Library.

All work contributed to this book is new, previously-unpublished material. The views expressed in this book are those of the authors, but not necessarily of the publisher.

For electronic access to this publication, please contact: eresources@igi-global.com.

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This chapter shows that in spite of management best efforts and desires to "do right thing," the general whine from the front-line trenches is that things are "good talk, but no real action." Assessments consistently show that as organizational success and growth come, things start falling apart, resulting in missed deliveries, waste, worker frustration, dissatisfied customers, and lower profit margins.

The objective of this chapter is to demonstrate that global competition in manufacturing production companies is placing increasing pressure on CEOs to innovate. The author implies that the level of productivity is the single most important determinant of a country's standard of living.

This chapter stipulates that in addition to information uncertainty, the domain of emergency response requires the interaction and collaboration of multiple stakeholders with different Standard Operating Procedures (SOP). The authors also analyze the impacts of lean principles in the conception and design of any system to minimize failures in information management. These multifaceted stakeholders can avoid responses that are as devastating as the disaster itself.

This chapter clarifies emerging aspects and trends of Lean Six Sigma (LSS) in healthcare through a systematic review of 162 peer-reviewed articles in business, management, and healthcare disciplines that have been published over a ten-year period from 2004 to January 2014. The author found that the analysis provides significant insights into the state of the art of LSS in healthcare research and clarifies the current confusion in the literature as to what constitutes LSS's role in improving the healthcare context.

Foreword

Lean Six Sigma Approaches in Manufacturing, Services, and Production focuses on a methodology that maximizes shareholder value by achieving a fast rate of improvement in customer satisfaction, operational cost, quality, process speed (cycle time and throughput), and operational excellence.

The book emphasizes the synergy of Lean and Six Sigma for the following reasons:

- Lean cannot bring a process under statistical control
- Six Sigma alone cannot significantly improve process speed nor ensure that operational excellence objectives are met

Thus, Lean and Six Sigma are two complementary methods that, when combined well, will help enable an organization to continuously improving its performance. Both methods require a focus on understanding the needs of the customers (internal and external) and then provides a roadmap for reducing non-value-added processes such as waste. The good understanding of both concepts, captured in this book, will result in a reduction of customer dissatisfaction as well as reduction of cycle times in any industries. Another very important benefit of this book to an implementing organization is the minimization or optimization of resources requirements to deliver goods, information, or service to the customers that are gearing toward waste elimination efforts and resulting decrease in inflated costs, lead times, and inventory.

In today's very competitive global business environment, with increasing customer expectations for value, speed, and ease of doing business, Lean Six Sigma can be the key to continuously improving the quality of goods and services as recounted in the book. The technique helps organizations to obtain superior results and provide a systematic approach to improve operations efficiencies and performance. A successfully deployed program will create breakthroughs in performance. By understanding their critical processes through analysis, organizational teams can implement changes to make processes faster and better for organizations and their customers. By using Lean Six Sigma tools and principles, corporations utilize data obtained from processes that are converted to information to quickly lead to changes to meet the needs of stakeholders.

The chapters in this book show that many organizations have created Lean Six Sigma programs for executing improvement projects that are intended to generate business financial benefits. Some results are better than others and the differentiator is the approaches utilized while focusing on the breadth of deployment and the execution of the strategy and process. There is no one approach that fits all, and each organization must determine the right approach that fits its situation. It must be understood that the project-based process improvement methodology can greatly benefit an organization, but it should be integrated into a strategic plan with well-defined goals and objectives for the business and the customers.

Lean Six Sigma is often the program of choice for many organizations looking for a systematic approach to process improvement. As illustrated in the book, this practice has been shown to be very successful throughout many deployments around the world with large, medium, and small organizations. Further, a solid knowledge base portrayed an understanding of the lessons learned from approaches already utilized and proven, in addition to the discovering of new and unique approaches that may work for any organization. The limitations of the methodologies are that they do not have a "boundary" as long as they are helpful in achieving the desired results and objectives.

The process improvement journey of this book begins with the reviews of various Lean Six Sigma approaches in Manufacturing, Service, and Production and shows how the synergy of Lean and Six Sigma can produce remarkable operational results as well as increase customer satisfaction. The reader will be able to understand and appreciate the importance of focusing on the highest-value projects that are supported by the right operational performance infrastructure. Approaches that illustrate how results can be achieved are provided.

The book offers additional knowledge, via examples, of how Lean and Six Sigma methodologies complement and reinforce each other. It also provides insight to a roadmap of implementation within any organization to start seeing significant returns.

Is Lean Six Sigma right for your organization? The reading of this book will help to answer the question by providing a reference of successful approaches that have been used by many organizations in the past. Lean Six Sigma concepts are shown to be very powerful in improving the quality and speed of all types of operational and transactional processes. Typical transactional processes can include sales and marketing, human resources, payroll, logistics, product development, returns, purchasing, etc. Manufacturing process also have multiple transactional processes that affect multiple locations that can be huge opportunities for improvements, often bigger than traditional improvements in the actual product manufacturing processes. This is often a tremendous opportunity for improvement which has been overlooked.

Throughout the book, Lean has been shown to have multiple tools that can be deployed and include but are not limited to current and future state value stream maps, 5S, visual factory, standard work, quality control process chart, Total Preventative Maintenance (TPM), quick changeover, mistake proofing, pull systems, kanbans, cell design, Overall Equipment Effectiveness (OEE), and voice of the customer. This enables the lean practitioners to create opportunities to eliminate or reduce the eight common wastes in processes:

- Defects
- Overproducing
- Transportation
- Waiting
- Inventory
- Motion
- Poor process design
- Underutilized employee creativity

John Sharp
TE Connectivity, USA

John Sharp*'s current responsibilities include directing the global quality initiatives and policies for the Channel/Distribution BU of TE. This involves understanding the distribution and end-customers' expectations and providing an extraordinary customer experience while also achieving TE business objectives. In the recent past, John has led/administered the North American ISO/TL Quality Management System as well as the Six Sigma and Lean process, quality metrics reporting, and analysis . Mr. Sharp is responsible for establishing strategic plans, policies, and procedures at all levels to ensure the QA program will meet or exceed internal and external customers' needs and expectations. Mr. Sharp coordinates and conducts the Six Sigma champions, black and green belt training, project selection and cost savings reporting process, as well as ongoing quality metrics reporting. He was the project manager who led the initiative resulting in three Tyco Business Units within North America becoming the first organizations in the world to be certified to the requirements of TL 9000, Release 3.0, and ISO 9001:2000 in May, 2001. This registration, which covered 29 sites and 12,680 employees, also represents the largest multi-site accreditation to these industry standards. Mr. Sharp is also involved with multiple problem-solving projects, acquisition integrations, acquisition assessments, and training and customer satisfaction initiatives. Prior to joining TE, Mr. Sharp was employed with AMP Inc/Tyco Electronics for 25 years in quality engineering, supervision, and management positions, as well as engineering assurance, global sourcing, and corporate consulting and self-assessment positions for worldwide business units utilizing the Malcolm Baldrige and AMP business excellence criteria. He has traveled extensively to Europe and the Far East. He has also been employed with the Gehl Co., an agricultural and construction equipment manufacturer, as the Total Quality Assurance Manager. John held early positions in quality assurance in the food industry with Murrys Inc. and was a naval nuclear lead-auditor with Allis-Chalmers Inc. Mr. Sharp teaches a variety of courses and seminars in TQM, Statistical Process Control, Quality Engineering and Auditing, Management, Marketing, Organizational Behavior, and Operations Management for the Penn State University – Middletown campus, Harrisburg Area Community College, Lebanon Valley College, and the Harrisburg section of the American Society for Quality. He is the past Chairman of the local ASQ section and is currently the education chairman.*

Preface

Lean Six Sigma Approaches in Manufacturing, Services, and Production provides a synergistic view of Lean and Six Sigma to educators, quality management practitioners, and managers to fulfill customer's demands through the knowledge of the most efficient use of resources that includes distribution capacity, inventory, and labor on a global scale. Various aspects of optimizing the supply chain by including lean principles in the processes are eliminating bottlenecks, sourcing strategically to strike a balance between lowest material cost and transportation, implementing JIT (Just In Time) techniques to optimize manufacturing flow, maintaining the right mix and location of factories and warehouses to serve customer markets, and using location/allocation, vehicle routing analysis, dynamic programming, and traditional logistics optimization to maximize the efficiency of the distribution side. Lean uses a systematic approach to eliminating non-value-added activities throughout a production system. Five basic principles characterize a lean production system: value definition, value stream mapping, flow optimization, pull production, and continuous improvement. Lean is all about speed and waste reduction. Lean is a methodology that can improve cycle time, throughput, and eliminate common types of process waste. Lean has a different focus from Six Sigma. It starts with defining value in terms of the benefits the customer gains from the goods and services produced via rapid improvement or kaizen events instead of "projects." Lean professionals work with subject matter experts to understand the "value streams" (the end-to-end process tasks that when combined together add value to the good or service produced). The teams review and match processes with customer demand.

The book is a repertory of ways to improve the quality of process outputs by identifying and removing the causes of defects (errors), while minimizing variability in manufacturing and business processes. It uses a set of quality management methods, including statistical methods, and an infrastructure of people within the organization ("Champions," "Black Belts," "Green Belts," "Orange Belts," etc.) who are experts in these very complex methods. Each Six Sigma project follows a defined sequence of steps through quantified value targets, namely process cycle time reduction, customer satisfaction, reduction in pollution, cost reduction, and/or profit increase.

The book also illustrates approaches used by companies to achieve world-class performance and customer satisfaction. Through the utilization of principles and techniques specific to Lean Six Sigma, many organizations improved their ability to provide added customer value to their products. A six sigma quality level metric is an indicator of how often defects are likely to occur. The higher the sigma quality level describes a process, the less likely it is to create defects. Six Sigma projects focus on reducing variability in critical processes that are important to the customer. Six Sigma is typically associated with a process model that systematically applies statistical tools to reducing process variation and thereby eliminating defects. The goal most frequently identified with Six Sigma is reducing process output variation on a long-term basis, producing a maximum of 3.4 parts per million defective. Typical disciplined roadmaps are utilized for new products and processes and also for improvements to existing products and processes. As a business improvement methodology that maximizes shareholder value by achieving the fastest rate of improvement in customer and employee satisfaction, Lean Six Sigma achieves cost reduction, quality, process speed, and invested capital. Nowadays, there is a very high demand for individuals with Lean Six Sigma expertise.

Lean and Six Sigma as process improvement methodologies have delivered results, when successfully implemented, over countless times and thousands of projects across hundreds of businesses (e.g. General Electric, Toyota, Caterpillar, Lockheed Martin, Northrup Grumman, Raytheon, and many others). This has been well documented in multiple research publications and textbooks.

What is inconsistent, however, is the efficiency by which organizations attain their desired results in achieving major cost, inventory, and lead-time reductions. Dramatic success can be obtained in a year and often over multiple years depending on the deployed strategy, resource commitments, and top management support. Typically, the Project Leaders (Belts) and Teams reach solutions to problems under the guiding support of Consultants or Master Black Belts (MBB), but it is crucial to have an organizational approach to ensure top management provides support via roadblock removal and providing the right resources of dollars and time. Many companies, and maybe direct competitors, are improving at a very slow rate. This fact can be a great competitive advantage to companies if they find a way to exploit the opportunity.

The best Lean Six Sigma programs require:

- A deep enough experience of how to tackle specific problems with an efficient approach.
- A broad enough experience to use the approach to tackle multiple/different types of problems that could be addressed in an organization.

- Technical skills to be able to guide Lean Six Sigma personnel in specific tool usage.
- An unrelenting commitment to the methodology realizing that it can have a positive impact on organizations' "quality culture" and improved customer satisfaction.
- Benchmarking the appropriate organizations and approaches that can provide the best solutions for the improvement process.

Any organization's employees will benefit from the increased training and education opportunities. Businesses can utilize employees' collective wisdom and knowledge to make the necessary operational improvements that are uncovered through the defined projects. This book is designed for professionals and researchers working in the field of supply chain, both from theoretical and practical points of view. It also provides insights to the executives responsible for understanding the technology and utilizing it to positively impact their businesses. The concepts introduced in this book fill the void created by the non-existence of an exhaustive source on the subject by demonstrating clearly how these key concepts and tools apply in decision making.

Practically, Six Sigma projects are selected by "Champions," working with others, to align projects with organizational goals. The Champions gather information from organization stakeholders and customers to determine the projects to launch. Project nominations can come from many sources such as reviewing customer complaint data, customer feedback surveys, review of internal cost of poor quality metrics, audits, alignment of business plans, and existing projects (separated into smaller, more manageable projects). Often the best approach is to ask the frontline employees (customer service, sales, etc.) who often are the first to recognize opportunities for improvement.

Champions, leaders, MBB, or other experts can collect specific, objective data on how each identified problem may impact the organization. Some common areas to collect data include:

- Satisfying internal stakeholders and external customers;
- Achieving strategic goals;
- Reducing cost;
- Enhancing employee satisfaction; and
- Reducing cycle time.

The chapters show that Lean Six Sigma methodology can be one of the best available to complete a project. The Master Black Belt and or Black/Green belts assigned to the project can determine the best tool set depending on the problem statement provided by the Champions. Many organizations start with a Six Sigma or just a Lean focus and ultimately find a convergence of the two approaches. No matter which one of the approaches is used to start—Lean or Six Sigma—it will eventually be driven to the other approach to achieve high quality, high speed, and low cost. When both Lean and Six Sigma are used simultaneously, improvements can be made across the organization much more rapidly, as shown by the formula below:

Six Sigma = Quality (variation reduction) and Lean = Speed. Therefore, Lean Six Sigma = Quality with Speed.

The audiences that will find this book valuable will be composed of the following:

- Process Improvement Project Leaders (Green or Black Belts) across all industries who are leading projects to improve processes using the tools and methodologies of Lean or Six Sigma.
- Project Champions or Sponsors pondering what questions to ask of project leaders and how to determine if the project is meeting objectives.
- Technical Leaders (Master Black Belts) looking to improve project and tool usage and mentoring skills.
- Deployment leaders seeking better project alignment and selection processes.
- Consultants seeking improvement in technical skills and strategy deployment of the methodologies.
- Senior Leaders who are looking for new approaches to “jump start” current improvement processes or to create an entirely different process within their organization.

The following is a brief description of each of the chapters.

Chapter 1 introduces the practices of Total Quality Management (TQM) in multinational corporations, thus explaining the history, overview, concept, and the various components of TQM. TQM practices and organizational culture, TQM practices and organizational performance (in terms of quality data and reporting, supplier quality management, product and service design, and process management), and the practical application of total quality management in service and manufacturing sectors are discussed. This calls for a change on the part of organization stakeholders to adopt these new practices through an effective in-service training for managers and staff to adequately put these principles into practice and by adopting an effective utilization of human resources to initialize and maintain the attempts to create a dynamic quality system. The chapter argues that applying total quality management practices in multinational corporations will significantly enhance organizational performance and achieve business goals in the global business environment.

Chapter 2 demonstrates how Enterprise Resource Planning (ERP) and Lean Six Sigma have been two of the hottest topics in business. The author affirms that companies have spent millions of dollars implementing both of these, and the resulting benefits have been mixed. In this chapter, the authors examine the basic foundation of ERP and what drives organizations to implement ERP systems that cost hundreds of millions of dollars. The chapter also explores the history of ERP and who was and are the major players in the marketplace.

Chapter 3 introduces a general framework for Nondestructive Evaluation (NDE) application in Supply Chain Management (SCM). With the support of emerging and existing technologies related to supply chain implementation, nondestructive evaluation provides an enabling platform to analyze the design, planning, and operational decisions within the upper and downstream ends of the supply chain system. This clarifies supply chain goals, supports making of efficient decisions without constraints, identifies managerial strategies that improve overall supply chain performance, competitive advantage, and profitability. Unfortunately, the desired attention has not been paid to how the numerous nondestructive evaluation technologies can be applied to supply chain management and implementation. This chapter, therefore, considers both technical and business perspectives of this application. It is from these viewpoints that an application framework is proposed. It covers the various nondestructive evaluation methods, operational scenarios for each method, and application issues and challenges within the supply chain.

Chapter 4 illustrates how models for evaluating and improving delivery performance play an important role in the management of supply chains. A review of supply chain delivery models that use Six Sigma methodologies indicate that the models are limited to only make-to-order supply chains where improvement in delivery performance occurs at a fixed (static) point in time. In this chapter, the authors present a generalized delivery performance model that overcomes these limitations. The model presented here can be used to measure delivery performance in both make-to-order and make-to-stock supply chains and supports improvement in delivery performance over a planned time horizon with definable milestones for attaining targeted levels of improvement. Numerical illustrations of the model are presented.

Chapter 5 defines *communication* as a sharing of information between individuals or groups to reach common understanding or goals. Ensuring effective and efficient communication is important when dealing with complex structures such as a nuclear power generation environment. This calls for a need for partnership and dialogue between major stakeholders in government, industry, employees, and the public at large. Even though communication can alarm people to seek safety, it can be used to calm employees as well as generate a sense of urgency. This chapter uses a survey to investigate the relationship between communication and 13 critical factors of lean management principles in an organization where safety is the fundamental component of the process. Data was collected and analyzed using Pearson's correlation coefficient and regression analysis. The results show that friendliness, willingness, guarantee, criticism, self-esteem, and acceptance are positive predictors of a lean communication and responsibility is negative.

Chapter 6 illustrates how the current management literature is replete with advocates for employee engagement. The author asserts that not many would argue that engendering ownership and responsibility along with the reported organizational benefits are worth aspiring to achieve. However, the actual results of workplace surveys report very little advancement towards widespread employee engagement. He continues arguing that disengagement appears to be more of the norm. In spite of management best efforts and desires to "do the right thing," the general whine from the front-line trenches is that things are "good talk, but no real action." The author demonstrates that assessments consistently shows as organizational success and growth come, things start falling apart, resulting in missed deliveries, waste, worker frustration, dissatisfied customers, and lower profit margins. Therefore, he clarifies that Lean best practices, heralded by many market-place leaders, demonstrate results-oriented and proven ways of gaining employee engagement along with extraordinary performance to everyone's satisfaction (customers, owners, employees, and community). The author concludes that this chapter is a recording of the employee engagement characteristics. This cataloguing effort can be matched to prevalent Lean principles that are promoted as providing a mature and proven system for advancing engagement, while at the same time being less theoretical than much of the published employee engagement guidance.

Chapter 7 reports that global competition in manufacturing production companies is placing increasing pressure on CEOs to innovate. The author use as evidence SA8000, global manufacturing organizations that have a responsibility to use manufacturing systems that ethically produce the most bottom-line profit which increases productivity. The author implies that the level of productivity is the single most important determinant of a country's standard of living. He defines Lean Six Sigma as a methodology that combines process speed with quality, which can enable manufacturing companies to continuously innovate, improve, and measure subsequent improvements for profitability globally. The author concludes that fostering industry, academic, and government relationships can prove to be an effective strategy for Lean Six Sigma innovation and implementation and that Lean Six Sigma principles must be taught and practiced if graduates are to be prepared to compete globally.

Chapter 8 analyzes several disaster events, such as September 11, 2001, Hurricane Katrina, and the Earthquake in Haiti, and the lessons they have taught America and the world about the importance of preparing for emergency response, both to natural and man-made disasters. The authors define a disaster as a condition or event that requires an emergency response, and in any form that often occurs without any prediction. They imply that there are various levels of information uncertainties that are associated with a disaster. Because of these uncertainties, emergency response decision making often relies on incomplete information and imprecise data. However, decisions to respond to disasters must be made in a timely manner as well as accurately so as to minimize possible loss of lives and properties. The authors stipulate that in addition to information uncertainty, the domain of emergency response requires the interaction and collaboration of multiple stakeholders with different Standard Operating Procedures (SOP). They also affirm that including lean principles in the conception and design of any system to minimize failures in information management of these multifaceted stakeholders can avoid a response that is as equally devastating as the disaster itself. Therefore, the authors analyze the impacts of lean principles in the understanding, conception design, and implementation of a Command and Control (C2), its nature, and the characteristics of an emergency domain, providing better insight to the problems associated with information processing during an emergency response planning.

Chapter 9 clarifies emerging aspects and trends of Lean Six Sigma (LSS) in healthcare through the systematic examination of 162 peer-reviewed articles in business, management, and healthcare disciplines that have been published over a ten-year period from 2004 to January 2014. Every article is analyzed using a scheme of six distinct dimensions including year of publication, journal, applications areas, tools and techniques, benefits and improvements, and research type. The chapter provides significant insights into the state of the art of LSS in healthcare research and clarifies confusion in the literature as to what constitutes LSS role in improving healthcare context.

Chapter 10 identifies specific leadership traits for green and black belt Six Sigma leaders that have a statistical relationship with the success of Six Sigma projects. The author tests the reliability of a scale created from the Leadership Trait Questionnaire (LTQ) tool. With approximately five hundred (N = 500) Six Sigma leaders who were selected from a Tyco Electronics database called Tyco Electronics Business Improvement Tracking (TBIT), the criteria for participation were:

- They were master black belts, black belts, green belts, or lean practitioners;
- Their projects were related to Six Sigma;
- Their projects had a hard cost savings; and
- They work in North America, Asia or Europe, Middle East, Africa (EMEA).

The author uses the LTQ tool to measure personal characteristics or traits that are directly related to the nature and demands of leadership with participant leaders being asked to respond to each trait on a five-point scale ranging from Strongly Agree to Strongly Disagree. Based on the results of the study, the author concludes that in times of economic uncertainty and increasing global competiveness, managers need to be able to recognize the individuals who possess the needed traits to make the companies profitable.

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Acknowledgment

We would like to express our profound gratitude to the many people who saw us through the preparation of this book, all those who provided support, talked things over, read, wrote, offered comments, allowed us to quote their remarks, and assisted in the editing, proofreading, and design. Among them are chapter contributors, referees, members of the advisory board, and IGI Global staff. We especially thank the editorial advisory board for giving us their valuable time, effort, and advice to improve the final product.

We also thank Hayley Kang, Editorial Assistant for Book Development at IGI Global, for helping us to stay on track and providing much needed guidance and feedback.

Above all, Edem wants to thank his wife, Momo, and their children, Shania, Kyle, and Evan, who supported and encouraged him in spite of all the time that was spent away from home during the preparation of this book. It was a long and difficult journey for them. Benedict would like to thank his wife, Faith (Nnenne), and their children for the love, patience, understanding, and faithful support shown while preparing this book.

Finally, we beg forgiveness from all those who provided useful insights over the course of the book preparation and whose names we have failed to mention. We would like to express our heartfelt gratitude for your efforts and assistance during the book project.

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Chapter 1
Total Quality Management Practices in Multinational Corporations

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ABSTRACT

This chapter introduces the practices of Total Quality Management (TQM) in multinational corporations, thus explaining the history, overview, concept, and the various components of TQM. TQM practices and organizational culture, TQM practices and organizational performance (in terms of quality data and reporting, supplier quality management, product and service design, and process management), and the practical application of total quality management in service and manufacturing sectors are discussed. This calls for a change on the part of organization stakeholders to adopt these new practices through an effective in-service training for managers and staff to adequately put these principles into practice and by adopting an effective utilization of human resources to initialize and maintain the attempts to create a dynamic quality system. The chapter argues that applying total quality management practices in multinational corporations will significantly enhance organizational performance and achieve business goals in the global business environment.

DOI: 10.4018/978-1-4666-7320-5.ch001

INTRODUCTION

Various studies have been carried out for the identification of the elements of successful quality management. Researchers have identified a number of tools and techniques for quality improvement that are necessary for TQM success. Managers need to know which aspects they must consider to successfully develop TQM in their firms. The rapid rate of change in global and niche markets has increased pressure in organizations to become more competitive (McAdam & Henderson, 2004), making it very important in today's business environment to adopt TQM principles, not only for profits, but survival (Yapa, 2012). Where the global environment compels companies toward being more responsive to customers and escalating requirements for higher quality (Iseri-Say, Toker, & Kantur, 2008), and almost every organization engages in quality initiatives aimed at increasing the quality of processes and products (Uyar, 2009), TQM allows firms to obtain a high degree of differentiation and to reduce costs (Tari, 2005). Changing from detection to prevention of errors requires not only the use of a set of quality management tools and techniques, but also the development of a new operating philosophy that requires a change in the way companies are managed (Hafeez, Malak, & Abdelmeguid, 2006).

Kasemsap (2014) stated that establishing the management practices of Lean Production of just in time, total productive maintenance, TQM, cellular manufacturing, and human resource management helps an organization to gain better organizational performance. A firm's quality improvement is positively influenced by the adoption of quality practices by the top management as well as process and data quality management (Psomas & Fotopoulos, 2010). Organizations need to accommodate divergent goals by developing a system and structure that allows enough flexibility for adapting different (even contrasting) management styles, between control and flexibility and between internal and external orientations, so that they may gain benefits from the multiple dimensions of TQM (Prajogo & McDermott, 2005). Much has been written on the impact of TQM on organizational performance (Flynn, Schroeder, & Sakakibara, 1994). TQM practices (i.e., supplier quality management, process management, and quality data and reporting) are found to help to achieve the operational performance goals (Baird, Hu, & Reeve, 2011).

BACKGROUND

A critical part of the management of quality is the strategic and systematic approach to achieving an organization's vision, mission, and goals. TQM is a method by which management and employees can become involved in the continuous improvement of the production of goods and services. TQM is a combination of quality and management tools aimed at increasing business and reducing losses due to wasteful practices. TQM requirements may be defined separately for a particular organization or may be in adherence to established standards, such as the International Organization for Standardization's ISO 9000 series. TQM can be applied to any type of organization. When it is properly implemented, this style of management can lead to decreased costs related to corrective or preventative maintenance, better overall performance, and an increased number of happy and loyal customers.

TOTAL QUALITY MANAGEMENT PRACTICES IN MULTINATIONAL CORPORATIONS

History of Total Quality Management

TQM is a management approach that originated in the 1950's and has regularly become more favorable since the early 1980's. Total quality is a definition of the culture, attitude and organization of a company that strives to provide customers with products and services that satisfy their needs. The culture requires quality in all aspects of the company's operations, with processes being done right the first time and defects and waste eradicated from operations. Idris and Zairi (2006) stated that there is a need for more empirical research to clarify how the TQM evolutionary path is related to critical success conditions within an economic sector, industry, and era. However, the success of the TQM research depends on the development of valid and reliable measures which replicate actual TQM practices companies adopt in the real world.

Overview of Total Quality Management

TQM is a management philosophy that seeks to merge all organizational functions (i.e., marketing, finance, design, engineering, production, and customer service) to focus on meeting customer needs and organizational objectives. TQM is a management model that aims to meet customer needs and expectations within an organization through continuous improvement of the quality of goods and services and by integrating all functions and processes within an organization (Prajogo & McDermott, 2005). TQM experts developed their concepts primarily based on their experience in industry. Grant, Shani, and Krishnan (1994) stated that the prescriptive approach developed by these gurus has created a perception that TQM involves no explicit theory, and caused business schools to dismiss.

TQM passes convergent validity test in the sense that there is substantial agreement among its founders about its key TQM assumptions and practices. Dean and Bowen (1994) suggested that there is a considerable overlap between TQM and existing management theory, hold that TQM has its own body of knowledge. For an organization to realize the benefits of TQM, the consideration of human factors is critical for the successful implementation of TQM (Joiner, 2007). TQM implemented within a supportive organization environment is more likely to motivate employees to work harder and smarter in achieving quality outcomes for the organization (Hackman & Wageman, 1995).

Concept of Total Quality Management

TQM views an organization as a collection of processes. It maintains that organizations must strive to continuously improve these processes by incorporating the knowledge and experiences of workers. The core of TQM is the customer-supplier interfaces related to a number of processes. This core must be surrounded by commitment to quality, communication of the quality message, and recognition of the need to change the culture of the organization to create total quality. These are the foundations of TQM, and they are supported by the key management functions of people, processes and systems in the organization. TQM is comprises three key terms namely: total, quality, and management. The terms "Total" expresses the integration of the manufacturing people, distribution, and outside suppliers. The term, total, in TQM underlines the continuous development enterprise including everybody and everything in an organization (Sallis, 2002). In the context of total quality management, the term "quality" can be defined as meeting the wishes and expectations of customers in an ideal economical level and in a most suitable manner or as a dynamic state that is meeting or exceeding customers' requirements, needs, expectations and desires (Goetsch & Davis, 1997). In TQM, the quality improvement process should begin and end with the customers (Senge, 1990). The third key term is management. Management is not supervision, but leadership. It may not be possible to have the desired quality without good management and leadership. Rather than focus on outcomes (i.e., management by numbers, work standards, meet specifications, zero defects, appraisal of performance), leadership should be put in place (Deming, 1986).

Components of Total Quality Management

TQM components must be considered by managers who desire to successfully implement TQM within their firms. Managers can use a set of methods in order to put in practice the critical factors of TQM. Components of TQM include leadership, customer satisfaction, education, continual improvement, involvement, teamwork, and data focused work as shown in the work done by Toremen, Karakus, and Yasan, (2009).

- **Leadership:** Leadership is not solely the responsibility of those who reside at the higher levels of the hierarchy. Instead, it's an activity in which anyone who's interested in the success of an organization can take part. The most difficult stage of TQM is to create a team spirit and to coordinate employees' efforts to a certain target. At this point, organizations require change management in order to achieve the goal of TQM.
- **Customer Satisfaction:** A customer can be any person or group that receives products or services from another person or group. Customer satisfaction is viewed as the criterion of quality. So, the needs of the customer should be determined to achieve a high level of quality. All the stakeholders in the processes of service or production, or the ones that are affected by the results of these processes can be considered as customers (Weaver, 1995).
- **Education:** Education is an important component of TQM. As the quality leaders, educational administrators are responsible for educating their staff. The educational administrators should act as a coach and teacher and provide their staff with necessary training and resources to carry out their duties as the parts of the quality system (Deming, 1986).
- **Continual Improvement:** Continual improvement drives an organization to be both analytical and creative in finding ways to become more competitive and more effective at meeting stakeholder expectations. This is among the main principles of quality. Continual improvements can amount collectively and steadily to considerable gains in quality and reduction of costs (Deming, 1986). Continual improvement requires well-defined targets, criteria and measurements.

- **Involvement:** An organization should exploit the innovative powers and mental abilities of all stakeholders and employees, and they should be involved in the quality process (Toremen et al., 2009).
- **Teamwork:** Teamwork involves the organization of cross-functional teams within the company. This multidisciplinary team approach helps workers to share knowledge, identify problems and opportunities, derive a comprehensive understanding of their role in the overall process, and align their work goals with those of the organization. High-level managers' efforts are not enough to produce the best product or service. All working people have to cooperate with each other (Weaver, 1995).
- **Data Focused Work:** Some TQM quality studies are based on the practices containing empirical data and statistical analysis. Gathering data and analysis is an inseparable part of the TQM. A supervisor is an auditor of failure and an analyzer of the numerical data while a quality leader listens and learns the system, studies and understands and works to improve the system (Deming, 1986).

Total Quality Management Practices and Organizational Culture

Organizational culture plays a pivotal role in practicing TQM in both private and public sector organizations. Organizational culture is defined as the general pattern of mindsets, beliefs and values that members of the organization share in common, and which shape the behaviors, practices and other artifacts of the organization which are easily observable (Sathe, 1985; Schein, 1985). Culture therefore is an explanatory variable that distinguishes one organization from another (Sathe, 1985; Schein, 1985). Many TQM implementations have failed, preventing companies from realizing its potential benefits because of the ignorance of the cultural factors (Oakland, 1995; Thomas, 1995; Wilkinson, Redman, Snape, & Marchington, 1998).

A common challenge in discussing TQM and culture results from the incomplete boundary between TQM as a set of management practices and TQM as an organizational culture (Batten, 1993; Kanji, 1997). The cultural dimension "teamwork/respect for people" is the most important factor in enhancing the use of TQM practices, while more outcome-oriented and innovative business units are also found to use TQM practices to a greater extent (Baird et al., 2011). Organizational culture contributes to the achievement of desired operational outcomes

(Sarros, Gray, Densten, & Cooper, 2005). Kumar and Sankaran (2007) defined TQM culture as one which uses teams, promotes pride in workmanship, drives out fear, allows participative management, promotes leadership in place of supervision and promotes long-term orientation among the members of the organization.

Dow, Samson, and Ford (1999) and Samson and Terziovski (1999) considered TQM practices (i.e., customer focus and people management) as soft elements in TQM, implying that they actually represent aspects of TQM culture. Zeitz, Johannesson, and Ritchie (1997) stated that organizational culture is distinguishable from TQM practices even though the two are closely related to each other. Zeitz et al. (1997) viewed TQM practices as behavioral, whereas organizational culture referred to attitudes, beliefs, and situational interactions. Schein (1985) stated that although TQM practice can be a reflection of organizational culture, it can only capture the surface level. Schein (1985) stated that organizational culture is concerned with something deeper, particularly when considering such elements as mindset, values, and beliefs.

Further support can be gained from a ground-breaking study by Powell (1995) promoting the importance of cultural aspects of TQM. Powell (1995) stated that TQM practices have to be implemented within a suitable culture emphasizing open communication. Tata and Prasad (1998) stated that people-oriented, flexible cultures are more conducive to the success of TQM implementation, compared to the opposing types (i.e. rational control). Tata and Prasad (1998) identified that such TQM practices as leadership, employee involvement and empowerment, teamwork, customer focus, and continuous improvement are the reflection of people-centered and flexible cultures or will be best implemented where such cultures control. Westbrook and Utley (1995) stated that creating culture where employees are valued and empowered leads to favorable quality management implementation.

Total Quality Management Practices and Organizational Performance

TQM has become a new management paradigm in all types of organizations. In recent years, many organizations have demonstrated that significant improvements in business can be achieved through TQM. TQM firms have advantage over firms that do not adopt TQM (Powell, 1995; Brah, Lee, & Rao, 2002). According to continuous improvement implemented in firms, firms that involve and motivate employees to achieve quality output and focus on satisfying customers' needs are more likely to outperform firms that do not have this focus (Joiner, 2007). The implementation of TQM practices is associated with enhanced organization performance (Joiner, 2007). Kaynak (2003) stated that four core TQM practices (i.e., quality data and reporting, supplier quality management, product and service design, and process management) are related to organizational performance as shown in the following:

Quality Data and Reporting

Quality data and reporting promote product and service design by utilizing control charts to build methodical information regarding cost of poor quality such as rework, scrap and warranty costs. In order to know how well an organization is performing, data on performance measures are necessary. TQM requires that an organization continually collect and analyze data in order to improve decision making accuracy, achieve consensus, and allow prediction based on past history. The TQM practice, quality data and reporting, refers to the extent to which quality data is accumulated, explored, and used for quality improvement purposes (Gotzamani & Tsiotras, 2001). Supplier quality may be maintained by creating a supplier performance measurement database to keep a complete record of material quality, parts defects rates, and supplier responsiveness (Forza & Filippini, 1998; Krause, 1998), with tools such as control charts often used in conjunction with the database. While in Australia there has been a reluctance to engage in quality cost reporting (Sower, Quarles, & Broussard, 2007), there has been a tendency for organizations to concentrate on meeting various quality standards, and to attempt to attain ISO certification (Rahman & Sohal, 2002).

Quality data and reporting facilitates product and service design by using control charts to construct systematic information regarding cost of poor quality such as rework, scrap and warranty costs. Quality data also assists by providing guidance on areas requiring correction (Choi & Eboch, 1998; Ho, Duffy, & Shih, 1999). In addition, quality data and reporting directly affects process management by informing workers about deficiencies in processes immediately so they can take corrective actions before defective products are produced (Handfield, Ghosh, & Fawcett, 1998; Ahire & Dreyfus, 2000). The appraisal and response on materials and components purchased will increase the quality of subsequent purchased products. Response on such quality ensures that purchasing functions understand the business internal production needs and external customer needs, and result in better process management (Carter, Smeltzer, & Narasimhan, 1998).

Supplier Quality Management

Supplier quality management has emerged as one of the outstanding business practices in the past few years. World-class manufacturers are making powerful investments in systems and processes to develop supplier quality. Supplier quality management involves the development of close partnerships, mutual trust, and parallel growth with suppliers (Gotzamani & Tsiotras, 2001). Effective supplier quality management is facilitated by long-term, cooperative relationships with as few suppliers as possible to obtain quality materials and/or services (Kaynak, 2003). Maintaining a small supplier base improves product quality and productivity of buyers by encouraging enhanced supplier commitment to product design and quality (Ansari & Modarress, 1990).

The relationship with suppliers is also expected to be directly related to process flow management, since purchased materials and parts are a dominant source of process variability. Supplier management can assist producers to procure materials and parts that can be used efficiently, which in turn will enable organizations to reduce waste, and create a leaner operation (Choi & Eboch, 1998; Krajewski & Ritzman, 2001), thus improving process management. Lean techniques such as just-in-time systems promote communication between manufacturers and suppliers to allow better movement of product requirements and specifications, thus enhancing the certainty that quality goods will be delivered on time, and facilitating the elimination of safety stock. Supplier management also helps producers to procure the materials and parts that can be used most productively. Dealing with a small number of suppliers expedites the solution of quality and delivery problems because buyers can pay close attention to individual suppliers (Burt, 1989). Supplier certification or qualification programs arrange assurance about the quality of incoming materials and parts by means of conveying manufacturer's quality expectations to suppliers (Flynn, Schroeder, & Sakakibara, 1995). A reliable supply chain which provides material from technically competent and flexible suppliers enlarges the quality of the final product (Stamm & Golhar, 1993). For example, Ahire and O'Shaughnessy (1998) found that supplier quality management is a statistically important predictor of product quality.

Product and Service Design

When planning on producing new product and service, the major factor is the product and service design. The design process is encouraged to be tied in with the organization's strategy and take into account some key considerations. Product and service design refers to the efforts to achieve clarity in respect to product and process design specifications prior to the offering of product and service to the market (Gotzamani & Tsiotras, 2001). Involving suppliers in the design process conveys product features and quality standards for incoming materials to suppliers, thus promoting manufacturing component standardization.

Incorporating customer's requirements into product and service design may require companies to change the way they treat their customers. Companies need to translate the words and ideas of customers into product and service specifications. The product and service design process diminishes process complexity and process variance, and increases manufacturing processes (Ahire & Dreyfus, 2000). Consideration of design for manufacturability will also lead to less manufacturing variances in the process (Ittner & Larcker, 1995). Practical product and service design is utilized as a valuable distinction tool in competitive industries.

Process Management

Process management is the collection of activities of planning and monitoring the performance of a process. Process management is the application of knowledge, skills, tools, techniques and systems to determine, foresee, measure, control, report and develop processes with the goal to meet customer requirements profitably. Process management takes a preventative approach to quality improvement, concentrating on the design of processes that are near infallible and stabilizing production schedules and work distribution (Flynn et al., 1995). Reduced process variation results in better output uniformity as well as reduced rework and waste (Forza & Filippini, 1998) due to the timely identification and rectification of quality problems in the production process (Ahire & Dreyfus, 2000).

Process management attempts to reduce variations in production processes (Ho et al., 1999) by encompassing quality features into the product during the production stage (Handfield et al., 1998). Regular preventative equipment maintenance improves product quality by improving machine reliability and reducing interruptions in production (Ahire & Dreyfus, 2000). Forza and Filippini (1998) found that process management directly and positively affects product quality. Flynn et al. (1995) found that effective process management results in increases in the percentage of goods passing final inspections with no rework required. Organizations should concentrate on monitoring activities and taking corrective actions to reduce scrap, rework and variations during the production/service delivery stage in order to arrange high-quality goods and services.

Practical Applications of Total Quality Management

This section introduces the practical applications of TQM in service sector and manufacturing sector as shown in the following sectors:

TQM in Service Sector

TQM concepts are widely used in health care industry to improve customer satisfaction. Ingram and Chung (1997) report that adopting TQM programs shifts moderately satisfied customers of health care organizations into maximally satisfied customers. Hasin, Seeluangsawat, and Shareef (2001) indicated that hospitals in Thailand use TQM because health care industry in Thailand has become very competitive. Customer satisfaction is an enormously important ingredient of TQM. Aghazadeh (2002) stated that TQM has only begun to take precedence in American companies, and since health care is an industry where individualized care and attention is needed, TQM is absolutely important for businesses.

Fening, Pesakovic, and Amaria (2008) studied 116 small firms in Ghana. Fening et al. (2008) examined the relationship of each of the Malcolm Baldrige National Quality Award (MBNQA) variables with the five performance indicators (i.e., profitability, customer satisfaction, sales growth, employee morale, and market share). Quality management is made up of variables that combine to form quality management and that the implementation of the practices must be done individually at a gradual pace (Fening et al., 2008). Jayamaha, Grigg, and Mann (2008) assessed the validity of the Baldrige Educational Criteria for Performance Excellence (BECPE) by means of data collected from a sample of 91 New Zealand organizations. Their results showed that business results are affected by human resources focus and process management. Process management is affected by customer and market focus, human resources focus, measurement analysis, and knowledge management (Jayamaha et al., 2008). With respect to human resources focus, customer and market focus is mainly affected by measurement analysis and knowledge management and secondarily by strategic planning. Strategic planning is affected by leadership and measurement analysis and knowledge management. Measurement analysis and knowledge management are largely influenced by leadership (Jayamaha et al., 2008). As mentioned above, process management in TQM application is concerned with customer and market focus, human resources focus, measurement analysis, knowledge management, leadership, strategic planning.

Su, Li, Zhang, Liu, and Dang (2008) conducted a survey of 151 ISO 9001 certified manufacturing and service firms in West China. The results suggested that quality management practices do not have a positive impact on the firms' business performance (i.e., sales growth, market share, and growth in market share) directly, but have an indirect impact on business performance mediated by quality performance (i.e., defects, product quality, durability, reliability, and delivery on time) and research and development performance (i.e., mistakes rate in design, research and development time, competency, and cost). The contribution of quality management practices to the firms' financial and marketing performance is greater in the service firms (Su et al., 2008).

TQM in Manufacturing Sector

Terziovski and Samson (1999) studied the impact of TQM programs on organizational performance of manufacturing industries in Australia. Terziovski and Samson (1999) reported that a typical manufacturing organization is more likely to achieve successes in employee relations, customer satisfaction, and business performance with TQM. Agus, Krishnan, and Kadir (2000) stated that TQM programs are widely used by manufacturing companies in Malaysia to enhance their financial performance. Agus et al. (2000) suggested that the impact of TQM on financial performance is mediated by customer satisfaction. Thus, an organization which implements TQM will have high customer satisfaction leading to improved financial performance (Agus et al., 2000).

Han, Trienekens, and Omta (2009), studying 229 pork processors in Eastern China, found that the integrated information technology and integrated logistics management improve the quality management practices used and that there is a direct relationship between the quality management practices and the firm's performance. Attention to quality management turns out to be critical to generate sales growth, improve customer satisfaction and provide profits for the company. Han et al. (2009) stated that the in-company quality management, supplier/customer quality management, employee involvement, quality design and the quality process management contribute to overall firm's performance.

Kumar, Choisne, Grosbois, and Kumar (2009) studied 15 Canadian finalists in the total quality category of the Canada Awards for Business Excellence (CABE), most of which are from the manufacturing sector. All of them are at an advanced stage of TQM adoption. The study provides evidence of the positive impact of TQM on company performance. According to the four domains of company performance studied, all of them are improved, in particular employee relations (i.e., improved employee participation and morale), operating procedures (i.e., improved products and services quality, process and productivity, and reduced errors/defects), customer satisfaction (reduced number of customer complaints), and financial results (increased profitability).

Salaheldin (2009) studied 139 small- and medium-sized enterprises (SMEs) in industrial sector in Qatar. Data analysis revealed three levels of critical success factors of TQM implementation, namely the strategic factors (i.e., leadership, organizational culture, continuous improvement, benchmarking, quality goals and policy), the tactical factor (i.e., team building and problem solving, employee empowerment, involvement and training, use of information technology, supplier management) and the operational factor (product and service design, process control, customer orientation, resources value addition process, resources conservation and utilization, inspection and checking work). Salaheldin (2009) stated that there is a substantial positive effect of the TQM implementation on both the operational performance (i.e., internal operation in terms of cost and waste reduction, improving the quality of products, flexibility, delivery and productivity) and the organizational research and development performance (i.e., revenue growth, net profits, profit to revenue ratio and return on assets, investments in research and development, new product development, and market orientation). The empirical findings confirmed the significant relationship between organizational performance of the SMEs and the central role of the strategic factor in the effective implementation of the TQM programs within the SMEs in Qatar.

Psomas and Fotopoulos (2010) studied 92 Greek food firms that were certified to ISO 9001:2000 and ELOT 1416 standard (hazard analysis critical control point, HACCP system certification). Data analysis revealed four latent factors regarding the TQM practices and three latent factors regarding the results achieved through implementing such TQM practices. Data analysis showed that mostly by improving a firm's quality and secondarily by focusing on customers' needs and suggestions, the main result is the achievement of satisfied customers. According to the findings, a firm's quality improvement is equally influenced by the adoption of quality practices by the top management as well as process and data quality management. A firm's quality improvement is found to be the factor that primarily contributes to customer satisfaction, while the customer focus is proved to be of secondary significance.

Psomas and Fotopoulos (2010) stated that market benefits are derived from customer satisfaction and a company's internal quality improvement. Customer satisfaction is the main driver that creates, along with the company's quality improvement, significant market benefits. Factors (i.e., process and data quality management, employee involvement, customer focus, and quality practices of the top management) are the main areas that these companies should focus on. Detecting reliable and valid latent factors of the results achieved through TQM practices implementation may motivate the food companies to strengthen their efforts in broadening their management system toward the TQM philosophy and business excellence (Psomas & Fotopoulos, 2010).

FUTURE RESEARCH DIRECTIONS

Future research direction should broaden the perspective of different practices of TQM in the knowledge-based organizations based on the industry such as hospitals, hotels and higher education and/or based on the ownership such as private and government. In addition, future research should study a greater understanding of TQM practices and other knowledge management-related variables (i.e., knowledge-sharing behavior, knowledge creation, organizational learning, learning orientation, and motivation to learn) in the knowledge-based organizations.

CONCLUSION

TQM can be summarized as a management system for a customer-focused organization that involves all employees in continual improvement. It uses strategy, data, and effective communications to integrate the quality discipline into the culture and activities across an organization, involving all departments and employees and extending backward and forward to include both suppliers and customers. To successfully implement TQM in multinational corporations, there is a need to accommodate change in terms of making practical arrangements, improving social networks for teamwork and cooperation, educating people to effectively participate in this process and inducing them to exert necessary effort for this process.

Executives and managers in multinational corporations require transformational leadership skills to systematically instill the TQM concept into the culture of multinational corporations and to accommodate change for successful implementation of TQM principles. Thus, executives and managers in multinational corporations should establish a systematic management by motivating their employees to actively contribute their manufacturing skills, enhancing the organizations' ability to succeed in the quality battle, recognizing the quality management effect that can be brought by employees, and promoting continuous improvement programs in order to achieve quality outcomes.

The driving force of higher standards and higher levels of expectation in TQM practices should compel executives and managers to do their best to improve quality. These educated managers in multinational corporations would control the TQM practices and provide feedback with their high standards for improving the quality system. Education is an important component of TQM both in the terms of informing staff on TQM practices and raising their levels of competency to effectively implement TQM principles. If they are informed about these practices, they could more easily adopt the necessary changes with less resistance. Also, if they are well-instructed, they are likely to more correctly apply the proper techniques for achieving a "zero defect" quality system. TQM is a dynamic process and demands a continuous change in an organization. For the success of these TQM practices, there is a need for a dynamic and not complacent human resource that is inclined to be easily adapted to necessary changes. According to the practices of TQM to favorably implement TQM principles in multinational corporations; there is a requirement for an effective change management that makes all the stakeholders adopt these new TQM practices, an effective in-service training for managers and staff in order to sufficiently put these TQM principles into TQM practices and an effective application of human resources to compute and sustain the efforts to build an energetic quality system. Applying the practices of TQM in multinational corporations will greatly improve organizational performance and reach business goals in the modern manufacturing workplace.

REFERENCES

Aghazadeh, S. (2002). Implementation of total quality management in the managed care industry. *The TQM Magazine*, *14*(2), 79–91. doi:10.1108/09544780210416694

Agus, A., Krishnan, S. K., & Kadir, S. L. S. A. (2000). The structural impact of total quality managementon financial performance relative to competitors through customer satisfaction: A study of Malaysian manufacturing companies. *Total Quality Management*, *11*(4-6), 808–819. doi:10.1080/09544120050008255

Ahire, S. L., & Dreyfus, P. (2000). The impact of design management and process management on quality: An empirical investigation. *Journal of Operations Management*, *18*(5), 549–575. doi:10.1016/S0272-6963(00)00029-2

Ansari, A., & Modarress, B. (1990). *Just-in-time purchasing*. New York, NY: Free Press.

Baird, K., Hu, K. J., & Reeve, R. (2011). The relationships between organizational culture, total quality management practices and operational performance. *International Journal of Operations & Production Management*, *31*(7), 789–814. doi:10.1108/01443571111144850

Batten, J. (1993). A total quality culture. *Management Review*, *83*(5), 61.

Brah, S. A., Lee, S. L., & Rao, B. M. (2002). Relationship between TQM and performance of Singapore companies. *International Journal of Quality & Reliability Management*, *19*(4), 356–379. doi:10.1108/02656710210421553

Burt, D. N. (1989). Managing suppliers up to speed. *Harvard Business Review*, *67*(4), 127–135.

Carter, J. P., Smeltzer, L., & Narasimhan, R. (1998). The role of buyer and supplier relationships in integrating TQM through the supply chain. *European Journal of Purchasing and Supply*, *4*(4), 223–234. doi:10.1016/S0969-7012(98)00013-6

Choi, T. Y., & Eboch, K. (1998). The TQM paradox: Relations among TQM practices, plant performance, and customer satisfaction. *Journal of Operations Management*, *17*(1), 59–75. doi:10.1016/S0272-6963(98)00031-X

Dean, J. W., & Bowen, D. E. (1994). Management theory and total quality: Improving research and practice through theory development. *Academy of Management Review*, *19*(3), 392–418.

Deming, W. E. (1986). *Out of the crisis*. Cambridge, MA: MIT Press.

Dow, D., Samson, D., & Ford, S. (1999). Exploding the myth: Do all quality management practices contribute to superior quality performance? *Production and Operations Management*, *8*(1), 1–27. doi:10.1111/j.1937-5956.1999.tb00058.x

Fening, F. A., Pesakovic, G., & Amaria, P. (2008). Relationship between quality management practices and the performance of small and medium size enterprises (SMEs) in Ghana. *International Journal of Quality & Reliability Management*, *25*(7), 694–708. doi:10.1108/02656710810890881

Flynn, B. B., Schroeder, R. G., & Sakakibara, S. (1994). A framework for quality management research and an associated measurement instrument. *Journal of Operations Management*, *11*(4), 339–366. doi:10.1016/S0272-6963(97)90004-8

Flynn, B. B., Schroeder, R. G., & Sakakibara, S. (1995). The impact of quality management practices on performance and competitive advantage. *Decision Sciences*, *26*(5), 659–691. doi:10.1111/j.1540-5915.1995.tb01445.x

Forza, C., & Filippini, R. (1998). TQM impact on quality conformance and customer satisfaction: A causal model. *International Journal of Production Economics*, *55*(1), 1–20. doi:10.1016/S0925-5273(98)00007-3

Goetsch, D. L., & Davis, S. B. (1997). *Introduction to total quality: Quality management for production, processing, and services*. Englewood Cliffs, NJ: Prentice-Hall.

Gotzamani, K. D., & Tsiotras, G. D. (2001). An empirical study of the ISO9000 standards' contribution towards total quality management. *International Journal of Operations & Production Management*, *21*(10), 1326–1342. doi:10.1108/EUM0000000005972

Grant, R. M., Shani, R., & Krishnan, R. (1994). TQM's challenge to management theory and practice. *Sloan Management Review*, *35*(2), 25–35.

Hackman, J. R., & Wageman, R. (1995). Total quality management: Empirical, conceptual, and practical issues. *Administrative Science Quarterly*, *40*(2), 203–270. doi:10.2307/2393640

Hafeez, K., Malak, N., & Abdelmeguid, H. (2006). A framework for TQM to achieve business excellence. *Total Quality Management*, *17*(9), 1213–1229. doi:10.1080/14783360600750485

Han, J., Trienekens, J. H., & Omta, S. W. F. (2009). Integrated information and logistics management, quality management and firm performance of pork processing industry in China. *British Food Journal*, *111*(1), 9–25. doi:10.1108/00070700910924209

Handfield, R., Ghosh, S., & Fawcett, S. (1998). Quality-driven changes and its effects on financial performance. *Quality Management Journal*, *5*(3), 13–30.

Hasin, M. A. A., Seeluangsawat, R., & Shareef, M. A. (2001). Statistical measures of customer satisfaction for health care quality assurance: A case study. *International Journal of Health Care Quality Assurance*, *14*(1), 6–13. doi:10.1108/09526860110366214

Ho, D. C. K., Duffy, V. G., & Shih, H. M. (1999). An empirical analysis of effective TQM implementation in the Hong Kong electronics manufacturing industry. *Human Factors and Ergonomics in Manufacturing*, *9*(1), 1–25. doi:10.1002/(SICI)1520-6564(199924)9:1<1::AID-HFM1>3.0.CO;2-L

Idris, M. A., & Zairi, M. (2006). Sustaining TQM: A synthesis of literature and proposed research framework. *Total Quality Management*, *17*(9), 1245–1260. doi:10.1080/14783360600750535

Ingram, B. L., & Chung, R. S. (1997). Client satisfaction data and quality improvement planning in managed mental health care organizations. *Health Care Management Review*, *22*(3), 40–52. doi:10.1097/00004010-199707000-00005 PMID:9258695

Iseri-Say, A., Toker, A., & Kantur, D. (2008). Do popular management techniques improve performance? Evidence from large businesses in Turkey. *Journal of Management Development*, *27*(7), 660–677. doi:10.1108/02621710810883580

Ittner, C. D., & Larcker, D. F. (1995). Total quality management and the choice of information and reward systems. *Journal of Accounting Research*, *33*, 1–34. doi:10.2307/2491371

Jayamaha, N. P., Grigg, N. P., & Mann, R. S. (2008). Empirical validity of Baldrige criteria: New Zealand evidence. *International Journal of Quality & Reliability Management*, *25*(5), 477–493. doi:10.1108/02656710810873880

Joiner, T. A. (2007). Total quality management and performance - The role of organization support and co-worker support. *International Journal of Quality & Reliability Management*, *24*(6), 617–627. doi:10.1108/02656710710757808

Kanji, G. K., & Yui, H. (1997). Total quality culture. *Total Quality Management*, *8*(6), 417–428. doi:10.1080/0954412979424

Kasemsap, K. (2014). The role of lean production on organizational performance. In V. Modrak & P. Semanco (Eds.), *Handbook of research on design and management of lean production systems* (pp. 358–388). Hershey, PA: IGI Global. doi:10.4018/978-1-4666-5039-8.ch017

Kaynak, H. (2003). The relationship between total quality management practices and their effects on firm performance. *Journal of Operations Management*, *21*(4), 405–435. doi:10.1016/S0272-6963(03)00004-4

Krajewski, L. J., & Ritzman, L. P. (2001). *Operations management: Strategy and analysis*. Upper Saddle River, NJ: Prentice-Hall.

Krause, D. R. (1998). The antecedents of buying firms' efforts to improve suppliers. *Journal of Operations Management*, *17*(2), 205–224. doi:10.1016/S0272-6963(98)00038-2

Kumar, M., & Sankaran, S. (2007). Indian culture and the culture for TQM: A comparison. *The TQM Magazine*, *19*(2), 176–188. doi:10.1108/09544780710730014

Kumar, V., Choisne, F., Grosbois, D., & Kumar, U. (2009). Impact of TQM on company's performance. *International Journal of Quality & Reliability Management*, *26*(1), 23–37. doi:10.1108/02656710910924152

McAdam, R., & Henderson, J. (2004). Influencing the future of TQM: Internal and external driving factors. *International Journal of Quality & Reliability Management*, *21*(1), 51–71. doi:10.1108/02656710410511696

Oakland, J. S. (1995). *Total quality management: The route to improving performance*. Oxford, UK: Butterworth-Heinemann.

Powell, T. C. (1995). Total quality management as competitive advantage: A review and empirical study. *Strategic Management Journal*, *16*(1), 15–37. doi:10.1002/smj.4250160105

Prajogo, D. I., & McDermott, C. M. (2005). The relationship between total quality management practices and organizational culture. *International Journal of Operations & Production Management*, *25*(11), 1101–1122. doi:10.1108/01443570510626916

Psomas, E. L., & Fotopoulos, C. V. (2010). Total quality management practices and results in food companies. *International Journal of Productivity and Performance Management*, *59*(7), 668–687. doi:10.1108/17410401011075657

Rahman, S., & Sohal, A. S. (2002). A review and classification of total quality management research in Australia and an agenda for future research. *International Journal of Quality & Reliability Management*, *19*(1), 46–66. doi:10.1108/02656710210413444

Salaheldin, S. I. (2009). Critical success factors for TQM implementation and their impact on performance of SMEs. *International Journal of Productivity and Performance Management*, *58*(3), 215–237. doi:10.1108/17410400910938832

Sallis, E. (2002). *Total quality management in education*. London, UK: Kogan Page.

Samson, D., & Terziovski, M. (1999). The relationship between total quality management practices and operational performance. *Journal of Operations Management*, *17*(4), 393–409. doi:10.1016/S0272-6963(98)00046-1

Sarros, J. C., Gray, J., Densten, I. L., & Cooper, B. (2005). The organizational culture profile revisited and revised: An Australian perspective. *Australian Journal of Management*, *30*(1), 159–182. doi:10.1177/031289620503000109

Sathe, V. (1985). *Culture and related corporate realities*. Homewood, IL: Irwin.

Schein, E. (1985). *Organizational culture and leadership*. San Francisco, CA: Jossey-Bass.

Senge, P. M. (1990). *The fifth discipline: The art and practice of the learning organization*. New York, NY: Doubleday.

Sower, V., Quarles, R., & Broussard, E. (2007). Cost of quality usage and its relationship to quality system maturity. *International Journal of Quality & Reliability Management*, *24*(2), 121–140. doi:10.1108/02656710710722257

Stamm, C. L., & Golhar, D. Y. (1993). JIT purchasing: Attribute classification and literature review. *Production Planning and Control*, *4*(3), 273–282. doi:10.1080/09537289308919445

Su, Q., Li, Z., Zhang, S. X., Liu, Y. Y., & Dang, J. X. (2008). The impacts of quality management practices on business performance: An empirical investigation from China. *International Journal of Quality & Reliability Management*, *25*(8), 809–823. doi:10.1108/02656710810898621

Tari, J. J. (2005). Components of successful total quality management. *The TQM Magazine*, *17*(2), 182–194. doi:10.1108/09544780510583245

Tata, J., & Prasad, J. (1998). Cultural and structural constraints on total quality management implementation. *Total Quality Management*, *9*(8), 703–710. doi:10.1080/0954412988172

Terziovski, M., & Samson, D. (1999). The link between total quality management practice and organizational performance. *International Journal of Quality & Reliability Management*, *16*(3), 226–237. doi:10.1108/02656719910223728

Toremen, F., Karakus, M., & Yasan, T. (2009). Total quality management practices in Turkish primary schools. *Quality Assurance in Education*, *17*(1), 30–44. doi:10.1108/09684880910929917

Uyar, A. (2009). Quality performance measurement practices in manufacturing companies. *The TQM Journal*, *21*(1), 72–86. doi:10.1108/17542730910924763

Weaver, C. N. (1995). *Managing the four stages of TQM: How to achieve world-class performance*. Milwaukee, WI: ASQ Quality Press.

Westbrook, J. D., & Utley, D. R. (1995). TQM – The effect of culture on implementation. *Engineering Management Journal*, *7*(2), 31–34.

Wilkinson, A., Redman, T., Snape, E., & Marchington, M. (1998). *Managing with total quality management – Theory and practice*. Basingstoke, UK: Palgrave Macmillan.

Yapa, S. (2012). Total quality management in Sri Lankan service organizations. *The TQM Journal*, *24*(6), 505–517. doi:10.1108/17542731211270070

Zeitz, G., Johannesson, R., & Ritchie, J. E. (1997). An employee survey measuring total quality management practices and culture – Development and validation. *Group & Organization Management*, *22*(4), 414–444. doi:10.1177/1059601197224002

ADDITIONAL READING

Alsaleh, N. A. (2007). Application of quality tools by the Saudi food industry. *The TQM Magazine*, *19*(2), 150–161. doi:10.1108/09544780710729999 anichchinchai, A., & Igel, B. (2009). Total quality management and supply chain management: Similarities and differences. *The TQM Magazine, 21*(3), 249-260.

Bugdol, M. (2005). The implementation of the TQM philosophy in Poland. *The TQM Magazine*, *17*(2), 113–120. doi:10.1108/09544780510583191

Chase, R. B., Jacobs, F. R., & Aquilano, N. J. (2007). *Operations management for competitive advantage*. Singapore: McGraw-Hill.

Dale, B. G. (2003). TQM: An overview. In B. G. Dale (Ed.), *Managing quality* (pp. 3–33). Oxford, UK: Blackwell.

Drew, E., & Healy, C. (2006). Quality management approaches in Irish organizations. *The TQM Magazine*, *18*(4), 358–371. doi:10.1108/09544780610671039

Feng, J., Prajogo, D. I., Tan, K. C., & Sohal, A. S. (2006). The impact of TQM practices on performance: A comparative study between Australian and Singapore organization. *European Journal of Innovation Management*, *9*(3), 269–278. doi:10.1108/14601060610678149

Fok, L., Hartman, S., Patti, A., & Razek, J. (2000). Human factors affecting the acceptance of total quality management. *International Journal of Quality & Reliability Management*, *17*(7), 714–729. doi:10.1108/02656710010306148

Fotopoulos, C. B., & Psomas, E. L. (2009). The impact of "soft" and "hard" TQM elements on quality management results. *International Journal of Quality & Reliability Management*, *26*(2), 150–163. doi:10.1108/02656710910928798

Germain, R., & Spears, N. (1999). Quality management and its relationship with organizational context and design. *International Journal of Quality & Reliability Management*, *16*(4), 371–391. doi:10.1108/02656719910266541

Gotzamani, K., Theodorakioglou, Y. D., & Tsiotras, G. D. (2006). A longitudinal study of ISO 9000 (1994) series' contribution towards TQM in Greek industry. *The TQM Magazine*, *18*(1), 44–54. doi:10.1108/09544780610637686

Gunasekaran, A., & McGaughey, R. E. (2003). TQM in supply chain management. *The TQM Magazine*, *15*(6), 361–363. doi:10.1108/09544780310502688

Gupta, M. C., & Boyd, L. H. (2008). Theory of constraints: A theory for operations management. *International Journal of Operations & Production Management*, *28*(10), 991–1012. doi:10.1108/01443570810903122

Heizer, J., & Render, B. (2006). *Operations management*. New Delhi, India: Pearson Education.

Hoang, D. T., Igel, B., & Laosirihongthong, T. (2006). The impact of total quality management on innovation: Finding from a developing country. *International Journal of Quality & Reliability Management*, *23*(9), 1092–1117. doi:10.1108/02656710610704230

Ju, T. J., Lin, B., Lin, C., & Kuo, H. J. (2006). TQM critical factors and KM value chain activities. *Total Quality Management*, *17*(3), 373–393. doi:10.1080/14783360500451614

Karia, N., & Asaari, M. H. A. H. (2006). The effects of total quality management practices on employees' work-related attitudes. *The TQM Magazine*, *18*(1), 30–43. doi:10.1108/09544780610637677

Kaynak, H., & Hartley, J. L. (2008). A replication and extension of quality management into the supply chain. *Journal of Operations Management*, *26*(4), 468–489. doi:10.1016/j.jom.2007.06.002

Kekale, T., & Kekale, J. (1995). A mismatch of cultures: A pitfall of implementing a total quality approach. *International Journal of Quality & Reliability Management*, *12*(9), 210–220. doi:10.1108/02656719510101295

Khan, J. H. (2003). Impact of total quality management on productivity. *The TQM Magazine*, *15*(6), 374–380. doi:10.1108/09544780310502705

Khanna, V. K. (2009). 5 "S" and TQM status in Indian organizations. *The TQM Journal*, *21*(5), 486–501. doi:10.1108/17542730910983407

Kumar, R., Garg, D., & Garg, T. K. (2009). Total quality management in Indian industries: Relevance, analysis and directions. *The TQM Journal*, *21*(6), 607–622. doi:10.1108/17542730910995873

Lau, A. W. T., & Tang, S. L. (2009). A survey on the advancement of QA (quality assurance) to TQM (total quality management) for construction contractors in Hong Kong. *International Journal of Quality & Reliability Management*, *26*(5), 410–425. doi:10.1108/02656710910956166

Mady, M. T. (2008). The impact of plant size and type of industry on manufacturing competitive priorities: An empirical investigation. *Competitiveness Review: An International Business Journal*, *18*(4), 351–366. doi:10.1108/10595420810920824

Mak, W. M. (1999). Cultivating a quality mind-set. *Total Quality Management*, *10*(4-5), 622–626. doi:10.1080/0954412997604

Miyagawa, M., & Yoshida, K. (2005). An empirical study of TQM practices in Japanese-owned manufacturers in China. *International Journal of Quality & Reliability Management*, *22*(6), 536–553. doi:10.1108/02656710510604872

Montes, F., Jover, A., & Fernandez, L. (2003). Factors affecting the relationship between total quality management and organisational performance. *International Journal of Quality & Reliability Management*, *20*(2), 189–209. doi:10.1108/02656710310456617

Moreno-Luzon, M. D., & Peris, F. J. (1998). Strategic approaches, organizational design and quality management – Integration in a fit and contingency model. *International Journal of Quality Science*, *3*(4), 328–347. doi:10.1108/13598539810243667

Perry, M., & Sohal, A. S. (2001). Effective quick response practices in a supply chain partnership: An Australian case study. *International Journal of Operations & Production Management*, *21*(5-6), 840–854. doi:10.1108/01443570110390516

Plenert, G. (1996). Total quality management (TQM) – Putting structure behind the philosophy. *International Business Review*, *5*(1), 67–78. doi:10.1016/0969-5931(95)00033-X

Prajogo, D. I. (2005). The comparative analysis of TQM practices and quality performance between manufacturing and service firms. *International Journal of Service Industry Management*, *16*(3), 217–228. doi:10.1108/09564230510601378

Rahman, Z., & Siddiqui, J. (2006). Exploring total quality management for information systems in Indian firms: Application and benefits. *Business Process Management Journal*, *12*(5), 622–631. doi:10.1108/14637150610691037

Robinson, C. J., & Malhotra, M. K. (2005). Defining the concept of supply chain quality management and its relevance to academic and industrial practice. *International Journal of Production Economics*, *96*(3), 315–337. doi:10.1016/j.ijpe.2004.06.055

Sakthivel, P. B., Rajendran, G., & Raju, R. (2005). TQM implementation and students' satisfaction of academic performance. *The TQM Magazine*, *17*(6), 573–589. doi:10.1108/09544780510627660

Seth, D., & Tripathi, D. (2006). A critical study of TQM and TPM approaches on business performance of Indian manufacturing industry. *Total Quality Management*, *17*(7), 811–824. doi:10.1080/14783360600595203

Sharma, M., & Kodali, R. (2008). TQM implementation elements for manufacturing excellence. *The TQM Magazine*, *20*(6), 599–621. doi:10.1108/17542730810909365

Siddiqui, J., & Rahman, Z. (2007). TQM principles' application on information systems for empirical goals: A study of Indian organizations. *The TQM Magazine*, *19*(1), 76–87. doi:10.1108/09544780710720853

Sila, I. (2007). Examining the effects of contextual factors on TQM and performance through the lens of organizational theories: An empirical study. *Journal of Operations Management*, *25*(1), 83–109. doi:10.1016/j.jom.2006.02.003

Singh, P. J., Feng, M., & Smith, A. (2006). ISO 9000 series of standards: A comparison of manufacturing and service organizations. *International Journal of Quality & Reliability Management*, *23*(2), 122–142. doi:10.1108/02656710610640916

Sit, W., Keng-Boon, O., Binshan, L., & Alain, Y. (2009). TQM and customer satisfaction in Malaysia's service sector. *Industrial Management & Data Systems*, *109*(7), 957–975. doi:10.1108/02635570910982300

Sitkin, S. B., Sutcliffe, K. M., & Schroeder, R. G. (1994). Distinguishing control from learning in total quality management: A contingency perspective. *Academy of Management Review*, *19*(3), 537–564.

Sohal, A. S., & Terziovski, M. (2000). TQM in Australian manufacturing: Factors critical to success. *International Journal of Quality & Reliability Management*, *17*(2), 158–168. doi:10.1108/02656710010304564

Sun, H. (2000). Total quality management, ISO9000 certification and performance improvement. *International Journal of Quality & Reliability Management*, *17*(2), 168–179. doi:10.1108/02656710010304573

Terziovski, M. (2006). Quality management practices and their relationship with customer satisfaction and productivity improvement. *Management Research News*, *29*(7), 414–424. doi:10.1108/01409170610690871

Thomas, B. (1995). *The human dimension of quality*. New York, NY: McGraw-Hill.

Thompson, K. R. (1998). Confronting the paradoxes in a total quality environment. *Organizational Dynamics*, *26*(3), 62–74. doi:10.1016/S0090-2616(98)90015-8

Vouzas, F., & Psychogios, A. G. (2007). Assessing managers' awareness of TQM. *The TQM Magazine*, *19*(1), 62–75. doi:10.1108/09544780710720844

Wahid, R. A., & Corner, J. (2009). Critical success factors and problems in ISO 9000 maintenance. *International Journal of Quality & Reliability Management*, *26*(9), 881–893. doi:10.1108/02656710910995073

Yang, C. C. (2006). The impact of human resource management practices on the implementation of total quality management: An empirical study on high-tech firms. *The TQM Magazine*, *18*(2), 162–173. doi:10.1108/09544780610647874

KEY TERMS AND DEFINITIONS

Continuous Improvement: A programmed flow of improvements realized under a scheme such as Kaizen, lean production, or total quality management.

Manufacturing Sector: Agglomeration of industries engaged in chemical, mechanical, or physical transformation of materials, substances, or components into consumer or industrial goods.

Multinational Corporation (MNC): An enterprise operating in several countries but managed from one (home) country.

Organizational Culture: The values and behaviors that contribute to the unique social and psychological environment of an organization.

Organizational Performance: An analysis of a company's performance as compared to goals and objectives.

Quality: A measure of excellence or a state of being free from defects, deficiencies, and significant variations.

Quality Management: Management activities and functions involved in determination of quality policy and its implementation through means such as quality planning and quality assurance.

Service Sector: An industry made up of companies that primarily earn revenue through providing intangible products and services.

Total Quality Management (TQM): A holistic approach to long-term success that views continuous improvement in all aspects of an organization as a process.

Chapter 2
Enterprise Resource Planning and Lean Six Sigma

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ABSTRACT

Over the last two decades, two of the hottest topics in business have been Enterprise Resource Planning (ERP) and Lean Six Sigma. Companies have spent millions of dollars implementing both of these, and the resulting benefits have been mixed. In this chapter, the authors examine the basic foundation of ERP and what drives organizations to implement ERP systems that cost hundreds of millions of dollars. The chapter also explores the history of ERP and who was and are the major players in the marketplace.

INTRODUCTION

The focus of this chapter is ERP. Initially this chapter will provide an overview of ERP and a historical perspective. The common characteristics of an ERP system are presented along with the current major vendors in the ERP marketplace. This will be followed by a discussion on implementation issues and challenges, along with the benefits of ERP systems. Literature reviews will be integrated throughout the chapter to align with the discussion topic of that section.

DOI: 10.4018/978-1-4666-7320-5.ch002

This chapter will also examine the critical success factors for ERP implementation and the relationship of those success factors with Lean Six Sigma. A more detailed analysis will follow addressing the functionality of ERP systems and the alignment with Lean Six Sigma concepts. This will be broken down into the major process areas as defined by of a leading vendor in the ERP marketplace and best practices integrated into these process areas. A review of some of the technical elements of an ERP system will also be presented at this point in the chapter.

The next section of the chapter will focus on the integration of Lean Six Sigma into the ERP implementation process. This will include a discussion on the requirements for a Lean Six Sigma approach to ERP systems and the implementation. The potential application areas of Lean Six Sigma concepts in ERP system will be included here. Specific areas that will be addressed include: production planning, manufacturing execution, purchasing, inventory management, sales, quality management, and service management. The end of the section will address how ERP can support an organizations Lean Six Sigma program, including an alignment framework, process applications and examples. The final section of the chapter will look at some of the new and potential future developments in ERP that impact Lean Six Sigma. This will include: big-data analytics, in-memory computing, mobile applications, and expansion of cloud ERP.

BACKGROUND OF ENTERPRISE RESOURCE PLANNING

Enterprise Resource Planning systems are defined as integrated sets of comprehensive software. These sets usually include a set of mature business applications and tools for financial and cost accounting, sales and distribution, materials management, human resource, production planning and computer-integrated manufacturing (Bancroft, Seip, & Sprengel, 1996). With combinations of these fundamental software modules, companies are able to model a wide variety of business processes (ASAP, 1996). Over the last 20+ years a majority of large corporations have implemented ERP systems to automate and to manage their complete organization. These companies count on the ERP system to coordinate order management, support manufacturing operations, track customers, vendors and employees, improve customer service, increase inventory accuracy, track cash flow and financial transactions, etc. Further complicating this environment is the interfacing of ERP systems between companies where organizations are partnering to create “business to business” electronic commerce.

ERP systems date back to the 1970s. However, the name Enterprise Resource Planning was given to these types of systems in 1990 by the Gartner Group. The history of the ERP systems begins with Materials Requirements Planning (MRP) developed by Joseph Orlicky in 1964. MRP focused on production planning and inventory control. Oliver Wight expanded MRP into MRP II (Manufacturing Resource Planning) in 1983. Wight integrated master scheduling, rough-cut capacity planning, capacity requirements planning (CRP), and sales and operations planning (SOP) into the MRP II. Both MRP and MRP II were software-based systems. In the 1970s, several IBM software engineers stared playing with the idea of integrating more financial processes into the software. These engineers eventually formed the company SAP.

The early ERP software companies were SAP, Baan, JD Edwards, and Lawson. In the late 1980s, Oracle and PeopleSoft got into the ERP market. In 1991, SAP introduced the client/server ERP architecture with SAP R/3. Currently, the ERP software market is estimated at over $25 billion annually. The largest player in the ERP market is SAP with a 25% market share. Oracle is next with 13%, followed by Sage and Infor with 6% each and Microsoft with 5%. Hundreds of other small and niche ERP companies divide up the remainder of the market (Columbus, 2013). The standard characteristics of most ERP systems include the following:

- Link all business processes automatically
- Reduce inter-processing time (transactions occur one time at the source)
- Maintain complete audit trail of all transactions
- Utilize one common database
- Perform automatic internal conversions (e.g., foreign currency, taxes, legal "rules" for payroll, product pricing)
- Improve customer service by putting data at the fingertips of any employee
- Involve users in the entire functional cycle

When examining the link between ERP systems and Lean Six Sigma one must look at the role of each. The primary objective of Lean is to remove waste, where the primary objective of Six Sigma is to reduce variation thereby reducing defects (improving quality). Now the question is how does ERP fit into this equation? (Ultra, 2012) If an organizations selects an ERP software package and decides to implement it "out of the box," in most cases they will be implementing "best practices" for the different processes supported by the ERP software. So the answer to the question is many ERP software packages contain the results of Lean and Six Sigma applications. However, many ERP implementations involve customizing the software to fit the organizations current processes, thereby eliminating the benefit of the built in "best practices."

THE ERP CONNECTION

ERP 101: Advantages and Challenges

What has been the driving force behind organizations implementing ERP systems? There is no one answer to this questions, there have been a variety of reasons that have lead organizations down the ERP implementation path. These include:

- Early adopters looking for process integration and the efficiencies created through this integration. These are the organizations that often view technology as the first solution choice in addressing process improvement, cost savings regeneration, and other business issues and challenges. A study published by the Aberdeen Group in 2007 indicated that companies in the aerospace and defense industry that had integrated technology (ERP systems) with a lean approach to manufacturing were 40% more likely to be best in class performers in the industry.
- Another group of organizations implementing ERP include those that are in an industry sector where the vast majority of firms are implementing ERP systems. These organizations do it almost out of survival, since the ERP system is sometimes viewed as a competitive advantage and not having an ERP system could be a big disadvantage. In highly integrated industries, such as oil and gas industry and the chemical industry, the pressure created by all your competitors implementing an ERP system is tremendous. Part of this is cause by the fact that your competitors can often be both customers and vendors also, so ERP to ERP integration is important for business process efficiencies. A study in 2011 showed that 79% of process manufacturing industry (measured by annual revenue) utilized the ERP systems from only one ERP vendor (SAP, 2011).
- Besides earlier adopters and industry sector ERP implementations, there is the large group of organizations who have implemented ERP systems based on the fact that the organizations legacy systems where out of date and causing process operation issues. These organizations

viewed ERP as both a way of improving operation efficiencies and saving money, plus as a replacement for aging information systems that were costing the organization money in maintenance and upgrades. In addition, many organization found themselves in the situation with old software that was no longer being supported by the software company that developed it or that software company was no longer in business. A study on ERP systems in higher education found that the leading reason to implement ERP was replacing old legacy systems (EDUCAUSE, 2002). What is interesting about this study is that it took place soon after the Y2K event, which was one of the reasons mentioned least in driving implementation of the new ERP system. However, the response deviations were highest for the Y2K event as a driver for implementation.

- One of the reasons for ERP implementations in the mid to late 1990s, was the issue of Y2K. Organizations were concerned that existing software would not support the movement from a 2 digit year to the 4 digit year. There were many "doomsday prophets" predicting that the systems would assume that it was 1900 instead of 2000 and business would come to a halt, along with utilities and government operations. While some organizations had minor issues, this ended up being a non-event. However, a large number of organizations where scared into implementing ERP systems to prevent this foretold "doomsday event."

These are just a couple of the variety of reasons that organizations have and continue to implement ERP systems. An extensive literature review addressed the use and implementation of ERP systems and lean. (Powell, 2013) In this article a framework was used to classify the themes of the literature. The first five themes dealt with the role, use and implementation of ERP systems and lean. These were:

- Enablers of competitive advantage
- Modes of implementation
- Support functionality
- The role and value of information
- Supply chain integration

One very important note here is that the article stated that no published research could be found that addressed implementation of ERP and lean at the same time or as parts of the same project. So the literature survey in this article examined these themes separately for ERP and lean.

Organizations want to identify advantages and benefits to implementing an ERP system or upgrading an existing ERP system. Some of the advantages seen in successful ERP implementations have included the following:

- **Fully integrated business functions or modules that support business processes:** The ability to have financial, sales, inventory, production, and human resource, just to name a few, passed seamlessly between these various functional areas if significant. The traditional "stove pipe" systems required data hand offs or access to multiple systems often to answer a single inquiry. For example, a customer calls the sales person involved in their order requesting a status update. In old legacy systems, this could require the sales person to check finished goods inventory, which would require either access to that information system or a call to an individual who had access to that system. One case would be that no information was available on the order in the finished goods inventory information system, so a call had to be made to someone in production to determine if the order was in process there. As you can imagine, this process could take hours if not days to get an answer back to the customer. This is not only frustrating to the customer, but very costly and inefficient to the organization selling the product. Having real time information at your finger tips, improves customer service and reduces time and costs, therefore reducing waste.
- **Helps develop understanding of business processes by tracking information thru the process:** One assumption that organizations make is that the people that work for them understand how different processes work. For example, all employees understand how the product gets to the customer at least at a cursory level. In many cases that is a false assumption. Employees usually understand only what is right around them and their own job duties. (Berman, 2010) When implementing an ERP system the introduction of an overview training session that covers how the systems works and how it connects different processes provides an excellent opportunity to show employees how the business works and how what they do impacts other people and the bottom line.
- **Move toward business process re-engineering:** This is one of the advantages of implementing an ERP system that is a direct link to Lean Six Sigma. However, this benefit is only achieved if the organization is willing to look at re-engineering processes before the implementation of the software. Otherwise, the most common result is customization of the software to meet the needs of the current processes which may or may not be optimized. Lean Six Sigma can play a very important role

here in getting the organization to eliminate waste and process variation before the implementation of the ERP system. This issue will be addressed in greater detail later on in the chapter.

- **Directly links to external systems:** The current generation of many ERP systems includes the functionality to link to other systems both internally and externally. These systems include other ERP systems and other enterprise system software such as; customer relationship management (CRM), product lifecycle management (PLM), and supply chain management (SCM). Also linking to data analytic software packages is almost a given with current ERP packages.
- **Improved organizational performance:** This is the number one goal of many ERP implementations. A recent study provided evidence of increased profits from ERP system implementations. (Hendricks, Singhal, & Stratman, 2007) The results of the research showed that early adopters of ERP had a greater improvement in financial performance. Another interesting conclusion with the limited impact on stock value, but this is influenced by much more than a single factor, such as ERP system implementation.

These are some of the advantages/benefits of implementing an ERP system. Along with these advantages and benefits are the challenges of ERP system implementation.

- **Expensive:** For large organizations ERP implementations can run into the hundreds of millions of dollars. This includes the cost of the software, hardware, implementation team (which is often an outside organization), training, project management, and other related costs.
- **Disruptive:** A new information system can be very disruptive to the business processes of an organization. People don't want to change to the new system so they may create work a rounds or ways to bypass the new system. Worse case, people will sabotage the new system. Other disruptions occur in the implementation process when you need to reassign people to the ERP implementation team and pull them out of their current job functions.
- **Change Management:** This area is either forgotten or given little attention. Organizations need to understand that the new ERP system will in most cases impact the ways employees do their job and could cause changes in the culture of the organization.

- **Best Practice vs. Current Practices:** Most organizations will believe that the way they are doing something is the best way for them and the business they are in. Convincing organizations (the people in them) that there are better practices for the processes of the organization is difficult. This is another issue that can be addressed through the application of Lean Six Sigma.
- **Difficult to Use:** This is a common response from people at their initial interface with the new ERP system. What they are really saying is that it is different than what they have been using. However, the complexity of large scale ERP systems does make them more difficult by nature. This issue can be addressed through ERP training and attention to change management issues.
- **Integration vs. Stove Pipe:** This challenge is another one that can benefit from the integration Lean Six Sigma into the ERP implementation process. Removing waste and non-value added activities from processes will result in better integration and the removal of the "stove pipe" mentality. When an organization sees the cost of the "stove pipe" approach to their organizational processes as revealed by the Lean approach, the need to eliminate these should become very apparent.

In order to gain a better understanding on the benefits achieved through adopting the Lean Six Sigma approach before an organization implements an ERP system, we will review reasons why ERP systems fail to perform as promised.

- **Lack of Top Management Support:** This applies to almost any project that creates cultural change within an organization. Having an organization committed to Lean Six Sigma will probably reduce the likelihood of only casual top management support for ERP implementation. Given the dollars invested in an ERP implementation, it is imperative to have top management's complete support and buy-in.
- **Underestimate Resource Requirements:** It almost guarantees failure of an ERP implementation to attempt to do it "on the cheap."
- **Too Much Customization:** The application of value stream mapping and other Lean tools should lead the organization to realignment of poor process and changing broken processes. In addition, the philosophy of eliminating waste should always drive the organization to adopting "best practices" that are built into the ERP system.

- **No Business Process Standardization, Optimization, or Alignment:** This issue is what often leads to organizations over customizing an ERP system. The organization ends up with automated poor and broken processes and no improvement through ERP implementation.
- **Data Cleanup Errors:** The principals of Six Sigma need to be applied here. Allowing data variation because of lack of data cleanup creates enormous problems in any ERP implementation.
- **Limited User Training:** This is an issue with most organization wide projects whether it be Lean Six Sigma or ERP. Employees need to understand what and why these projects are being undertaken and then provided the training to make them successful.
- **Too Much Reliance on Consultants:** Organizations often rely heavily on outside consultants for projects like ERP implementations or Lean Six Sigma. A better approach is to develop an internal group of experts who then determine the roles played by these outside consultants.
- **Not Getting Users Involved Early:** The people that are using the current systems and processes often know what is wrong with them and what should be fixed. Make some of them part of the project team early and avoid solving non-problems.
- **Poor Software Selection Process:** The right ERP software package for you may not be the one your competitor has selected. It is important to understand your needs and select a package that aligns with those needs. This is another issue that speaks to having an active Lean Six Sigma effort going on before you move to ERP.
- **Poor Implementation Partner Selection Process:** This follows the same reasoning as the poor software selection issue. In addition, an implementation partner needs to understand your organization culture and be able to operate within that culture.
- **Lack of Change Management Process:** Forcing people to change just because they work for you and this is what the organization needs to do is not a very good approach. As mentioned in both user training issues and getting users involved early, people want to know the why before they buy into something. This is another area where an active Lean Six Sigma effort can have a significantly positive impact.
- **Cost Cutting During Implementation:** As has been mentioned several times, ERP implementations are not cheap. Moving into a cost cutting mode during the implementation of an ERP system will usually spell disaster. One of the first things to go is training and then testing. The end of 2013 saw what happens when you don't test a new information system thoroughly before go-live (Kirchgaessner, 2013).

- **No or Poor Internal Project Management:** project management needs to be an internal function for ERP implementations. Depending on outside consultants to also provide project management oversight of the project could lead to scope creep and other scheduling issues without much organization input.

A summary of a variety of causes for ERP system implementation failures are discussed in this section. Research into actual ERP implementation failures has supported this summary along with identifying other reasons that are more behavioral in nature (Nagai, Law, & Wat, 2008). One study on ERP system implementations identified ten categories of why implementations failed: (Umble, Haft, & Umble, 2003)

1. Strategic goals not clearly defined
2. Top management not committed to project
3. Poor project management
4. Organization not committed to change
5. Weak implementation team
6. Poor training and education of end users
7. Data accuracy issues
8. No project performance measures
9. Multiple locations issues not addressed
10. Technical difficulties with implementation

This same article also identified organizations that had successful ERP implementations that were generating positive financial results including significant reductions in inventory, reduced procurement costs, and savings in logistics operations costs. Other research studies that have looked at both successes and failure have identified the costs of ERP implementation failures (Ehie & Madsen, 2005). In this article numerous cases of major ERP implementation failures are reviewed with financial losses reported in the hundreds of millions of dollars. Some companies even claim that the ERP implementation was a major factor in them going bankrupt. This article examined eight critical success factors for an ERP implementation. They are:

- Project management principles
- ERP project feasibility evaluation
- Human resource development
- Business process reengineering
- Top management support

- Cost/budget
- IT infrastructure
- Consulting services

The results of the study showed that these factors explained over 85% of the variance affecting ERP implementations. The factor that impacted ERP implementation the most was project management principles.

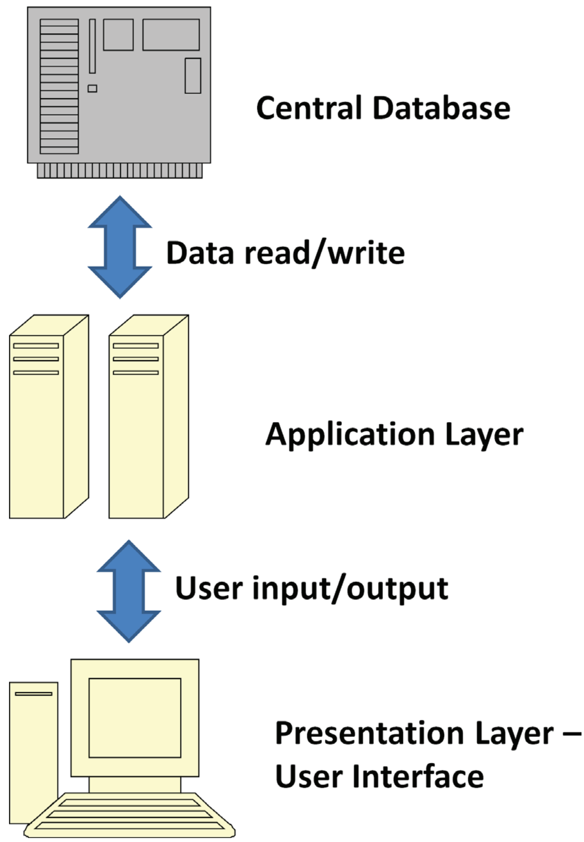
One important part of the implementation process is the selection of the ERP system software. The authors of the previous referenced article also recommended a thirteen step process for the selection of ERP software (Umble et. al., 2003):

1. Create a project vision.
2. Define features and functionality requirements.
3. Create a list of potential software vendors.
4. Reduce vendor list to smaller list of "good fit" prospects.
5. Create and issue the request for proposal (RFP).
6. Review proposals based upon predetermined criteria.
7. Select the two or three finalists for further vetting.
8. Have all finalists demonstrate product and functionality based predetermined standards.
9. Select the winner using predetermined selection criteria.
10. Create project financial justification.
11. Negotiate the contract.
12. Have selected vendor perform pilot project to demonstrate software functionality.
13. Make final go, no-go decision.

ERP 102: ERP Functionality

The key driver behind Lean is the elimination of waste. In the implementation of an ERP system one needs to determine at what level the organization wants to push Lean when it comes to ERP system hardware requirements. The concept of eliminating waste, thereby sizing ERP hardware properly is a delicate balance between current needs and future needs plus system redundancy. A standard hardware infrastructure for an ERP system is called "3 Tier," shown in Figure 1. This means a database tier, an application tier (ERP application software), and a client tier (ERP system interface – often called the graphical user interface or GUI). In addition to the hardware required for the three tier system architecture, there are hardware requires for

Figure 1. Three tier client/server architecture



the network and support equipment (UPS – uninterruptable power supply and cooling). The application of Lean in this situation is demanding. To provide a clearer understanding of the system architecture the following descriptions are provided:

- Client/Server Environment:
  - **Client:** Hardware/software environment that can make a request for services for a central repository of resources.
  - **Server:** Hardware/software combination that can provide services to a group of clients in a controlled environment.
- Three-Tier Structure:
  - **GUI:** Graphical User Interface or Web Interface.
  - **Application Server:** One or more, help distribute work load.
  - **Database Server:** One single data repository.

The system components of an ERP system usually include the following.

- Transactional database
- User portal/dashboard (web based interface instead of the GUI)
- Data analytics
- Customizable reporting
- External access to other systems
- Document management
- Workflow management
- User communication (internal ERP email)
- Data warehouse

The functional side of the ERP system contains numerous processes and the supporting processes. The most common ones are:

- **Financial Accounting:** Accounts payable, accounts receivable, asset management, cash management, general ledger, billing and invoicing, consolidation.
- **Management Accounting:** Activity based costing, budgeting, cost management, profitability analysis, cost center and profit center management.
- **Sales and Marketing (fulfillment):** Customer relationship management, sales forecasting, sales commissions management, customer service, customer contact management, sales support, call center management.
- **Supply Chain Management:**
  - **Purchasing:** Purchase requisitions and orders, quotation processing, vendor management, procurement planning, supplier scheduling.
  - **Inventory and Warehouse Management:** Warehouse configuration, inventory control, internal fulfillment, receiving, order fulfillment, product configuration.
  - **Distribution and Transportation:** Order fulfillment, claims processing, third party logistics.
- **Manufacturing:** Bill of materials, MRP, MPS, capacity planning, work center management, shop floor control, quality management, engineering, cost management, product lifecycle management (PLM).
- **Human Resource Management:** Recruiting, compensation, benefits, training, payroll, time and attendance, event management, retirement planning, professional development, performance evaluation.

- **Project Management:** Project planning, scheduling, costing and cost management, work breakdown structure (WBS), activity and task management.

Visual examples of three of the processes are presented in Figures 2, 3 and 4.

Figure 5 shows how these three processes integrate. Starting with the fulfillment process, an availability check results in identifying no finished goods inventory to satisfy the sales order, so master production scheduling (MPS) with MRP (materials requirements planning) is performed to create a production order to produce the required finished goods. During the production order process it is determined that raw materials need to be ordered to support the production order, so a purchase requisition is created to procure the required raw materials. These raw materials are eventually delivered to the production process and the finished goods are created and delivered to inventory. The fulfillment process can be completed now by shipping the finished goods to the customer.

Figure 5 shows the process integration that is standard in ERP systems. Organizations can chose to automate as many or as few of the integration touch points as they want. Lean Six Sigma would lead us in most case to automate as many as possible with overview validation to avoid process quality issues.

Figure 2. A procurement process

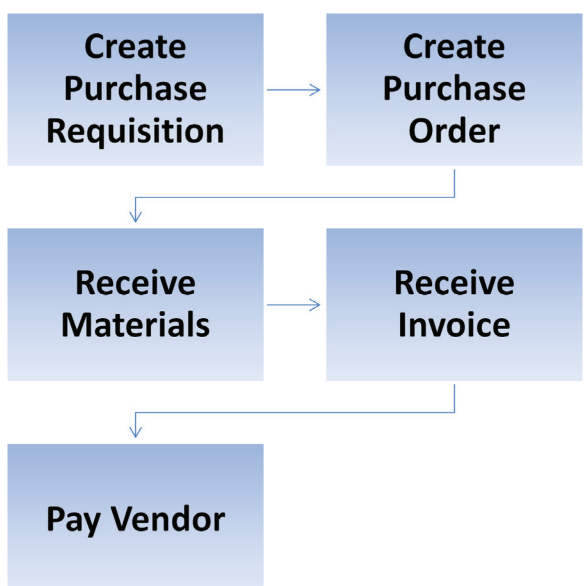


Figure 3. A production process

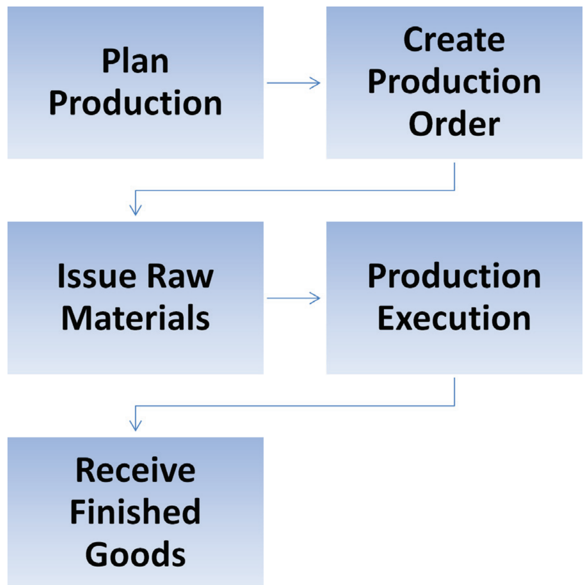


Figure 4. A fulfillment process

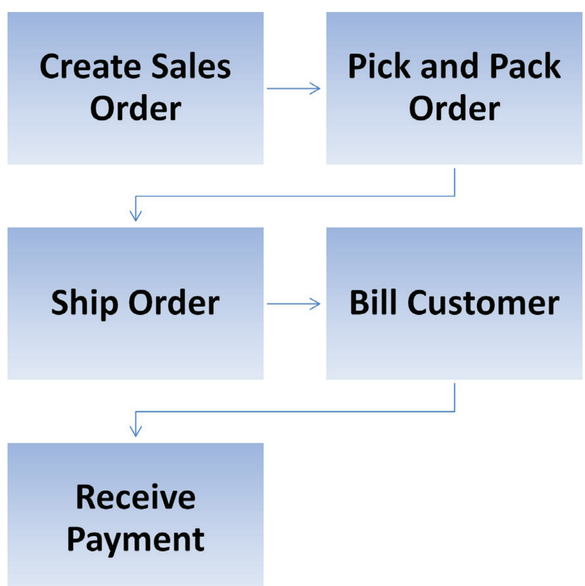
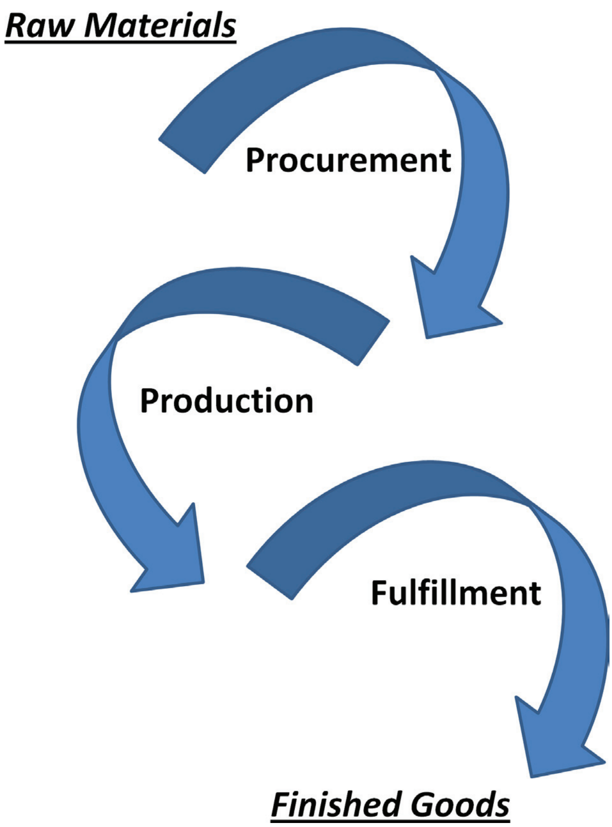


Figure 5. Process integration



Linking ERP with Lean Six Sigma

Over the years there have been many battles over the integration on ERP into a Lean Six Sigma environment, especially in the manufacturing plant. In his 2004 article in Industry Week, Doug Bartholomew points to many individuals who feel that ERP is a liability in for manufacturing companies. (Bartholomew, 2004) The criticism of ERP includes the includes issues such as;

1. Dependence on sales forecast,
2. Emphasis on planning,
3. Unnecessary data collection,
4. Not enough focus on flow functionality, and
5. A top down approach instead of bottom up.

These issues created an environment in many lean manufacturing companies where the ERP system was basically disconnected in the production for material planning and scheduling. However, organizations have found ways for Lean and ERP to exist side by side.

Doug Bartholomew revisited this issue 8 years later in a follow on article in Industry Week (Bartholomew, 2012). During this 8 year time gap, organizations had developed ways to be lean with an ERP system. This was accomplished through a variety of approaches. ERP software vendors have recognized the need for flow functionality in the software. Some of this was driven by the rise of niche software that could be bolted on to an ERP package. Organizations also realized that redesigning your business process first with lean and then standardizing them with an ERP system could lead to waste reduction in both manufacturing processes and support processes such as purchasing and finance. The ability to use ERP as a paperless communication system in a lean environment has proven very beneficial to some organizations.

The one caveat mentioned numerous times in the implementation of an ERP system in the lean environment is the absolute requirement to lean and redesign the organization's processes before implementing ERP (Bartholomew, 2004, 2012). This applies to both lean and non-lean organizations. The automation of a bad process will create more problems than it solves. In fact, through the automation of poorly designed and implemented processes the organization may just go out of business quicker.

As mentioned earlier in this chapter, there are limited studies examining ERP and lean implementation together (Powell, 2013). One thought paper addresses the integration of ERP and lean and feasibility of this integration (Deis, 2006). This chapter looks at the evolution of ERP systems and the development of more lean friendly ERP systems. As in some of the earlier papers on the topic, this article recognizes the almost love-hate relationship between lean and ERP. The author suggests that recent developments in many ERP systems have integrated lean concepts into these systems and recommends that when evaluating ERP systems for a lean organization the factors that need to be considered include.

- An embedded lean business philosophy
- Flexible processes
- Easy to integrate with other software
- Supports
    - Lean operations
    - Lean accounting
    - Flow manufacturing

- Kanban
- JIT
- Line balancing
- Vendor managed inventory
- Cycle time management
- Quality management
- Constraint management
- Process control

A white paper addresses several of the issues mentioned by Deis (2006) (Bjorklund, 2009). This paper examines approaches in the use of ERP to assist an organization in lean. The paper proposes ten requirements that will move a manufacturing organization towards lean or support the current lean philosophy, namely:

1. Balance manufacturing productivity with customer service requirements.
2. Provide extensions of the ERP system into your supply chain.
3. Have the ability to run manufacturing in multiple modes depending on product demand patterns.
4. Improve the demand management process, most organizations cannot eliminate some level of need for forecasting.
5. An integrated quality management solution needs to be part of the ERP system.
6. The ERP system needs to include flexible and accurate demand management tools.
7. Multiple modes of manufacturing need to be supported by the ERP system.
8. The ERP system must include pull strategies, JIT, and Kanban functionality.
9. Multi location ability is critical for the ERP system selected.
10. The ERP system must contain master data management capabilities that support multiple currencies and languages, supply chain extension, and standardization.

A more recent study investigated the requirements of ERP systems in support of the five principles of lean; value, value stream, flow, pull, and perfection (Powell, Alfnes, Strandhagen, & Dreyer, 2012). The authors identified 15 areas in which ERP needs to support lean production. Each of the 15 requirements is attached to one of the five lean principles. These requirements include: Kanban support, line balancing capabilities, JIT purchasing provision, and quality management tools.

Another article by the same group of authors as the previous study, proposes a process for an ERP implementation using lean principles (Powell, Alfnes, Strandhagen, & Dreyer, 2013). The study uses a standard ERP implementation process called Proven Path and integrates lean principles into the implementation guidelines (Wallace & Kremzar, 2001). The process proposed by Powell et al (2013) provides an implementation road map integrating a standard ERP implementation guide with the concepts and tools of lean. The major steps in this process are:

- Vision, planning and training
- Cost-benefit analysis
- Forming implementation team
- Establishing the lean principles foundation
- ERP system selection
- ERP system implementation
- Value stream analysis and waste reduction
- ERP go-live
- Lean manufacturing strategy
- Lean accounting
- Continuous improvement commitment
- Ongoing audit and assessment of implementation, go-live and operations

A framework is proposed to link ERP modules and functionality with lean principles. The purpose of the framework presented in Table 1 is to align lean with ERP processes.

The framework presented in Table 1 provides a summary of the ERP modules and imbedded processes in those modules that support lean principles. This is by no means an exhaustive list, but illustrates the comprehensive functionality of current ERP systems. The ERP system used for this framework is the SAP ERP system, which is part of the SAP Business Suite (SAP, 2014). The SAP Business Suite contains many additional software packages including; customer relationship management, enterprise asset management, product lifecycle management, supply chain management, sustainability, enterprise performance management, and predictive analytics.

In his paper Deis (2006) mentioned that many of the ERP software vendors had integrated more lean thinking and concepts into the software. An example of this is provided by a paper on the SAP website that addresses the "lean

Table 1. Lean/ERP alignment framework

Lean Principle	ERP Module (SAP ERP)	ERP Processes
Value	Sales and distribution Workflow Financial accounting	Sales order management Customer master data Automatic data transfer and sharing Automatic account determination Evaluated receipt settlement Budgeting and monitoring
Value Stream	Materials management Production planning Financial Accounting Controlling	Inbound and outbound logistics Inventory management Warehouse management Lean warehousing Life-cycle data management Product development Enterprise asset management Financial supply chain management Product costing Cost settlement
Flow	Production planning Sales and distribution Materials Management	Line balancing Shop floor control Mix mode planning Demand management Sales and profitability analysis Material master Transportation
Pull	Production planning Materials Management	Manufacturing Execution Kanban Poka Yoke processing Lean six sigma analysis JIT purchasing Supplier collaboration
Perfection	Quality management Plant maintenance Sales and distribution Human capital management Business warehouse	Quality notification Quality management tools Quality reports Preventive maintenance planning Predictive maintenance Service management Development and training Talent management Real-time data Financial analytics Operations analytics Workforce analytics

thinking" philosophy at SAP (SAP, 2012). SAP is the largest ERP vendor in the world and is actively involved in lean. Many of the SAP ERP products now integrate lean concepts and tools. SAP products have evolved over the last 40 years to include modules in lean manufacturing, lean warehousing, lean six sigma analysis, and make-to-order supply chain management to name a few. SAP industry applications of lean six sigma include consume product manufacturing, aerospace, chemical, retail, defense, logistics, automotive, and talent management to name just a few.

There are an ever expanding number of potential applications of ERP in a lean organization. The following is a short summary of some of these applications.

- **Manufacturing and Production Planning:** ERP can be great communication tool in this area, eliminating paper and improving data accuracy. In addition, ERP systems can provide real-time information. Some of the concerns here are not spending too much time or money on collecting data that is not important or slows down the flow.
- **Purchasing:** This is a good area for the implementation of ERP to support a lean organization. Real-time data can streamline the procurement process and reduce unneeded raw material inventories. Buyers can work in an integrated fashion with manufacturing to make sure what is needed and when it is needed is optimized to reduce waste in the system. The ERP systems can also assist in linking vendors with the organization in a more efficient manner that will save both time and money.
- **Inventory and Warehouse Management:** The ERP system must support the reduction in inventory that is the result of leaning the organization. This requires that the inventory management module of the ERP software must be capable of supporting the flow environment. If this is the case, the inventory management module will provide real-time insight into the inventory of the organization and allow employees to identify inventory problems much quicker. In addition, the ERP system supports the reduction and elimination of waste in the warehouse operations. This can include storage utilization optimization and reduction of warehouse space needed by implementation of ERP lean manufacturing applications.
- **Product and Service Sales:** Using the flow approach and reducing the need or usefulness of sales forecast is needed to have ERP and lean coexist. Lean organizations must resist the desire to return to dependence on long-term sales forecast for production planning.
- **Quality Management:** The quality management modules in ERP systems need to support Six-Sigma programs within the lean organization. Like its partner lean, six-sigma should be applied before the implementation of an ERP system. Once operational, six-sigma can be integrated into the quality management module of an ERP system.

- **Service Management:** This is an excellent area for a Six-Sigma program to integrate with ERP. Through the service management functionality of an ERP system the organization can collect quality data related to failure rates and modes, which can be used in a quality improvement and validate defect reductions.
- **Plant Maintenance:** Lean Six-Sigma organizations need to also focus on the reduction of waste in terms of time and materials related to production and support equipment failure. The optimal scheduling and implementation of a preventive maintenance program can reduce waste and improve process efficiency. ERP systems can provide an automated approach to the preventive maintenance process that can support the lean Six-Sigma environment.

ISSUES, CONTROVERSIES, PROBLEMS

The integration or coexistence of ERP and lean Six-Sigma has had a varied past. Some lean organizations who were earlier adopters of ERP found that some of the concepts of ERP were in direct opposition to the philosophy of lean (Bartholomew, 2004). In contrast, other organization found ways to make ERP and lean Six-Sigma work together. These organizations would use the ERP system to communicate information up and down the supply chain or automate previously manual processes (Bartholomew, 2004). The successful implementation of ERP into a lean Six-Sigma organization included applying lean concepts to the processes of the organization first and eliminating the waste in the processes before implementing the ERP system. Automating poor and inefficient processes does not improve organizational performance; in fact it could do the opposite.

Another issue in the ERP/Lean area has been the early lack of flow functionality in many ERP systems. This issue has been addressed by many of the large ERP vendors and has also provided a niche market for ERP system add-ons that focus on lean flow (Bartholomew, 2012). A 2004 study on lean by the Aberdeen Group, reported that many of the early ERP software vendors had begun to progress past the standard MRP based ERP systems to systems that included lean capabilities (Aberdeen, 2004).

Solutions and Recommendations

Some individuals claim that Lean, Six-Sigma and ERP can work together to achieve even greater results from continuous improve efforts (Ultra, 2012).

The model that is proposed here is using Lean and Lean tools to eliminate waste and streamline organizational processes. Six-Sigma tools are used to measure this process improvement and continue the pursuit of quality in all areas of the organization. ERP is then employed to facilitate Lean processes, automate Six-Sigma data collection and analysis, and provide real time transaction information to support the continuous improvement process. In addition, ERP systems will provide the process integration that will assist the Lean initiatives in reducing waste and increasing efficiencies. An example of making this happen is presented in a video on how Harley-Davidson uses ERP, Lean and Six-Sigma to manage a lean manufacturing (SAP, 2013).

FUTURE RESEARCH DIRECTIONS

As ERP systems integrate more and more lean and six-sigma concepts this eventually will result in technology enabled lean and six-sigma programs. The ERP systems through expanded data analytics will provide organizations the information to monitor and modify the organizations lean and six-sigma initiatives in real time.

Future research in this area could focus on further study of lean/six-sigma organizations and the use of ERP in these organizations. Some of the research questions could deal with implementation issue, organizational culture issues, software issues, and results. Another research direction could examine the change in ERP software to support lean/six-sigma initiatives. This research stream could examine the evolution of both the major ERP software vendors and the rise of niche ERP vendors who focus on lean and/or six-sigma organizations.

Future ERP Developments

One of the disruptive technologies that could have a tremendous impact on Lean/Six-Sigma is big data analytics (Analytic Systems, 2014). The ability to collect and analyze large amounts in data rapidly can have a significant impact on eliminating waste in an organization by being able to identify it in almost real time. An example of this is Nongfu Spring, a water company in China with sales approaching $2 billion per year (SAP, 2014). The application if in-memory computing to data analytics has resulted in tremendous improvements in efficiencies. The company has reduced transportation costs by 35% and improved on time delivery. In addition, freight and distribution reports that often took 24 hours to process now run in 37 seconds. The company's transportation plan for deliveries took 2 days to run, now that same plan take a little over 3 minutes.

Another development in the ERP space that could impact lean and six-sigma is ERP in the cloud. This impact could be very positive if the ERP service that is chosen is one that supports lean and six-sigma environments. The benefits here are the ability to handle changes in manufacturing compliance issues, supply chain issues, data security and data exchange. Selecting the right Cloud ERP solution can assist the organization is dealing with many of these issues (Garnand, 2012). There is also the potential for selecting an ERP Cloud solution that does not maintain currency in manufacturing compliance issues. This leads to the organization to constantly track these changes and then determine what software modifications are needed to address the IT side of the issue. For this reason, many lean organizations may prefer to keep the ERP systems in house and not in the cloud.

CONCLUSION

The partnership between Lean/Six Sigma and ERP has changed over the last several decades. Originally they were viewed by some as competing philosophies and running an organization. Some believed that adopting an ERP system created a very rigid set of rules and processes that fought against the idea of Lean and Six Sigma. Lean organizations were focused on elimination of waste and continuous improvement of process. Leaders of these lean organizations felt these goals could not be achieved in an ERP environment. However, others felt that if you adopted lean and six-sigma concepts first, then the integration of an ERP system would standardize the now streamlined processes.

Over the years as ERP vendors continued to integrate lean and six-sigma into the software and niche software vendors continued to build lean add-ons to ERP systems, the alignment between the concepts has become closer. Now you have lean organizations that run very robust ERP systems that include many of the concepts of lean and six-sigma. So the bottom-line is that ERP and Lean/Six-Sigma can exist very happily together in an organization.

REFERENCES

Aberdeen Group. (2004). *The Lean Strategies Benchmark Report.* Retrieved on January 22, 2014, from http://www.synergyresources.net/pdf/Aberdeen_LeanBenchmark_Study06_2004.pdf

Aberdeen Group. (2007). *Early Lean Adopters Embrace Technology.* Retrieved on April 1, 2014, from http://www.slideshare.net/findwhitepapers/early-lean-adopters-embrace-technology-aberdeen-group-sector-insight

Analytic Systems. (2014). *What Lean Manufacturing Means to You and Analytic Systems*. Retrieved on January 29, 2014, from http://www.analyticsystems.com/about/lean.php

Bancroft, N., Seip, H., & Sprengel, A. (1997). *Implementing SAP R/3* (2nd ed.). Greenwich, CT: Manning Publications.

Bartholomew, B. (2004). *Lean vs. ERP*. Retrieved on January 1, 2014, from http://www.industryweek.com/articles/lean_vs_erp_413.aspx

Bartholomew, B. (2012). *Can Lean and ERP Work Together?* Retrieved on January 1, 2014 from http://www.industryweek.com/articles/can_lean_and_erp_work_together_27092.aspx

Berman, R. (2010). *How Much Do Your Employees Know About Your Business?* Retrieved on December 30, 2013, from http://www.rob-berman.com/how-much-do-your-employees-know-about-your-business/

Bjorklund, J. (2009). *10 Ways to use ERP to Lean the Manufacturing Supply Chain*. Retrieved on April 2, 2014, from http://download.ifsworld.com/shop/images/WP-10_Ways_Use_ERP_to_Lean_Supply_Chain.pdf

Columbus, L. (2013). *2013 ERP Market Share Update: SAP Solidifies Market Leadership*. Retrieved December 27, 2013, from http://www.forbes.com/sites/louiscolumbus/2013/05/12/2013-erp-market-share-update-sap-solidifies-market-leadership/

ULTRA Consultants. (2012). *Lean, Six Sigma and ERP: Putting it all together for Improved Performance*. Retrieved on December 27, 2013, from http://www.ultraconsultants.com/

Deis, P. (2006). Lean *and ERP-can they co-exist?* Retrieved on April 1, 2014, from http://www.articlesbase.com/strategic-planning-articles/lean-and-erp-can-they-coexist-47604.html

EDUCAUSE Center for Applied Research. (2002). *Enterprise Systems for Higher Education*. Retrieved on April 1, 2014, from http://net.educause.edu/ir/library/pdf/ERS0204/rs/ers02043.pdf

Ehie, I. C., & Madsen, M. (2005). Identifying Critical Issues in enterprise Resource Planning (ERP) Implementation. *Computers in Industry*, *56*(6), 545–557. doi:10.1016/j.compind.2005.02.006

Garnand, L. (2012). *Can cloud computing make manufacturing compliance easier?* Retrieved on January 29, 2014 from http://searchmanufacturingerp.techtarget.com/feature/Can-cloud-computing-make-manufacturing-compliance-easier

Hendricks, K. B., Singhal, V. R., & Stratman, J. K. (2007). The Impact of Enterprise Systems on Corporate Performance: A Study of ERP, SCM, and CRM System Implementations. *Journal of Operations Management*, *25*(1), 65–82. doi:10.1016/j.jom.2006.02.002

Kirchgaessner, S. (2013). *'Obamacare' rollout issues raise concerns*. Retrieved on April 3, 2014, from www.ft.com/cms/s/0/b81e566e-35b8-11e3-952b-00144feab7de.html

Ngai, E. W. T., Law, C. C. H., & Wat, F. K. T. (2008). Examining the critical success factors in the adoption of enterprise resource planning. *Computers in Industry*, *59*(6), 548–564. doi:10.1016/j.compind.2007.12.001

Powell, D. (2013). ERP Systems in Lean Production: New Insights for a Review of Lean and ERP Literature. *International Journal of Operations & Production Management*, *33*(11/12).

Powell, D., Alfnes, E., Strandhagen, J., & Dreyer, H. (2012). *ERP Support for Lean Production. In Advances in Production Management Systems. Value Networks: Innovation* (Vol. 384). Technologies, and Management IFIP Advances in Information and Communication Technology.

Powell, D., Alfnes, E., Strandhagen, J., & Dreyer, H. (2013). The Concurrent Application of Lean Production and ERP: Towards an ERP-based Lean Implementation Process. *Computers in Industry*, *64*(3), 324–335. doi:10.1016/j.compind.2012.12.002

SAP. (2011). *SAP Corporate Profile*. Retrieved on April 1, 2014, from http://chemicalsbestpractices.sap.com/Files/2_SAP_In_The_Chemical_Industry/SAP_Corporate_Profile.pdf

SAP. (2012). *Co-Innovation at SAP*. Retrieved on April 2, 2014, from http://www.sap.com/index.html

SAP. (2013). *Improve Performance in Manufacturing, R & D, and Sustainability.* Retrieved on January 29, 2014, from http://www.sap.com/solution/lob/manufacturing.html

SAP. (2014a). *Almost Instant Gratification for Thirsty Consumers.* Retrieved on January 29, 2014, from http://www.sap.com/customer-testimonials/consumer/nongfu-spring.html

SAP. (2014b). *SAP Software & Solutions*. Retrieved on April 2, 2014, from http://www.sap.com/index.html

Umble, E. J., Haft, R. R., & Umble, M. M. (2003). Enterprise resource planning: Implementation procedures and critical success factors. *European Journal of Operational Research*, *146*(2), 241–257. doi:10.1016/S0377-2217(02)00547-7

Wallace, T., & Kremzar, M. (2001). *ERP: Making IT Happen: The Implementer's Guide to Success with Enterprise Systems Planning*. Hoboken, NJ: John Wiley & Sons.

ASAP World Consultancy. (1996). Special Edition: Using Sap R/3. Indianapolis, IN: Que.

ADDITIONAL READING

Adhikari, R. (1999, March). ERP Meets the Middle Market. *Industry Week*.

Antonucci, Y., Corbitt, G., Stewart, G., & Harris, A. (2004). Enterprise Systems Education: Where are we? Where are we going? *Journal of Information Systems Education*, *15*(3).

Becerra-Fernandez, I., Murphy, K., & Simon, S. (2000). Integrating ERP in the Business School Curriculum. *Communications of the ACM*, *43*(4).

Boykin, R., Martz, W., Jr., & Mensching, J. (1999). The Integration of Enterprise Information Systems in the Operations Management Curriculum. *The Journal of Computer Information Systems, 4*.

Joseph, G., & George, A. (2002). ERP, Learning Communities, and Curriculum Integration. *Journal of Information Systems Education*, *13*(1).

Magal, S., & Word, J. (2011). *Integrated Business Processes with ERP Systems*. Hoboken, NJ: John Wiley & Sons.

Motwani, J., Subramanian, R., & Gopalakrishna, P. (2005). Critical factors for successful ERP implementation: Exploratory findings from four case studies. *Computers in Industry*, *56*(6), 529–544. doi:10.1016/j.compind.2005.02.005

Sager, J., Mensching, J., Corbitt, G., & Connolly, J. (2006). Market Power of ERP Education – An Investigative Analysis. *Journal of Information Systems Education*, *17*(2).

Sandoe, K., Corbitt, G., & Boykin, R. (2001). *Enterprise Integration*. New York: John Wiley & Sons.

Watson, E., & Schneider, H. (1999). Using ERP Systems in Education. *Communications of the Association for Information Systems*, *1*(9).

KEY TERMS AND DEFINITIONS

Business Process: A set of tasks or activities that produce a specific business outcome/service/product. For example, the purchasing process involves purchase requisition, purchase order, good receipt, invoice receipt and payment to the vendor.

Client/Server: Is a distributed computing structure where request for information or performing transactions are issued at the client level using resources (software and applications) from the server level.

Cloud ERP: Is the delivery of enterprise resource planning software over the internet.

Data Analytics: The process of analyzing raw data to develop conclusions from the data.

Enterprise Resource Planning: A suite of integrated business software applications covering the majority of business processes of an organization.

Enterprise Systems: Are enterprise-wide software applications that involve all or most of the business processes of an organization and the analytical engines to provide real time assessment.

In-Memory: Is a technology that stores data in RAM instead of disk drives for processing, thereby reducing computational time significantly.

Transaction: A single step in a business process performed by an enterprise system (e.g. create sales order).

Chapter 3
A Framework for Nondestructive Evaluation Application in Supply Chain Management

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ABSTRACT

This chapter introduces a general framework for Nondestructive Evaluation (NDE) application in Supply Chain Management (SCM). With the support of emerging and existing technologies related to supply chain implementation, nondestructive evaluation provides an enabling platform to analyze the design, planning, and operational decisions within the upper and downstream ends of the supply chain system. This clarifies supply chain goals, supports making of efficient decisions without constraints, identifies managerial strategies that improve overall supply chain performance, competitive advantage, and profitability. Unfortunately, the desired attention has not been paid to how the numerous nondestructive evaluation technologies can be applied to supply chain management and implementation. This chapter, therefore, considers both technical and business perspectives of this application. It is from

DOI: 10.4018/978-1-4666-7320-5.ch003

these viewpoints that an application framework is proposed. It covers the various nondestructive evaluation methods, operational scenarios for each method, and application issues and challenges within the supply chain.

1. INTRODUCTION

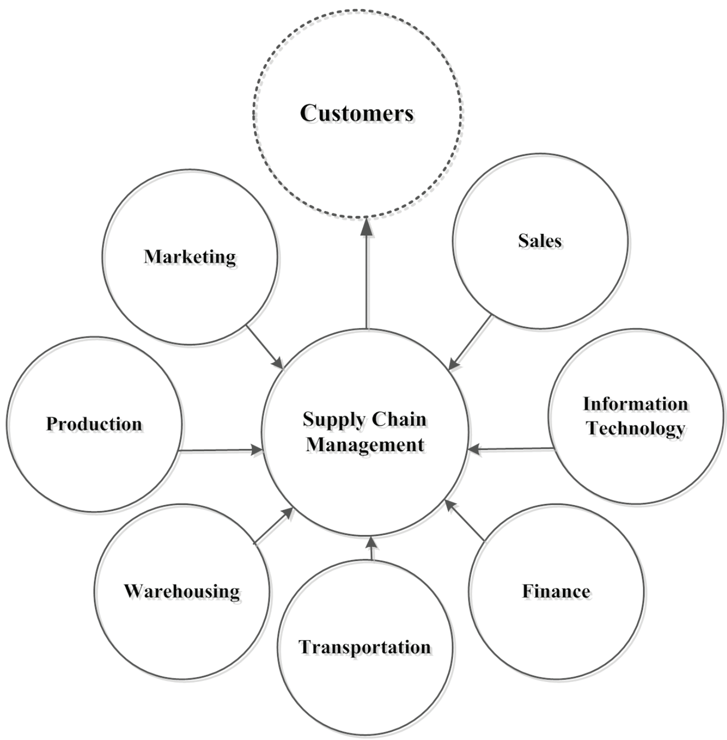
Supply chain management centers on the idea that practically every product that reaches an end user represents the cumulative effort of multiple institutions and activities. These institutions are referred to collectively as the supply chain. The overall goal of supply chain management is for production to meet the demands of the customers. However, various risk factors are prevalent in the supply chain system. These supply chain associated risks can greatly impact production and the opinion of the customer regarding a product. Understanding both the causes and effects of risks can help supply chain management stakeholders to become more proactive and productive in both avoiding mistakes and in profit maximization. These stakeholders within supply chain management work collectively in order to promote efficiency. All aspects of this collaboration ensure product success in the market. The implication of this collaboration is that all supply chain stakeholders that work within supply chains do have a common goal which hinges on meeting the ever-changing demands of customers.

In Figure 1, all stakeholders in supply chain management are shown. The supply chain is not only limited to the manufacturers and suppliers of products but includes other functional activities like transportation, warehousing, finance, customer service, information technology, sales and marketing.

A typical supply chain is dynamic and involves continuous flow of information and other resources (human, material, methods, money and machines) at every point in time. Supply chain design, planning and implementation decisions play a major role in determining whether a supply chain organization will succeed or fail. The process view of supply chain underscores the sequence of flows that occur between different functional activities which combines to satisfy the need of the customer. For a successful supply chain management, stakeholders must work together to make production, quality and logistical decisions that improve profitability.

As alluded to earlier, supply chain risk factors abound. Typical examples of risk factors are supply risk, demand risk, internal risks, and external or environmental risks. External or environmental risks cannot always be predicted but precautions can be made so that the problems that may arise can be avoided or mitigated. Supply risks are risks on the supply or inbound side of the supply chain. Such risks may be defined as the possibility of disrup-

Figure 1. SCM stakeholders



tions of product availability from the supplier or disruptions in the process of transportation from the supplier to the customer. Another crippling risk factor is known as demand risk. Demand risk is the downstream equivalent of supply risk and is present on the demand and outbound side of the supply chain. There are also risks associated with events that are related to internal operations of the organization. Such risks are known as internal risks. Examples include chemical spillage leading to plant closure, labor strikes, quality problems, and shortage of employees.

There is the notion that most of the flaws within materials and inventory are to blame for most product failures in supply chain system. Nondestructive evaluation can be a mitigating factor. A combination of more than one of the various nondestructive evaluation methods will benefit production significantly. Non-destructive evaluation (NDE) is a special analysis technique widely used in manufacturing, mechanical, systems, industrial engineering settings and aerospace applications. The term nondestructive evaluation has similarity to:

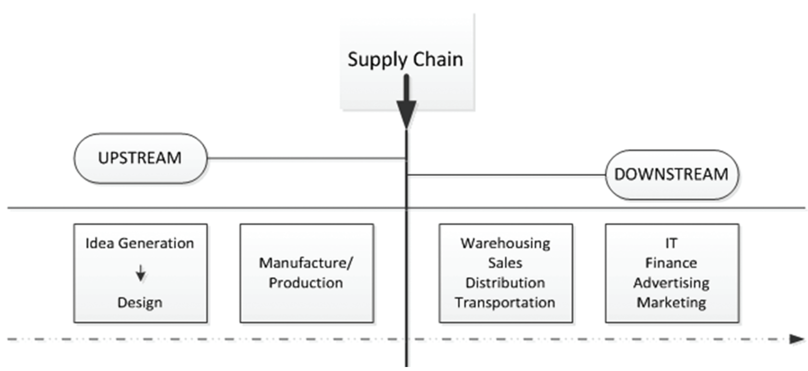
1. Nondestructive Testing (NDT)
2. Nondestructive Inspection (NDI)
3. Nondestructive Examination (NDE)

Nondestructive evaluation (NDE) will be used interchangeably for NDT, NDE and NDI respectively for the remainder of this chapter. All are commonly used terms and highly valuable techniques that can save both money and time in product evaluation, troubleshooting and research, and they are closely connected to supply chain management.

2. BACKGROUND

Supply chain management encompasses the process of creating a product from early conception design and production, and then marketing it for meeting the needs of customers. This holistic nature of supply chain management requires attention to the process of creating a product and making it available to the end customers, quite unlike focusing on only one aspect of that process. This approach connects several businesses operations involved in this process, thereby creating a system rather than a single layer of business operational activity. A typical area of movement along a supply chain pipeline concerns the raw materials themselves. These raw materials make their way from suppliers to manufacturing centers, where they are assembled into a product. Each product goes through the process of design, testing and deployment. This upstream design, manufacturing and movement of given products ensures that quality materials are utilized to create an efficient and effective product that will serve the needs of the customers downstream as shown in Figure 2.

Figure 2. Upstream and downstream SCM



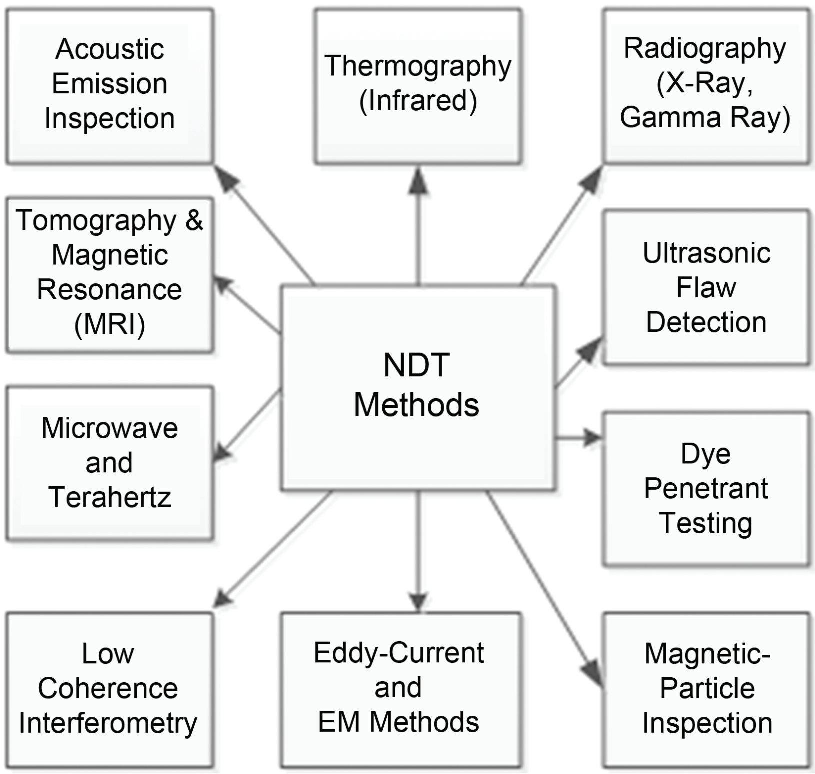
The upstream flow of product in the supply chain pipeline refers to movement through the life cycle journey from conception, design, and production of goods to the supplier. The supplier, in this case, is the source of the product supply chain. On the other hand, the downstream sector refers to the movement in the direction of the consumer, end user or customer. Consequently, the downstream level of supply chain management refers to the various management and evaluation practices that safely move materials and information to the end-user. Essentially, product(s) flowing from a source within the supply chain toward the customer is flowing downstream. In the same vein, all activities that are performed prior to a specific point on the product supply chain are characterized as upstream activities. It is important to understand how the various functional activities work together as well as knowing the strategies behind them. Furthermore, effective supply chain management, implementation and expansion can be enhanced depending on how information flows in both the upstream and downstream level of supply chain management can be integrated through various technological tools. It is important to note that classifying an activity to be upstream or downstream of supply is a function of the point of analysis of a particular supply chain.

Typically, a manufacturer or producer may consider suppliers as upstream while the customers are classified as downstream within the supply chain network. As products make their way through the supply chain network, the integrity of such products must be guaranteed. This is, therefore, the premise for advocating the use of some available nondestructive testing or evaluation technologies to pinpoint flaws within materials and equipment that support supply chain operations. Using Non Destructive evaluation can benefit a supply chain greatly by ensuring that all machinery within a supply chain is maintained and more importantly that all products are maintained up to the point where the customer receives the product. There are many valuable Non-Destructive evaluation methods that are used in order to ensure the efficiency of products. These testing methods all ensure the analysis of structures without interfering or damaging the products being evaluated.

Various nondestructive evaluation methods are shown in Figure 3.

A critical goal of any supply distribution system is to meet the demands of the customer and to accomplish that objective in a timely and cost effective manner. This requires striking a balance between the source and the customer or the supply and demand (Pearson et al., 2012). The authors discussed the various sizes of above-ground storage tanks (ASTs) commonly used in the petrochemical industries where the larger sizes are located near the source and the smaller sizes tend to be located nearer the consumer, thus, reflecting the relative supply and demand capacities across the entire supply

Figure 3. Various NDE methods



chain operations. Due to the hazardous nature of the petrochemical products to the environment, supply chain integrity is increasingly being called to question. Appropriate maintenance programs (inspection, examination, testing, evaluation, and repair) can mitigate such doubts. Crespo-Marquez and Lung (2008) discussed maintenance support to include the resources, services and management required to enable proactive decision process execution. Essentially, nondestructive testing technologies for monitoring the condition of products or systems will play an increasing role in maximizing efficient supply chain operations and minimizing unforeseen disruptive events in a less costly manner.

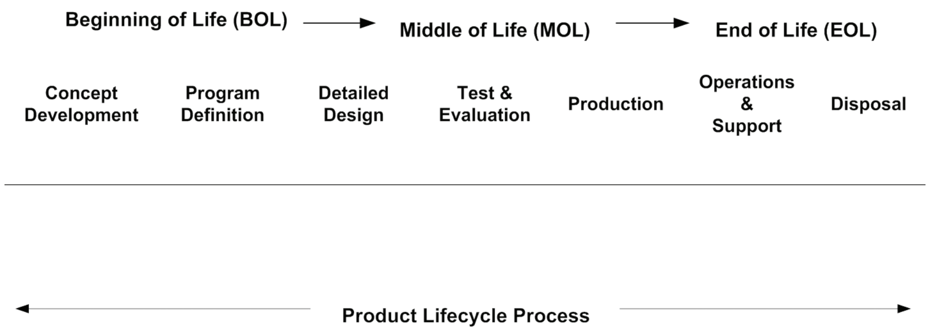
This chapter presents an overview of the various nondestructive evaluation methods and possible applications areas within supply chain management and implementation. Applications and various challenges will be discussed. For this purpose, a SCM/NDT framework is proposed. At the end, this review paper will make a modest contribution to providing an overall framework of NDE applications within the area of supply chain and supply chain management. It is understood that NDE application in the area of supply chain is still in its infancy, the framework proposed here can address design and operational issues concerning various supply chain application scenarios both in the upstream and downstream levels of supply chain management. Limitations and challenges imposed by the application of the various NDE methodologies are explored.

It is worthy of mention that nondestructive evaluation is not a new technology but an analysis technique that allows the detection and evaluation of defects in materials without disrupting the underlying properties of the surface. Ultrasonic waves and application marked the starting history of NDT where attempts were made to detect flaws in metal objects (Misiunas et al., 2006). Potts et al. (2000) presented and analyzed enhancements of the nondestructive testing workbench, a software package, for ultrasonic NDE data. The authors highlighted the tight integration between NDT datasets and 3D CAD geometries of the inspected components, which allowed proper accounting of the surface reflections during the image reconstruction process. Misiunas (2008) discussed failure management and pipe condition assessment in water supply chain systems. The author explained the difficulties associated with finding one leak detection and location technique that would have optimal performance in all instances. In effect, a good knowledge of the NDI method and the product to be tested becomes very important. These techniques can be divided into two distinct groups namely: visual NDE and non-visual NDE. A nondestructive pipe evaluation designed for condition assessment of transmission lines was discussed by Misiunas et al. (2006) and Misiunas et al. (2005) as a proactive failure management tool and for rehabilitation planning.

2.1. Product Lifecycle, Supply Chain Management, and Evaluation

Product Lifecycle Management (PLM) is an innovative paradigm that enables the management of designed products across their lifecycles. This concept represents an all-embracing vision for managing pertinent design and support related data. An effective PLM activity can improve supply chain and product life cycle performance decisions. Alting (1995) and Westkamper et al. (2001) describe the lifecycle concept as the journey from the womb to the tomb. However, the question may arise as to when the life of a designed product lifecycle should begin and when it should end (Figure 4). How well the lifecycle activities of products are evaluated can potentially defer the end of life period of the product.

Figure 4. Product lifecycle process phases (adapted from Stanke, 2001)



Through continuous evaluation, the operational lives of these products will be substantially enhanced. For example, through these activities, the operational lifetime of products like automobiles and other complex durable products are increasing (Westkamper et al., 2000).

Stanke (2001) defines product lifecycle management as the "process of managing the entire lifecycle of a product. Process and product evaluation play a major role in achieving this goal. This evaluation process begins from the concept and design phase, to production, to the supply chain and up to the point where the product is disposed of or retired" as shown in Figure 4. "Product lifecycle management covers the beginning of life (BOL), the middle of life (MOL) and the end of life (EOL) of the product" (Hong-Bae et al., 2007, p.1680). PLM, therefore, is a new strategic approach of managing the entire lifecycle of a product from its conception, through design and manufacture, to service and disposal.

The main challenge of product lifecycle management and evaluation is to enhance effectiveness while reducing costs over the lifecycle of a product taking into consideration the product's performance, effectiveness, reliability, maintainability, supportability, quality, recyclability, and cost (Fabrycky & Blanchard, 1991). PLM and evaluation must place great emphasis on the design stage of the product lifecycle, since according to (Dowlatshahi, 1992), this is where most of the product's lifecycle cost is determined.

2.2. Supply Chain and Product Lifecycle Value Analysis

All supply chain systems aim for the best lifecycle value. The best lifecycle value concept is rooted in lifecycle considerations to support a holistic perspective of product or system development or management. Although different systems may define lifecycle value differently, there are common elements of the concept that have been identified. Based on four in-depth case studies and existing models, Stanke (2001) developed a theoretical framework for lifecycle value creation which consists of three sequential and iterative processes, namely:

1. Value identification,
2. Value proposition, and
3. Value delivery

The combination of the framework and the practices from the case studies form a lifecycle value creation model, suggesting a lifecycle value approach illustrates successful strategies for product development and design. To achieve best practice, the stakeholders have to collaborate and tap into the know-how of all team members at every stage of the product or system lifecycle. In order to minimize the risks and to secure the maximum results, all lifecycle stakeholders should be part of the value-stream adding processes. Continuous product and process testing and retesting is therefore critical to achieving these goals. However, this largely depends on the extent of the value that they contribute. Kiritsis et al. (2003) proposes and discusses an approach for creating value by means of transforming information into knowledge using an approach known as Product Lifecycle Management and Information tracking using Smart Embedded systems (PROMISE). Basically, the transformation process takes place at every phase of the lifecycle of a product. This process improves the service, quality, efficiency, and sustainability and supportability of a product. RFID technology is one of the main technologies that allows for PROMISE to be realized. In the context of this paper, RFID becomes a veritable tool for product tracking for evaluation at every stage of the product's journey through the supply chain. Kiritsis' et al. (2003) work proposes a way to allow workers at all lifecycle stages of a product (such as designers, maintenance operators, and recyclers) to contribute to the tracking, managing, and controlling of product lifecycle information.

2.3. NDE Application in Supply Chain Management

A handful of failure tests and quality inspections have been performed using nondestructive techniques (NDTs) over a wide range of materials/functions within their own limitations. These drawbacks are to be identified and classified with standard technology while passing through risk-zone factors in the consumable market. Most of the optical non-destructive testing (NDT) including fiber optics, electronic speckle, infrared thermography, endoscopic and terahertz technology etc. has gained more attention in recent years (Zhu, 2011). Another practical and popular technique is the ultrasonic inspection technique for nondestructive evaluation and structural health monitoring. There is a discussion of pulse echo based ultrasonic testing for the inspection of adhesive bonds between very thick composite plates (Chakrapani, 2012). In order to improve the simulation efficiency of ultrasonic field, a new explicit integration algorithm of time domain has also been introduced for numerical simulation of electromagnetic acoustic testing (EMAT) signals (Pei et al, 2010).

However, ultrasonic waves are not very effective in detecting internal defects in some materials such as ceramic foam tiles used in the thermal protection system of the space shuttle, thick polymer composites, and polymer tiles used in various applications. On the other hand the electromagnetic radiation in THz (1000 GHz) frequency range can penetrate deep inside these materials and opens a new direction of internal NDTs especially for non-metallic materials (Rahani et al., 2011; Lopato & Chady, 2013; Chen et al., 2009).

An additional nondestructive technique for determining thermal conductivity and volumetric specific heat of the thermal barrier coatings by laser based harmonic heating of the film is being developed Bennett and Yu, 2005). Other approaches to the detection of various types of defects such as delaminations, disbonds, foreign object inclusions and porosity are possible- several non-destructive evaluation techniques like ultrasonic, low frequency acoustics, infrared thermography and shearography can also be used (Dragan & Swiderski, 2010; Vijayakumar et al., 2012). There is a recent study about image processing methods applied on the radiographic images of welding defects such as slag inclusion, porosity, lack-of-root penetration and cracks with other NDT methods to make accept/reject decisions as per the international standard (Rathod et al., 2012; Yazid et al., 2012). Similarly, a quantitative imaging of defects in conductive materials by means of eddy current testing (ECT) and numerical models of the interaction between the probe and the defect has been reported (Rubinacci et al., 2009).

Out of a dozen of standard NDTs, ultrasonic testing (UT) becomes impracticable and irrelevant for certain complex and rough surfaces inspections as discussed above, while radiography takes over the challenge and works very well. Conversely, radiography also becomes non-operative for a very thick or dense material where ultrasound works easily. Additionally, updated version or modified NDT methods such as digital radiography, phased array ultrasonic or ultrasonic guided wave inspections are readily available in the market with their own merits and demerits. Therefore, it is essential to investigate as well as acknowledge the flaw detection mode that appears during testing, and needs further prevention prior to entering the channel to the market. Therefore, threshold of flaw detection is itself a major variable that should be measurable in the whole process of NDTs. Several factors including proper training and personal management for non destructive inspections cannot be avoided even if using cutting edge software, sophisticated code and industrial standards.

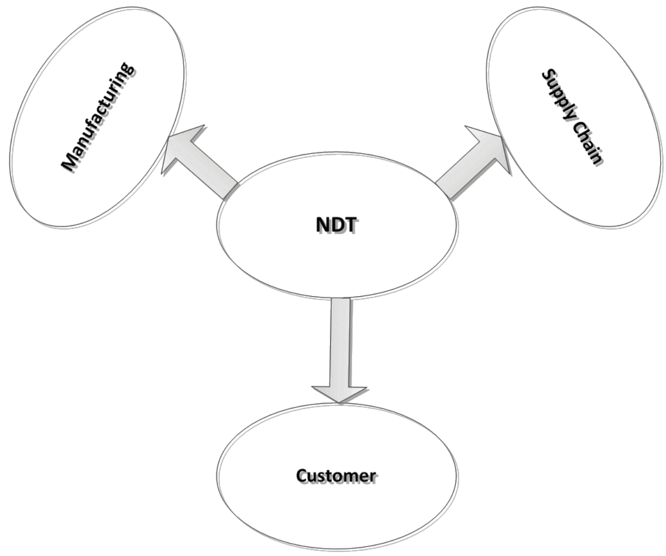
Debates about improved NDT technologies and their consumable marketing behavior regarding product reliability and their functionality are very important. Parameters such as cost effectiveness, device portability, and user-friendly interface are essential factors that can be assessed through the supply chain pipeline, in contrast to other more expensive methods. Therefore, a proper integration of a selective Nondestructive inspection method with the emergent consumable market value makes the technology comparatively cost effective. For example, portable phase-array ultrasonic NDTs are to be acceptable in near future while updating inspection codes, operation procedures and maintaining industrial standards, comparison to the conventional UTs (Jesse & Moles, 2005; Phased array testing basic theory for industrial applications, 2010). Similarly, ultrasonic guided wave NDT has more operational window over a larger surface, can be controlled remotely, and could potentially be integrated with energy harvesting applications, could make 10% of the market value per year in 2020 vision. Major marketing variables such as consumable cost, operation skill, relative sensitivity, training procedures etc. can be modeled through randomness or distribution functions, for a timely selection of best inspection method (Rose, 2010; 2011).

Typical uses of NDEs in supply chain environments (Figure 5) abound. Nondestructive evaluation can be utilized to assess the presence of hazardous physical objects inside of a product as well as microbial contaminants (Opara, 2002). The author discussed NDI within the purview of quality and safety measurement technology as a technological innovation that can be applied in a system where accurate and timely traceability of products and activities are required, especially in the food and agribusiness.

SCM is identified as an essential integrating tool for activities of the various supplier partners (Viaene & Verbeke, 1998) with a view to improving supply chain performance through the delivery of safe, desirable and good quality food products in an efficient and cost effective manner.

Products and their components require complex testing and evaluation procedures. For complex durable products like airplane engine parts or components, the testing process can be time consuming and complicated (Guide et al., 2003). In Figure 5, nondestructive inspection is relevant to the manufacture and production of a product, the movement as well as the delivery of

Figure 5. NDT and supply chain



such product(s) to the ultimate customer. These networks of organizations and processes, according to Christopher (2008) involve upstream and downstream linkages that produce value in the form of finished products for the benefit of the final consumer. Speck (2005) discussed sources of potential risks in supply chains. The author described these risks as consequential risks or unanticipated side-effects to supply chain processes which arise from specific managerial decisions, requirements or general trends in the industry. Furthermore, the attraction of outsourcing, the global nature of supply, and counter trade agreements have been identified as legitimate sources of potential risk to efficient and effective supply chain performance. The challenge imposed by the safety-critical nature of some products in the supply chain network and overall complex operational and industrial environment are noteworthy.

Carino (2013) views visual inspection as a powerful nondestructive test (NDT) method for evaluating the condition of concrete structures with the assistance of knowledge and experience. The author utilized an impact-echo method to illustrate the type of information with which team members conducting evaluation should be familiar. Four distinct topic areas were isolated: basic principles that form the foundation of the method, significance of data acquisition parameters and testing variables, planning for investigation and interpretation and verification of data. These topical areas are applicable to any NDT method. Procurement of electronic devices, for example, requires highly skilled practice and therefore can benefit from the analytic capability of the analytic team that provides guidance on the part form, fit and function to meet a device or part specification (Shade, 2009).

Therefore, the NDT market can grow not only through the improvement of conventional technology but also through the emergence of new ideas or methods with cost effective, safe, user friendly and increasingly accurate approach. The example of Terahertz ND inspection is the newly selected technology owing to its ability to detect flaws over strongly curved surfaces and with high resolution image processing capability in contrast to digital radiography techniques. Similarly, nanotechnology based NDTs which are versatile in detecting nanocracks or defects much ahead of the materials' failure need urgent attention for use in the emergent market. There looks to be a vast application of such ND evaluation for aerospace, highways, government and private sectors, due to the current marketing trends of using improved software, high speed devices, large coverage, portability etc. to create a low-risk product.

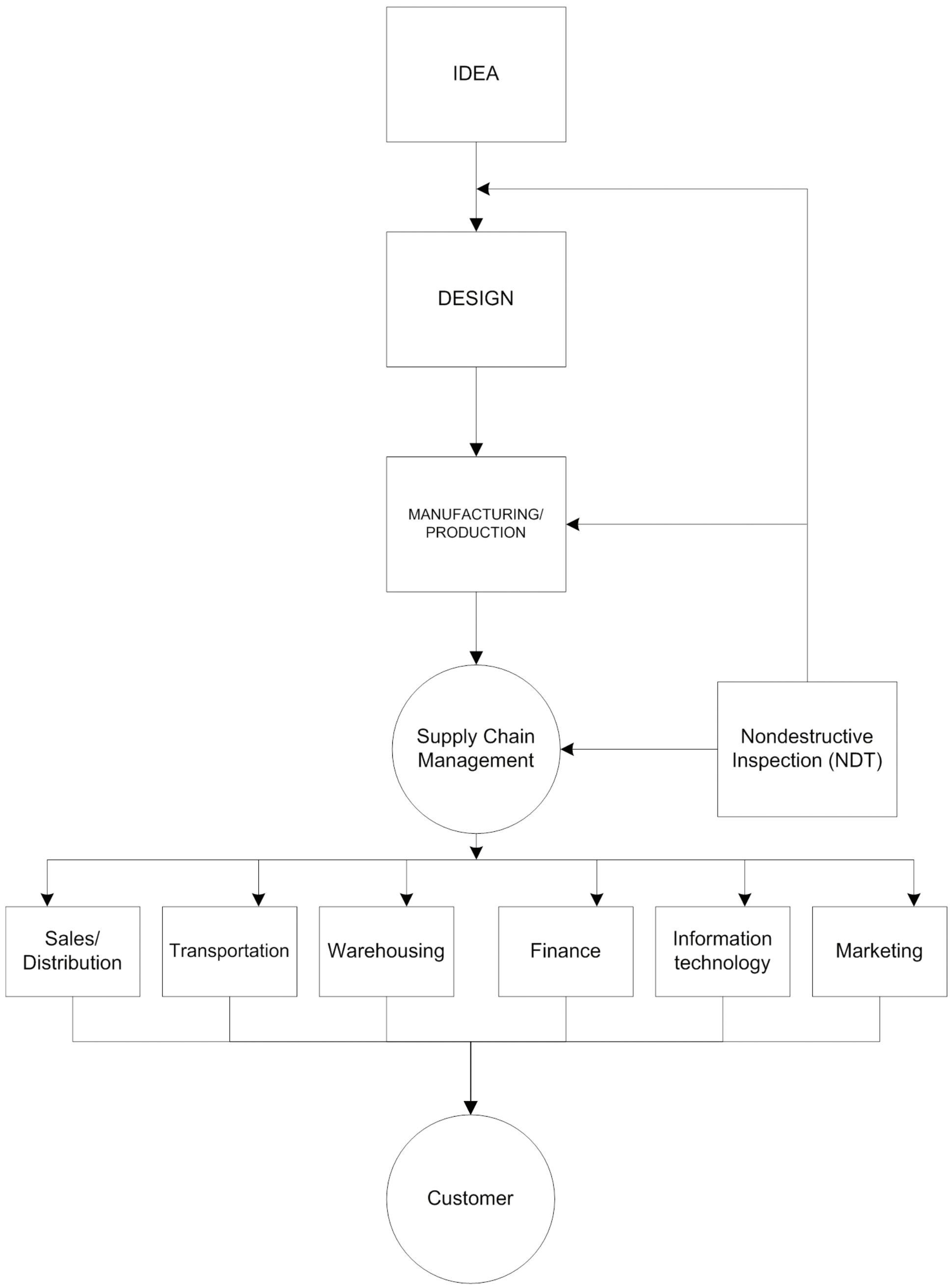
3. NDT/SCM FRAMEWORK

The objective when designing an NDT and supply chain framework is to fully take advantage of the operational performance of the supply chain stakeholders while at the same time satisfying the needs of customers. In the framework, the journey of a product begins from the ideation stage. After careful and sustained iterations, the idea is transformed to design. From the design profile, the product goes into production and manufacturing. Once the production is complete, the product begins its life cycle journey. Beginning of life (BOL), according to Jun et al. (2009), is where the product is physically realized. Once the product is physically realized, it goes into the supply chain system where all the functional areas of supply chain operational environment have to interact so as to realize the goals of supply chain management and operation.

Figure 6 shows NDT/SCM framework which captures the transitional stages of product from the conception stage till it reaches the consumer or end use.

To design an efficient framework supply chain system designers must consider all factors and functional relationships described in the framework. Perhaps the greatest risk to a company's success is an unsatisfied customer. A supply chain is most productive when the demands of the customers are met. All stakeholders within the supply chain are geared towards ensuring the satisfaction of the customers. Perhaps the greatest risk to a company's success is an unsatisfied customer and the supply chain is most productive

Figure 6. NDT/SCM framework



when the demands of the customer are met. An organization aspiring to be ahead of its competition must constantly improve its products and also create new, innovative and smart supply chain system that capture changes in the taste of customers and their preferences.

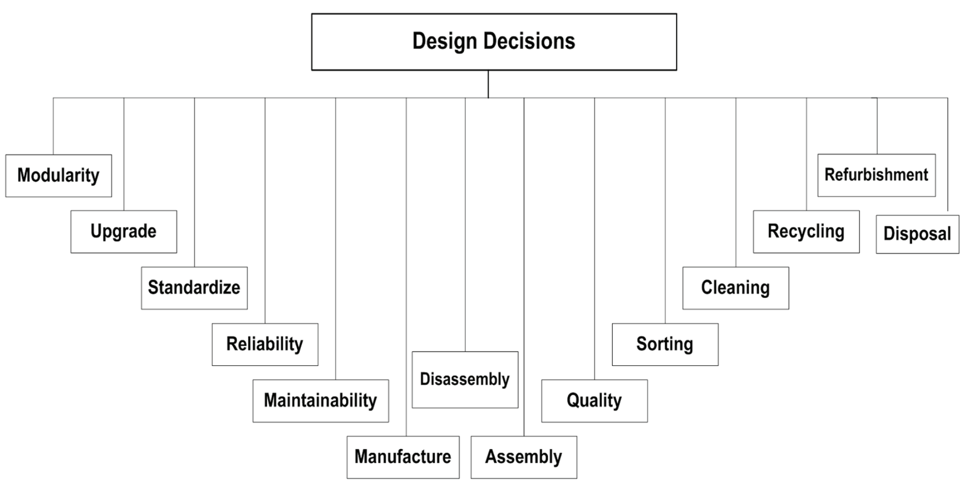
Any successful organization must continually improve the products in its supply chain and the whole idea is to create methods that guarantee customer friendly value delivery. Managing life cycle data becomes possible because reliable tools to manage a product's design and improvements throughout its operational life cycle will be provided. This ensures that products undergo continual improvement over the course of their lives. Also, supply chain organizations are able to optimize their processes regarding quality and regulatory standards. In addition, it has the potential to improve reaction time to market oscillations and other unforeseen and potentially crippling challenges.

3.1. NDT and Product Design

Designing a product encompasses multiple stages and multiple decisions as shown in Figure 7.

These stages begin with conducting requirement analysis, followed by preliminary design and then a more detailed design. Experience has shown that design is an open ended process and therefore continues to evolve until a seal of approval is given. Product design scope cuts across a variety of subject areas and faces challenges that range from complexity of design, specifications, integration and support. Likewise, design output can range

Figure 7. Major product design decisions (Uzochukwu & Udoka, 2012)



from design of products and systems, to design of processes and services. Noninvasive and nondestructive evaluation should be carried out at every stage of the product design process. Figure 6 shows major product design decisions.

Design practices are becoming dynamic and these changing trends are global in nature. Therefore, product and a system designer's preparedness to respond quickly and innovatively to changing customer demands has the advantage of offering products with higher performance and greater overall customer appeal. In his contribution, Kamrani (2001) emphasized the need for organizations to make products that can be easily configured to offer distinctive capabilities. Sacket and Holbrook (1988) saw a connection between high manufacturing costs and why early design tools focused so much on design for assembly. These decisions will provide a unified perspective on what sustained performance requirements are and how appropriate data is gathered for making the requisite design decisions to ensure sustainment and supportability of the product when deployed.

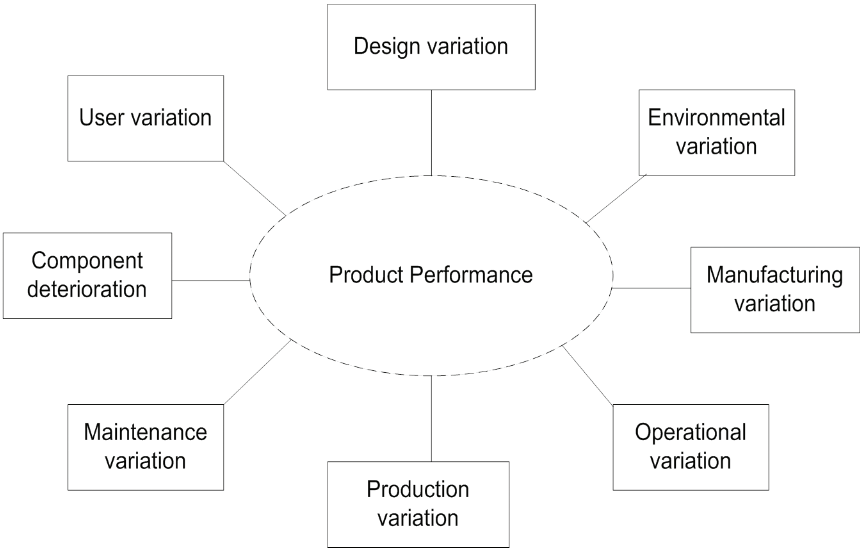
3.2. Manufacture and Production

Integrating a full range of policies, techniques, and practices that cause a product to be designed for the optimal manufacturing cost, quality, and overall operational lifecycle supportability defines design for manufacture and production (Stoll, 1990). This definition ties into the objectives of the design for manufacture and production which includes identification of product concepts that are inherently easy to manufacture or produce, focusing on ease of manufacture as well as integrating the manufacturing process design and product design to ensure the best matching of needs and requirements are met (Figure 8).

Incorporating the robust design approach can lessen warranty returns by making unplanned product failures less likely. Therefore, robust reliability design and robust sustainment design can analyze failure times to identify significant factors, and their optimal settings for reliability and sustainability using statistically designed experiments.

Other noninvasive tests include environmental stress testing (EST) and accelerated life testing (ALT) addresse various environmental noise factors that are encountered. This underscores the need to make products robust against environmental stresses. Environmental stress testing (EST) is usually conducted in the design cycle, thus becoming a value-added process in terms of product reliability improvement. In the case of ALT, it is useful in identifying potential failure modes and normal operational stress levels of products at the design stage of product development.

Figure 8. Robust design performance issues



4. COMPARATIVE ANALYSIS OF VARIOUS PARAMETERS WITHIN NDT/SCM APPLICATION

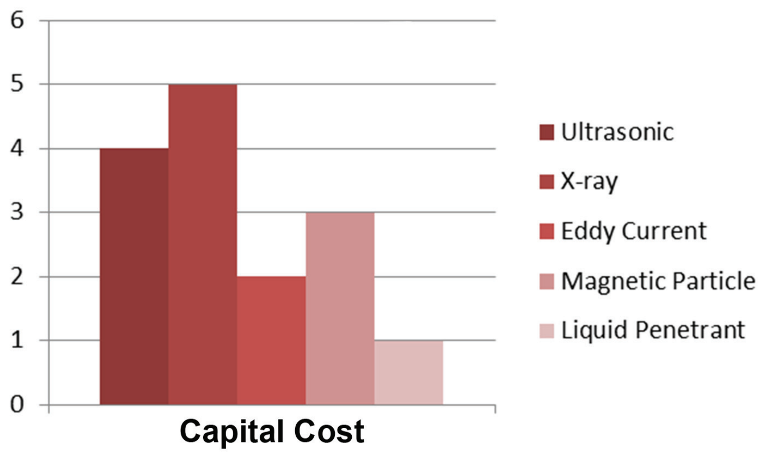
In this section, analyses of five selected NDE methods are shown. The NDE methods are Ultrasonic, X-ray, Eddy Current, magnetic particle and Liquid Penetrant. The parameters that are taken into consideration are capital cost, consumable cost, relative sensitivity, operators skills, training needs and portability of equipment.

4.1. Capital Cost

Capital cost is a very important variable to consider when determining which NDT method to perform. Every test requires a certain amount of financing to perform quality inspections. Capital cost takes into consideration all the important financial aspects that a test must include like man hours, equipment, transportation, training and education (Pearson et al., 2012). The cost of implementing an NDT method needs to be properly assessed before considering which test is most suitable for a certain product. In Figure 9, the capital cost implications are shown.

The financial organization within a supply chain is responsible for the accounting of all major expenses and finding the means to provide funding for other organizations within a supply chain. According to Management

Figure 9. Capital cost

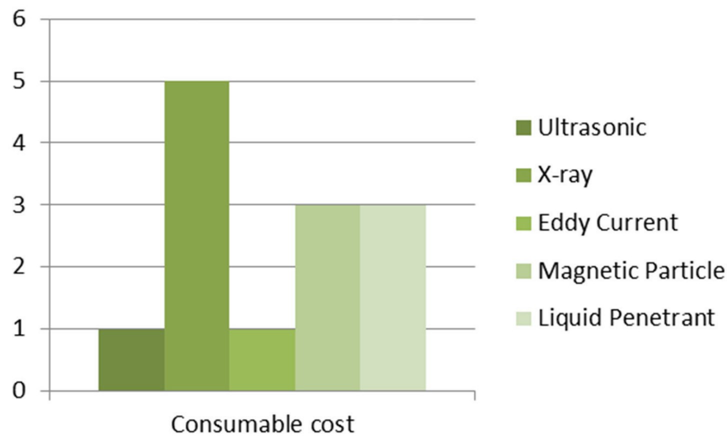


Review (2001), many researchers have been searching for better ways to pinpoint flaws within materials, since many experts in manufacturing believe that materials are to blame for most product failures. Having the financial stability to ensure the satisfaction of a customer by using NDT methods proves that a method is reliable (Management Review, 1966). Haywood and Peck (2003) identified the combined impact of irregular demand patterns, measures introduced to reduce costs, changes and upgrades to product specifications, and customer determined network reconfigurations as the main reason behind high levels of uncertainty and constant change within the supply chain network. Numerous nondestructive evaluation methods can be required to fully meet the demands of a specific inspection application. This assertion holds true for radiography. In this area, a wide variety of films have been developed for the specific quality requirements. Currently options for radiography encompass not only film application, since it is now possible to meet a wide range of NDT evaluation applications with digital solutions that are dependable and cost effective.

4.2. Consumable Costs

Consumable costs are the needed expenses that a manufacturer must make in order to administer a nondestructive evaluation of a product. It is imperative for funding to be in place for all consumable costs that may arise during NDT tests because a failure to consolidate the means to fund a test may result in a loss of profits and a lack of funding available to perform a proper testing

Figure 10. Consumable cost

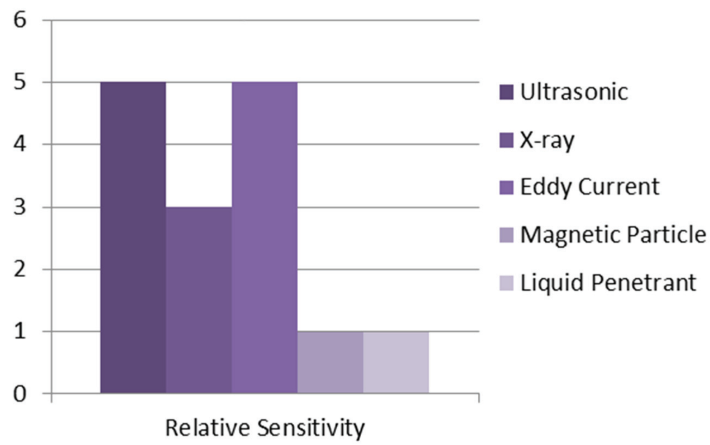


method. The much needed cost saving can be achieved by detecting defects in a product or part of a product before the product gets to the place where potential consumers can find it. In Figure 10, the consumable cost comparision between impacts are shown.

4.3. Relative Sensitivity

Certain NDT methods are implemented with equipment that is more sensitive than other methods. For instance Ultrasonic testing requires certain instruments to block audio interactions that would interfere with the results. Factoring in the sensitivity of NDT methods would allow a company to be able to make the necessary arrangements so that the results are more accurate. Qaddoumi et al. (2002) discussed variations in microwave testing of thick composite structures and how challenging it can be. Testing of some products within the supply chain can also be an important and challenging exercise. The authors noted that, although, these methods are very sensitive to the presence of thin disbonds and delaminations, they are also very sensitive to changes in the standoff distance. This change can be produced as a result of a number of reasons such as the scanning procedure, surface roughness or slowly changing undulations associated with a composite specimen (Figure 11). The paper also articulated the results of a study in which complex sandwich composites with authentic anomalous regions were used and how a microwave testing system capable of automatically eliminating the adverse influence of standoff distance and surface roughness changes was developed.

Figure 11. Relative sensitivity

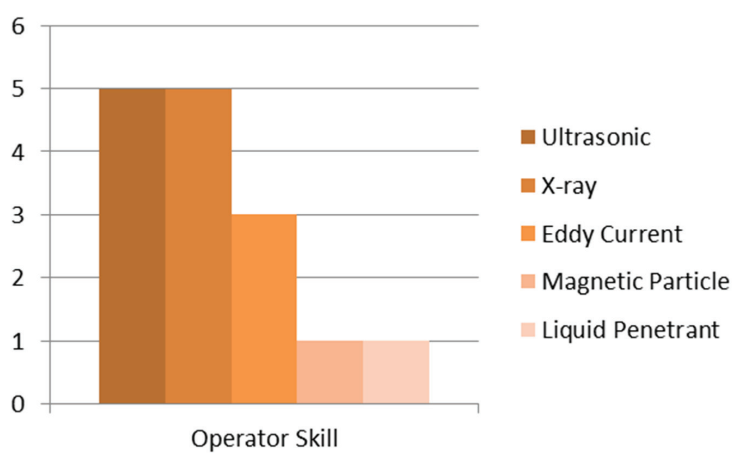


4.4. Operator Skill

Some NDT methods require background experience in order to perform. Knowing which NDT method needs experience is important so that employees with little experience are not qualified to perform methods with certain instruments. For example, liquid penetrant inspection can be performed with minimal capital expenditure (Figure 12).

The reason is primarily because materials used are low in cost per use and the method is applicable to complex shapes. Also, it is widely used for gen-

Figure 12. Operator skill



eral product assurance (Rummel & Matzanin, 1997). The capability of' this liquid penetrant depends on the material, procedure, experience and skill of the operator.

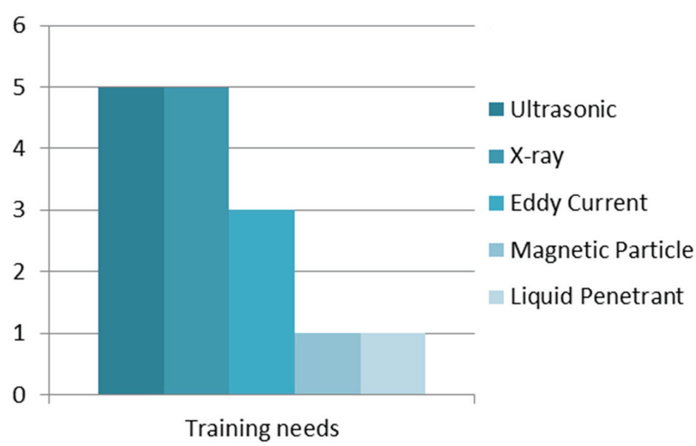
Shitole et al. (2006) discussed the ultrasonic Time-of-Flight Diffraction (TOFD) technique as a reliable form of nondestructive testing. This technique is gaining rapid prominence in non-destructive testing because of its high accuracy level in the detection, positioning and sizing of weld flaws in steel structures. This is relevant in the product supply chain operational environment. This NDT method is good at detecting most internal defects with the added benefit of immediate results. In addition, testing can be performed 'on site' as the equipment is fully portable with low running costs and a good safety hazards record. However, the authors caution that TOFD interpretation requires experienced operators for reliable detection of defects.

4.5. Training Needs

All NDT methods require knowledge and experience in order to find valuable results that will benefit a company. Adequate training (Figure 13) is needed for certain methods and some methods require greater amounts of training for employees. In the same essay it is pointed out that knowledge of the advantages and limitations of various test methods is needed to select the most appropriate technique or combinations of techniques for a project (Carinos et al., 2011).

Brence and Brown (2002) described the discovery and comparison of empirical models to predict corrosion damage from non-destructive test

Figure 13. Training needs



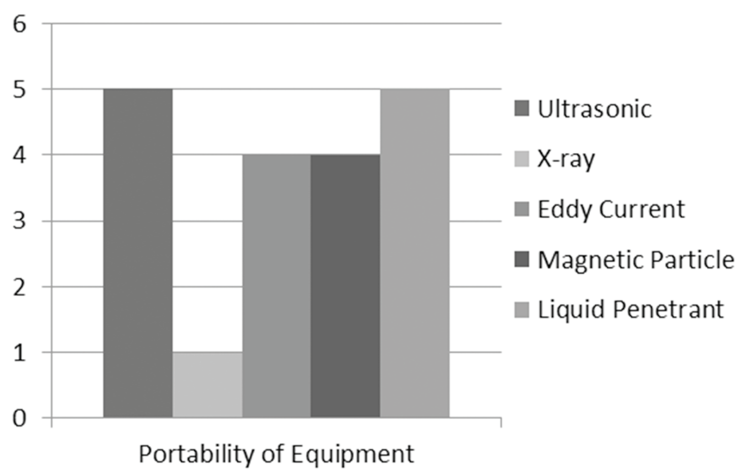
(NDT) data. These data were derived from eddy current (EC) scans of the United States Air Force's (USAF) KC-135 aircraft. Personnel to carry out this task must be well trained in all rudimentary tasks associated with this exercise. The author asserts that this is because the NDT data have been converted into false color images that are analyzed visually by maintenance operators. Due to the complex nature of the models, personnel to handle the appropriate data mining approaches must be extensively trained. This is to ensure these personnel can more effectively handle noisy data through more complex models as opposed to when they are simple. Operators with strong training backgrounds can manipulate the modeling techniques which can predict corrosion with reasonable accuracy the complex relationships between the eddy current measurements and the actual amount of corrosion. In "Training: Often the missing link in using NDT methods," engineers require training to distinguish between features that are expected and those that are not expected and indicators of abnormal conditions (Carinos et al., 2011).

4.6. Portability of Equipment

Certain facilities require different NDT methods because of the size of the equipment and that equipment's ability to be moved as shown in Figure 14. Products within the pipeline supply chain require that inspections be performed in very difficult and challenging situations

Understanding the portability of the equipment that a company can facilitate can ensure easy and efficient testing. In Zhu Jinying's (2013) essay "Com-

Figure 14. Portability of equipment



parison of NDT Methods for Assessment of a Concrete Bridge Deck," it was evident that the portability of the NDT equipment that would be used was also an important factor to consider before deciding on a method. Satter and Brenner (2009) discussed the development of a portable nondestructive testing (NDT) robotic arm that can be carried by climbing and walking robots (CLAWAR). According to the authors, the arm is designed and required to maintain, during a scanning trajectory, a desired NDT probe contact force and orientation to evaluate defects in turbine blades. In their research, tests were performed on turbine blades using eddy-current inspection techniques to assess the quality of defective data using manual inspection and automated inspection.

4.7. Summary

While there is no such thing as a perfect NDE method, it is possible to find a method that is better suited for a certain task. This chart below shows five popular NDE methods and important issues to consider before implementing these methods like capital cost, consumable cost, time to results, effect of geometry, access problems, type of defect, relative sensitivity, formal record, operator skill, operator training, training needs, portability of equipment, dependent on material composition, ability to automate, and capability.

5. DISCUSSIONS

As of the current trends of miniaturization of electronics devices including integrated circuits, new packaging technology continues to be developed. Packaging has a role to play in supply chain management as it can potentially influence how the supply chain is to be managed. Sarkis (2003) identified procurement, production, distribution and reverse logistics as key elements of a product's operational life cycle. The author also included packaging as an element within the operational life cycle because of its profound and lasting impact on supply chain as whole but adds that packaging may not necessarily be viewed as a typical stand-alone operation. The devices that are presently being fabricated with sub-22 nm features definitely require novel nondestructive evaluation (NDE) techniques, in order to analyze defects that evolve especially at the micron or nano-scale. The key issues of defect formations are due to micro or nano-cracks in the packaging materials, voids at the grain boundary, intermetallic phases, thermo-mechanical stress etc. Modern nano technologies such as near- field-scanning optical microscopy, atomic force/acoustic microscopy, nano-Raman/X-ray microscopy, and thermal wave microscopy, are being used for precise and accurate ND evaluations. These NDEs have their own technological limitations and capabilities compared to the conventional methods (Wolter et al,. 2007). Similarly, electrical parameters of semiconductors should be tested by non-destructive methods to provide high quality and reliability factors of electronics devices generally. For such reason, microwave based contactless NDTs are well suited for the measurement or evaluation of electrical properties of semiconductor materials as described (Laurinavicius, 2014).

In complying with production quality control and condition monitoring in services, novel approaches should be developed in the industrial pipeline (Savage, 2007). For example; due to technological and manufacturing factors, adhesively bonded joints are of great interest and require quality assurance of the structures and strength evaluation in comparison to conventional joints such as welding. However, there are certain issues in assessment of integrity and reliability of finding particular NDTs to evaluate such joints accurately. Recent ultrasonic and X-ray radiography based NDTs are being used on fiber reinforced epoxy joints that are being loaded till failure in order to determine their bond strength accurately (Kumar, 2013). Likewise, non-destructive monitoring by means of low frequency electrical and magnetic methods has been performed thoroughly for fiber reinforced concrete and cementitious composites that play a significant role in the framework of quality control and performance prediction Faifer et al. (2013). Furthermore, electrical methods including impedance spectroscopy or equivalent capacitance evaluation between the two electrodes of a probe has been investigated in terms of reliability and sensitivity for measurement of fiber orientation, clumping, segregation etc. that are applicable to industrial scale problems as well (Ozyurt et al., 2006; Faifer et al., 2009). Yin et al. (2013) investigated capacitive imaging as a novel electromagnetic non-destructive evaluation technique, which has been successfully used for glass/carbon fiber composite, steel, concrete, etc. The general goal of this experiment is only to find the perfect NDT technique based upon the designing principle of a perfect capacitive imaging probe. It has been mentioned that a bigger electrode area provides a stronger signal at the cost of the imaging resolution. Therefore, the geometry of the electrodes should be determined according to the desired penetration depth and imaging resolution for a suitable capacitive imaging probe.

Additionally, due to rapid application of composite materials in the industrial sectors of automotive, energy, and additional manufacturing units, there is increasing motivation to detect the material or device failures as quickly as possible and in a cost effective manner. Thermography using ultrasonic analysis gives such potential for a quick affordable single point or area detection mode on the above parts (Maier et al., 2014). Generally, during thermography based ND inspection, the infrared images are taken for the cracks, defects, and voids etc that reveal the hidden failures. Therefore, the method of heating the tested sample is important and can be performed either by a short laser pulse, induced eddy-currents, elastic waves, or sinusoidal modulated lock-in technique (Ibarra-Castanedo et al., 2009; Mignogna et al., 1998; Wu, 1998; Vaviloy et al., 1998).

In addition to a variety of non-destructive testing and evaluation (NDTE) methods that have been used in both academia and industry, optical coherence tomography (OCT) is the novel optical technique with special feature like non-contact, non-invasive, and yield high resolution images at the submicron level Huang et al. (1991). According to the authors, OCT is not only used as a biomedical imaging technique, rather in other fields of applications such as surface defect detection, microstructure evaluation and strain mapping etc. (Bashkansky et al., 1996; Duncan et al., 1998; Bashkansky et al., 1998; Wiesauer et al., 2005; Wiesauer, 2006). Similarly, the other potential candidates which can detect deep sub-surface defects are superconducting quantum interference device (SQUID) NDT sensor. The sensor has been utilized in stress-strain measurement in magnetic materials, detection of tendon rupture in pre-stressed steel tendons of concrete bridges through magnetic flux leakage method, and detection of ferrous inclusions in aircraft turbine etc. (Weinstock et al., 1986; Weinstock, 1991; Krieger et al., 1999; Tavrin et al., 1999). Despite its limitation that operates only at the cryogenic temperature, has advantages of wide bandwidth, high sensitivity, broad dynamic range etc. (Krause & Kreutzbruck, 2002).

6. CONCLUSION

This paper discussed the nondestructive evaluation applications framework in the area of supply chain management. Several application areas in supply chain management including Manufacturing, Production, Warehousing, and Transportation were explored. Different parameters have been utilized to compare various NDE methods. The use of these major categories would benefit supply chains operations. Understanding certain information is vital before any supply chain enterprise decides on an NDE method for use. This paper has shown how NDE methods compare. Understanding this can be vital to the success of an organization because certain methods are better suited for certain products in the supply chain system. Therefore, the knowledge of each method's applicability can mean the difference between success and failure of a product within the supply chain operational network.

Furthermore, no single NDE method is perfect, but after each method is examined the data can be evaluated to form opinions that will shape a method's future usage or adoption. Finally, in today's competitive business environment, supply chain partners should work diligently to improve their entire operation and nondestructive testing has proved to be a very powerful tool in achieving that goal.

FUTURE RESEARCH DIRECTIONS

With respect to expanding the debate on the application of nondestructive testing methods to supply chain and supply chain management and implementation, the time is ripe for utilizing one of the several types of nondestructive testing methods and applies that to address supply chain challenges and vulnerabilities. It should be emphasized that nondestructive testing may be carried out for several reasons. The overall goal should depend on information that is available on a particular type of NDT that will influence its choice. It may be that a combination of methods will be needed.

REFERENCES

Alting, L. (1995). Sustainable industrial production/environmental issues in product development. In *Life Cycle Modelling for Innovative Products and Processes, Proceedings of the IFIP WG5.3 International Conference on Lifecycle Modelling for Innovative Products and Processes*. Berlin, Germany: Academic Press.

Bashkansky, M., Battle, P. R., Duncan, M. D., Kahn, M., & Reintjes, M. J. (1996). Subsurface defect detection in ceramics using an optical gated scatter reflectometer. *Journal of the American Ceramic Society*, *79*(5), 1397–1400. doi:10.1111/j.1151-2916.1996.tb08602.x

Bennett, T. D., & Yu, F. (2005). A nondestructive technique for determining thermal properties of thermal barrier coatings. *Journal of Applied Physics*, *97*(1), 13520. doi:10.1063/1.1826217

Brence, J. R., & Brown, D. E. (2002). Data mining corrosion from eddy current non-destructive tests. *Computers & Industrial Engineering*, *43*(4), 821–840. doi:10.1016/S0360-8352(02)00142-0

C'Shekhar, N., Shitole, O., Zahran, & Al-Nuaimy, W. (Eds.). (2006). *NDT 2006, the 45th Annual British Conference on NDT*. Stratford-upon-Avon, UK: NDT.

Carino, N. J. (2013). Training: Often the missing link in using NDT methods. *Journal of Construction and Building Materials*, *38*, 1316–1329. doi:10.1016/j.conbuildmat.2011.03.060

Chakrapani, S. K., Dayal, V., Krafka, R., & Eldal, A. (2012). Ultrasonic testing of adhesive bonds of thick composites with applications to wind turbine blades. *AIP Conference Proceedings*, *1430*, 1284–1290. doi:10.1063/1.4716366

Chen, Z., Yusa, N., & Miya, K. (2009). Some advances in numerical analysis techniques for quantitative electromagnetic nondestructive evaluation. *Nondestructive Testing and Evaluation, 24*(1-2), 69-102.

Christopher, M. (1998). *Logistics and Supply Chain Management*. London: Pitman Publishing.

Crespo-Marquez, A., & Lung, B. (2008). A review of e-maintenance capabilities and challenges, *Journal of Systemics*, *Cybernatics and Informatics*, *6*, 62–66.

Current Developments in Non Destructive Testing. (1966). *Management Review, 55*(4), 28.

Dalius Misiunas. (2008). Failure Monitoring and Asset Condition Assessment in Water Supply Systems. In *Proceedings of 7th International Conference on Environmental Engineering*, (pp. 648-655). Academic Press.

Dowlatshahi, S. (1992). Purchasing's Role in a Concurrent Engineering Environment. *International Journal of Purchasing and Materials Management*, 21-25.

Dragan, K., & Swiderski, W. (2010). Studying Efficiency of NDE Techniques Applied to Composite Materials in Aerospace Applications. *Acta Physica Polonica A*, *117*(5), 878–883.

Duncan, M., Bashkansky, M., & Reintjes, J. (1998). Subsurface defect detection in materials using optical coherence tomography. *Optics Express*, *2*(13), 540–545. doi:10.1364/OE.2.000540 PMID:19381226

Fabrycky, W. J., & Blanchard, B. S. (1991). *Life Cycle Cost and Economic Analysis*. Englewood Cliffs, NJ: Prentice-Hall.

Faifer, M., Ferrara, L., Ottoboni, R., & Toscani, S. (2013). Low frequency electrical and magnetic methods for Non-destructive analysis of fiber dispersion in fiber reinforced cementitious composites: An Overview. *Sensors (Basel, Switzerland)*, *13*(1), 1300–1318. doi:10.3390/s130101300 PMID:23337334

Faifer, M., Ottoboni, R., Toscani, S., Ferrara, L., & Felicetti, R. (2009). A multi-electrode measurement system for steel fiber reinforced concrete materials monitoring. In *Proceedings of IEEE International Instrumentation and Measurement Technology Conference*, (pp. 303–308). IEEE. doi:10.1109/IMTC.2009.5168466

Green, M. R., Henneke, E., & Reifsnider, K. (1981). Thermographic investigations of high-power ultrasonic, heating in materials. *Ultrasonics*, *7*, 159–163.

Guide, V., Daniel, R., Vaidy, J., & Linton, J. D. (2003). Building contingency planning for closed-loop supply chains with product recovery. *Journal of Operations Management*, *21*(3), 259–279. doi:10.1016/S0272-6963(02)00110-9

Haywood, M., & Peck, H. (2003). An investigation into the management of supply chain vulnerability in UK aerospace manufacturing. In *Proceedings of the EUROMA/POMS Conference*, (*Vol. 2*, pp. 121-30). EUROMA/POMS.

Hong-Bae, J., Kiritsis, D., & Xirouchakis, P. (2007). Product Life-Cycle Metadata Modeling and its Application with RDF. Knowledge and Data Engineering. *IEEE Transactions on Knowledge and Data Engineering, 19*(12), 1680–1693. doi:10.1109/TKDE.2007.190661

Huang, D., Swanson, E. A., Lin, C. P., Schuman, J. S., Stinson, W. G., & Chang, W. et al. (1991). Optical coherence tomography. *Science*, *254*(5035), 1178–1181. doi:10.1126/science.1957169 PMID:1957169

Ibarra-Castanedo, C., Piau, J. M., Guibert, S., Avdelidis, N. P., Genest, M., Bendada, A., & Maldague, A. (2009). Comparative study of active thermography techniques for the nondestructive evaluation of honeycomb structures. *Res. Nondestructive. Evaluation.*, *20*(1), 1–31. doi:10.1080/09349840802366617

Jesse, G., & Moles, M. (2005). Portable phased array applications. *Materials Evaluations, 63* (4), 394-404.

Kamrani, A. K., & Sa'ed, S. M. (2001). *Product Design for Modularity. Springer*.

Kiritsis, E., Georgios, K., Tetradis, N., Tomarasad, N., & Zarikas, V. (2003). Cosmological evolution with brane-bulk energy exchange. Institute of Physic Publishing for SISSA/ISAS.

Krause, H. J., & Kreutzbruck, M. V. (2002). Recent developments in SQUID NDE. *Physica C*, *470* (23), 2079-2126.

Krieger, J., Krause, H.-J., Gampe, U., & Sawade, G. (1991). Magnetic field measurements on bridges and development of a mobile SQUID system. In *Proc. Intl. Conf. on NDE Tech. Aging Infrastr.*, (pp. 229-239). Newport Beach, CA: Academic Press. doi:10.1117/12.339929

Kumar, R. L., Bhat, M. R., & Murthy, C. R. L. (2013). Non-destructive evaluation of degradation in bond line of glass fiber reinforced polymer composite adhesive lap joints. *International Journal of Aerospace Innovations*, *5*(3 & 4), 61–71. doi:10.1260/1757-2258.5.3-4.61

Laurinavicius, L. (2014). Simple microwave technique for non-destructive testing of electrical properties of magnetized materials. *Acta Physica Polonica A*, *125*(2), 205–207. doi:10.12693/APhysPolA.125.205

Lopato, P., & Chady, T. (2013). Terahertz detection and identification of defects in layered polymer composites and composite coatings. *Nondestructive Testing and Evaluation, Taylor & Francis*, *28*(1), 28–43. doi:10.1080/10589759.2012.694882

McBride, D. (2003). Design for Manufacturability. *EMS Consulting Group*. Retrieved from http://www.emsstrategies.com

Misiunas, D., Lambert, M. F., Simpson, A. R., & Olsson, G. (2006). *Condition assessment of water transmission pipelines using hydraulic transients*. Water Management.

Oh, T., Kee, S., Arndt, R., Popovics, J., & Zhu, J. (2013). Comparison of NDT Methods for Assessment of a Concrete Bridge Deck. *J. Eng. Mech.*, *139*, 305–314.

Opara, L. U. (2003). Traceability in agriculture and food supply chain: A review of basic concepts, technological implications, and future prospects. *Journal of Food Agriculture and Environment*, *1*(1), 101–106.

Ozyurt, N., Mason, T. O., & Shah, S. P. (2006). Nondestructive monitoring of fiber orientation using AC-IS: An industrial scale application. *Cement and Concrete Research*, *36*(9), 1653–1660. doi:10.1016/j.cemconres.2006.05.026

Pearson, N. R., Mason, J. S. D., & Priewald, R. H. (2012). The influence of maintenance on the life cycle of above-ground storage tanks. *Journal of Insights*, *54*(6), 311–315. doi:10.1784/insi.2012.54.6.311

Peck, H. (2005). Drivers of supply chain vulnerability: An integrated framework. *International Journal of Physical Distribution & Logistics Management*, *35*(4), 210–232. doi:10.1108/09600030510599904

Pei, C., Chen, Z., Wu, W., & Mao, Y. (2010). IOS Press Method improvement of EMAT signals simulation and its applications in TBC inspection. *International Journal of Applied Electromagnetics and Mechanics*, *33*, 1077–1085.

Potts, A., McNab, A., Reilly, D., & Toft, M. (2000). Presentation and Analysis enhancements of the NDT workbench: A software package for ultrasonic NDT data, CP509, Review of progress in Quantitative Nondestructive Evaluation. (D. O. Thompson & D. E. Chimenti, Eds.). American Institute of Physics.

Qaddoumi, N., Bigelow, T., Zoughi, R., & Brown, L. (2002). Reduction of sensitivity to surface roughness and slight standoff distance variations in microwave testing of thick composite structures. *American Society for Nondestructive Testing Inc, ASNT*, *60*(2), 165–170.

Rahani, E. K., Kundu, T., Wu, Z., & Xin, H. (2011). Mechanical Damage Detection in Polymer Tiles by THz Radiation. *IEEE Sensors Journal*, *11*(8), 1720–1725. doi:10.1109/JSEN.2010.2095457

Rathod, V. R., Anand, R. S., & Ashok, A. (2012). Comparative analysis of NDE techniques with image processing. *Nondestructive Testing and Evaluation*, *27*(4), 305–326. doi:10.1080/10589759.2011.645820

Rose, J. L. (2010). Guided wave successes and challenges for ultrasonic testing in NDT and SHM. *Materials Evaluation*, *68*(5), 495–500.

Rose, J. L. (2011). The upcoming revolution in ultrasonic guided waves. *Proceedings of the Society for Photo-Instrumentation Engineers*, *7983*, 798302, 798302-30. doi:10.1117/12.897025

Rubinacci, G., Tamburrino, A., & Ventre, S. (2009). Fast numerical techniques for electromagnetic nondestructive evaluation. *Nondestructive Testing and Evaluation*, *24*(1-2), 165–194. doi:10.1080/10589750802195568

Sacket, P. J., & Holbrook, A. E. K. (1988). DFA as a primary process decreases design deficiencies," Emerald Insight. *Assembly Automation*, *8*(3), 137–140. doi:10.1108/eb004710

Sarkis, J. (2003). A strategic decision framework for green supply chain management. *Journal of Cleaner Production, 11*, 397.409

Savage, G. (2007). Failure prevention in bonded joints on primary load bearing structures. *Engineering Failure Analysis*, *14*(2), 321–348. doi:10.1016/j.engfailanal.2005.11.013

Schmidt, M. A. R., Oswald-Tranta, B., & Schledjewski, R. (2014). Non-Destructive Thermography Analysis of Impact Damage on Large-Scale CFRP Automotive Parts. *Materials (Basel)*, *7*(1), 413–429. doi:10.3390/ma7010413

Shade, G. F. (2009). Response to Counterfeit Integrated Circuit Components in the Supply Chain: Part II Insight Analytical Labs. *EDFAAO*, *1*, 14–21.

Stanke, A. K. (2001). *A Framework for achieving lifecycle value in product development*. (Unpublished Master's thesis). Massachusetts Institute of Technology, Cambridge, MA. Retrieved from http://hdl.handle.net/1721.1/28239

Stoll, H. W. (1990). *Simultaneous Engineering*. In C. W. Allen (Ed.), *Design for Manufacturing,* (pp. 23–29). SME Press.

Tariq, P. S., & Alina-Alexandra, B. (2009). Robotic system for inspection of test objects with unknown geometry using NDT methods. *Industrial Robot: An International Journal*, *36*(4), 340–343. doi:10.1108/01439910910957093

Tavrin, Y., Siegel, M., & Hinken, J. H. (1999). Standard method for detection of magnetic defects in aircraft engine discsusing a HTS SQUID gradiometer. *IEEE Transactions on Applied Superconductivity*, *9*(2), 3809–3812. doi:10.1109/77.783857

Vavilov, V. P., Almond, D. P., Busse, G., Grinzato, E., Krapez, J. C., & Maldague, X. et al. (1998). Infrared thermographic detection and characterization of impact damage in carbon fibre composites: results of the round robin test. In *Proceedings of the 4th Conference on Quantitative Infrared Thermography (QIRT)*. Lodz, Poland: QIRT.

Viaene, J., & Verbeke, W. (1998). Traceability as a key instrument towards supply chain and quality management in Belgian poultry meat chain. *Supply Chain Management: An International Journal*, *3*(3), 139–141. doi:10.1108/13598549810230868

Vijayakumar, R. L., Bhat, M. R., & Murthy, C. R. L. (2012). Nondestructive evaluation of adhesively bonded carbon fiber reinforced composite lap joints with varied bond quality. *AIP Conference Proceedings*, *1430*, 1276–1283. doi:10.1063/1.4716365

Ward, D. R., & Matzkanin, G. A. (1997). Nondestructive Evaluation (3rd ed.). Nondestructive Testing Information Analysis Center.

Weinstock, A. (1991). A review of SQUID magnetometry applied to non-destructive evaluation. *IEEE Transactions on Magnetics*, *27*(2), 3231–3236. doi:10.1109/20.133898

Weinstock, H., & Nisenoff, M. (1986). Article. In D. O. Thompson & D. Chimenti (Eds.), Defect detection with a SQUID magnetometer Review of Progress in QNDE 6 (pp. 669–704). New York: Plenum.

Westkamper, E., Alting, L., & Arndt, G. (2000). A keynote paper on Life cycle management and assessment: Approaches and visions towards sustainable manufacturing. *Proceedings - Institution of Mechanical Engineers*, *215*.

Wiesauer, K., Pircher, M., Goetzinger, E., Hitzenberger, C. K., Engelke, R., & Ahrens, G. et al. (2006). Transversal ultrahigh-resolution polarization-sensitive optical coherence tomography for strain mapping in materials. *Optics Express*, *14*(13), 5945–5953. doi:10.1364/OE.14.005945 PMID:19516764

Wiesauer, K., Pircher, M., Götzinger, E., Bauer, S., Engelke, R., & Ahrens, G. et al. (2005). En-face scanning optical coherence tomography with ultra-high resolution for material investigation. *Optics Express*, *13*, 1015–1024. doi:10.1364/OPEX.13.001015 PMID:19494965

Wolter, K. J., Oppermann, M., Heuer, H., Kohler, B., Schubert, F., & Netzelmann, U. et al. (2007). *Micro and Nano-NDE for Micro-Electronics*. IV Conferencia Panamericana de END.

Wu, G. B., & Busse, G. (1998). Lock-in thermography for nondestructive evaluation of materials. *Revue Generale Thermique*, *37*(8), 693–703. doi:10.1016/S0035-3159(98)80047-0

Wu, J., Li, J., Wang, S., & Cheng, T. C. E. (2009). Mean-variance analysis of the newsvendor model with stockout cost. *Omega*, *37*(3), 724–730. doi:10.1016/j.omega.2008.02.005

Yazid, H., Arof, H., & Yazid, H. (2012). Automated thresholding in radiographic image for welded joints. *Nondestructive Testing and Evaluation*, *27*(1), 69–80. doi:10.1080/10589759.2011.591795

Yin, X., Hutchins, D. A., Chen, G., & Li, W. (2013). Preliminary studies on the design principles of capacitive imaging probes for non-destructive evaluation. *International J. Appl. Electromagnetics and Mechanics*, *42*, 447–470.

Zhu, Y. K., Tian, G. Y., Lu, R.-S., & Zhang, H. (2011). A review of optical NDT technologies. *Sensors (Basel, Switzerland)*, *11*(12), 7773–7798. doi:10.3390/s110807773 PMID:22164045

ADDITIONAL READING

Coyle, J. J., Langley, C. J., Novack, R. A., & Gibson, B. J. (2013). Supply Chain Management: A Logistics Perspective (9th Edition). South-Western Cengage Learning. ISBN 13: 978-0-538-47918-9.

Karbhari, V. M. (2013). Non-Destructive Evaluation (NDE) of Polymer Matrix Composites, Woodhead Publishing. Hull, B. (2012). Non-Destructive Testing, 2012, Springer-Verlag, New York Inc. ISBN: 13:9781468462999

Maierhofer, C., Reinhardt, H.-W., & Dobmann, G. (2010). Non-Destructive Evaluation of Reinforced Concrete Structures, Volume 2: Non-Destructive Testing Methods, Woodhead Publishing.

Schmerr, L., & Song, J. S. (2007). Ultrasonic *Nondestructive Evaluation Systems: Models and Measurements,* Springer. Fahr, A. (2013). *Aeronautical Applications of Non-destructive Testing Perfect*, DEStech Publications.

Wisner, J. D., Keah-Choon, T., & Leong, G. K. (2012). Principles of Supply Chain Management: A Balanced Approach (3rd Edition). South-Western Cengage Learning, USA. ISBN: 13: 978-0-538-47546-4

KEY TERMS AND DEFINITIONS

Atomic Force Acoustic Microscopy (AFAM): AFAM is an Atomic Force Microscope (AFM) based ND technique, where flexural and tensional cantilever vibrations are excited by out-of-plane and in-plane sample surface vibrations.

Digital X-Ray Radiography: The digital x-ray radiography consists of portable x-ray source and silicon based flat panel detector. The adhesive joints are tested keeping in between the source and the detector.

Near-Field Optical Nondestructive Techniques: Near-field scanning optical microscopy (NSOM) based optical imaging technique providing sub-wavelength resolving power and has profound applications in materials, biomedical, photonics, and energy sectors.

Non-Destructive Monitoring: Nondestructive analysis and evaluation in the framework of quality control and performance prediction.

Optical Coherence Tomography (OCT): OCT is a non-contact, non-destructive, and non-invasive technique, which provides 3D depth resolved image data of sub-surface regions in-situ and in real-time.

Production Life Cycle: Beginning of life to the end of life of a product.

Stakeholder: Anyone with vested interest in an organization or business.

Supply Chain Management: The integration of major organizational processes regarding the flow materials from raw materials suppliers to the ultimate consumer.

Superconducting Quantum Interference Device (SQUID): (SQUID) works at the cryogenic temperature, has advantages of measuring stress-strain relationship in magnetic materials, and detection of ferrous inclusions in aircraft turbine.

Thermography Analysis: Thermography is a microscopic thermal wave technique where the resolution is determined by a highly focused laser beam that generates local temperature oscillations.

Ultrasonic Pulse Echo Method: This is another time domain ultrasonic testing technique, uses a single transducer to transmit and receive the ultrasonic energy unlike two probes in case of ultrasonic through transmission.

Ultrasonic through Transmission: This is a time domain ultrasonic testing method used for the testing joints to know about their bond quality. The system is made of two coaxial probes, one generates the ultrasonic energy which passes through the specimen, and the other receives the transmitted energy.

Chapter 4
Improving Supply Chain Delivery Performance Using Lean Six Sigma

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ABSTRACT

Models for evaluating and improving delivery performance play an important role in the management of supply chains. A review of supply chain delivery models that use Six Sigma methodologies indicate that the models are limited to only make-to-order supply chains where improvement in delivery performance occurs at a fixed (static) point in time. In this chapter, the authors present a generalized delivery performance model that overcomes these limitations. The model presented here can be used to measure delivery performance in both make-to-order and make-to-stock supply chains and supports improvement in delivery performance over a planned time horizon with definable milestones for attaining targeted levels of improvement. Numerical illustrations of the model are presented.

DOI: 10.4018/978-1-4666-7320-5.ch004

INTRODUCTION

In reaction to today's globally competitive business environment, organizations face challenges to improve customer service while simultaneously reducing costs and shortening product lifecycles. In response to these challenges many organizations have adopted the supply chain management (SCM) philosophy. Under the SCM philosophy, processes such as production planning and inventory control, sourcing, vendor relations and customer relationship management are viewed as value adding activities requiring coordination and integration among functional areas that are both internal and external to the organization. The positive impact of the SCM philosophy on firm performance has been empirically established in the literature (Beheshti, Oghazi, Mostaghel, & Hultman, 2014; Leuschner, Rogers, & Charvet, 2013; Huo, 2012; Wagner, Grosse-Ruyken, & Erhun, 2012; Shi & Yu, 2012; Johnson & Templar, 2011; Kim, 2009).

As discussed in Ramaa, Subramanya, and Rangaswamy (2013), Martin and Patterson (2009), Shepherd and Günter (2006) and Gunasekaran, Patel, and McGaughey (2004), performance measurement plays an integral role in the SCM philosophy. Performance measurements assist managers in meeting short term day-to-day objectives as well as long term strategic goals. For effective performance measurement, formal quantitative models for performance measurement are needed that are capable of incorporating a wide range of factors (Suwignjo, Bititci, & Carrie 2000; Bititci, Suwignjo, & Carrie, 2001). Frameworks for supply chain performance evaluation may be found in Cuthbertson and Piotrowicz (2011), Azevedo, Carvalho, and Cruz-Machado (2011) and Chan, Chan, and Qi (2006) while specific metrics for use in measuring supply chain performance are found in Gopal and Thakkar (2012), Sambasivan, Mohamed, and Nanden (2009) and Gunasekaran and Kobe (2007).

In this chapter we concentrate on one aspect of overall supply chain performance, delivery timeliness to the final customer. As summarized in Bushuev and Guiffrida (2012), the delivery process within a supply chain is of critical concern to supply chain managers since delivery performance directly impacts customer satisfaction levels. This assessment of the importance of measuring delivery performance in supply chains is in agreement with recent research by Chapman, Beron, and Haggett (2011), Rao, Rao, and Muniswamy (2011), Forslund, Jonsson, and Mattsson (2009), Lockamy and McCormack (2004) and Vachon and Klassen (2002). As a time-based measure, delivery performance within supply chains is typically evaluated with respect to a customer defined delivery window (Safaei, Issa, Seifert, Thoben, & Lang, 2013; Guiffrida & Nagi, 2006). The customer defines benchmarks in time to which delivery times are compared by using a delivery window. Based on the delivery window, a delivery is classified as being early, on-time or late. For a compilation of actual delivery windows used in industrial supply chains the reader is referred to Guiffrida (2014).

Quantitative models for measuring and improving supply chain delivery performance that utilize delivery windows have appeared in the literature and Guiffrida, Chen, Liang, Ngniatedema, and Tanai (2013) provide a comprehensive review of this literature. Supply chain delivery window models can be broadly classified into the following two categories: cost-based models and index-based models. Cost-based models use loss functions to translate the probability of untimely (early and late) deliveries into an expected cost measure. Index-based models utilize Six Sigma statistical tools such as process capability indices, tolerancing and control charts to provide cost based metrics for evaluating delivery performance. In both classes of models costs are incurred when deliveries are untimely (early or late) and for investments dedicated to improving delivery performance. Continuous improvement in delivery performance is captured within the modeling frameworks of both cost-based and index-based supply chain delivery models through the reduction of variability in the delivery time distribution. Reducing the variance of the delivery time distribution for a stated delivery window and fixed mean delivery time reduces the probability of early and late deliveries (which are considered to be delivery process defects) while increasing the probability of on-time deliveries.

The importance of Six Sigma in improving supply chain operations has received considerable attention in the literature (see for example Tetteh, Eyob, & Amewokunu, 2013; Salah, Rahim, & Carretero, 2011; Nabhani & Shokri, 2009; Yang, Choi, Park, Suh, & Chae, 2007; Knowles, Whicher, Femat, & Canales, 2005). Index-based delivery performance models are attractive for Six Sigma initiatives to improve supply chain delivery performance since the foundation of these models, which is based on process capability indices, tolerancing, and control charting, directly aligns with the core statistical methodologies that are fundamental to the Six Sigma philosophy. The current class of index-based supply chain delivery performance models is limited in two aspects. First, the models only allow for a make-to-order orientation of product flow in the operation of the supply chain and ignore make-to-stock product flows. A make-to-order product flow is characteristic of a pull-type supply chain where a make-to-stock orientation is characteristic of a push-type supply chain. As identified in Birou, Germain, and Christensen (2011), differences exist in the return on internal process improvement investment between firms who operate under make-to-order (MTO) versus make-to-stock (MTS) operating policies. From a supply chain management perspective, integrating and coordinating internal process improvement is easier under a MTO orientation than under a MTS orientation (Birou et al., 2011, pp. 829). Hence generalizing delivery models to accommodate both MTO and MTS supply chains may contribute to improving overall supply chain performance. Second, delivery improvement (which is achieved through variance reduction of the delivery time distribution) is static with all improvement occurring at one point in time. A more realistic modeling approach to delivery improvement would utilize a defined planning horizon with set milestones for attaining incremental improvements.

In this chapter we propose a generalized supply chain modeling framework that utilizes Six Sigma delivery performance metrics to:

1. Allow for delivery performance to be evaluated for both make-to-order and make-to-stock policies, and
2. Support the implementation of continuous improvement in delivery performance over a planned time horizon with definable milestones for attaining targeted levels of variance reduction in the delivery time distribution.

Key modeling features of the generalized supply chain modeling framework include Monte Carlo simulation and learning curve theory. A Monte Carlo simulation methodology is used to model and evaluate supply chain delivery performance for both make-to-order and make-to-stock customer ordering policies. Learning curve theory is used to establish a continuous improvement program which features a defined time horizon for improvement that contains embedded milestones for improving delivery performance through the learning-based reduction in the variance of the delivery time distribution. For background information on the use of Monte Carlo simulation and learning curve theory in supply chain management applications, the reader is referred to Kleijnen (2005) and Jaber (2011).

BACKGROUND

Significant research has shown the usefulness in companies adopting concepts such as Six Sigma, TQM, Lean Management, and Continuous Improvement (see for example, Andersson, Eriksson, & Torstensson, 2006; Hellsten & Klefsjö, 2000). Six Sigma is considered by many to be the most important advancement in quality management and process improvement in the last two decades (Schroeder, Linderman, Liedtke, & Choo, 2008). The Six Sigma quality initiative has been shown to save money from operations costs and quality improvement (Magnusson, Kroslid, Bergman, Häyhänen, & Mills, 2003; Lee, 2002). For a gateway review of the evolution of Six Sigma and the supporting Six Sigma literature the reader is directed to the work of Pepper and Spedding (2010), Lee and Chang (2010) and Brady and Allen (2006). Zhang, Hill, and Gilbreath (2011) provide a comprehensive descriptive analysis of the core elements of Six Sigma and its implementation.

The benefit of adopting Six Sigma concepts in supply chain management has been investigated by several researchers across a wide range of applications. For example, Kokkranikal, Kosgi, and Losekoot (2013) examined the application of Six Sigma in the hospitality supply chain. Lin and Li (2010) demonstrated the importance of using Six Sigma metrics to evaluate supply chain performance. Byrne, Lubowe, and Blitz (2007) investigated the role of Six Sigma in driving supply chain innovations. Christopher and Lee (2004) examined the application of Six Sigma tools in reducing supply chain risk. Wang, Du, and Li (2004) explored Six Sigma concepts in supply chain supplier development. Dasgupta (2003) studied the use of Six Sigma metrics to evaluate and improve supply chain performance. Within this wide span of application we focus on the role that Six Sigma plays in measuring and improving delivery performance within supply chains.

Table 1 summarizes index-based models which use delivery windows to evaluate supply chain delivery performance. The common feature to these models is their adoption of the Six Sigma methodology which advocates using statistical analysis (process capability indices, tolerancing and control charting) to improve on-time delivery within the supply chain by reducing the variability in delivery performance.

The models summarized in Table 1 are limited in two aspects. First, the models only allow for a make-to-order orientation in the operation of the supply chain whereby an order placed by the end customer must sequentially visit each upstream stage of the supply chain. Clearly it is possible that only a subset of the upstream chain members may be needed to satisfy the end customer's order. For example, consider the three-stage supply chain consisting of a retailer, manufacturer and raw material supplier. Under a pure make-to-order scenario, the customer places an order with the retailer who in turn places an order with the manufacturer who in turn places an order with the raw material supplier. Thus the total delivery time to the end customer would be defined by the sum of the activity processing times of the retailer, manufacturer and raw material supplier. A make-to-stock orientation

Table 1. Summary of index-based supply chain delivery performance models

Authors	Model Description	Six Sigma Attributes
Hsu, Hsu, and Shu (2013)	Integrates process capability measures and Six Sigma concepts to develop a delivery performance chart for measuring supply chain delivery performance.	• S_{pk} process capability index • Delivery performance chart
Roy, Gupta, and Dasgupta (2013)	Presents a nonlinear optimization model for determining the cost optimal mix of logistics service providers to meet customer delivery requirements in a make to order supply chain.	• Statistical tolerancing of delivery times • Reduction in mean delivery time for fixed variance
Wang and Du (2007)	Develops a capability index to model continuous improvement when delivery performance is measured subject to a delivery window.	• S_{pk} process capability index • Reduction of mean and variance of delivery time
Choudhary, Singh, and Tiwari (2006)	Presents a nonlinear optimization model for minimizing the cost of untimely delivery when delivery performance is measured as a Six Sigma based capability index measure.	• C_{pk} process capability index • Variance reduction of delivery times
Garg, Naraharai, and Viswanadham (2006)	Utilizes a Six Sigma based delivery capability index to optimally distribute the pool of individual stage activity variance in a multi-stage supply chain to satisfy customer delivery expectations.	• C_p and C_{pk} process capability indexes • Variance reduction of delivery times
Chan, Swarnkar, and Tiwari (2006)	Employ a Genetic Algorithm heuristic to synchronize and optimize process tolerances in a supply chain network to meet customer delivery requirements and minimize supply chain cost.	• C_p and C_{pk} process capability indexes • Process tolerancing • Variance reduction of delivery times

could occur in several ways. For example, if stock for the customer order existed in the finished goods inventory of the retailer, no demand would be placed on the upstream manufacturing and raw materials stages of the supply chain, and delivery time to the customer would be defined only by the activity time of the retailer. Alternatively, a customer order could require processing only at the retail and manufacturing stages (but not the raw material stage) and the delivery time to the customer would be defined by a sum of the activity times of the retailer and the manufacturer.

A second limitation of the models summarized in Table 1 is that delivery improvement (which is achieved primarily through variance reduction) is static with all improvement occurring at one point in time. In reality, implementing changes within a supply chain to improve delivery performance is temporal in nature and often requires a planning horizon of several years in length.

In this chapter we propose a generalized supply chain delivery modeling framework that utilizes Six Sigma delivery performance metrics to:

1. Allow for delivery performance to be evaluated for both make-to-order and make-to-stock ordering policies, and
2. Support the implementation of continuous improvement in delivery performance over a planned time horizon with definable milestones for attaining targeted levels of variance reduction in the delivery time distribution.

The supply chain delivery model presented herein will use a Monte Carlo simulation methodology to capture the make-to-order and make-to-stock aspects of customer ordering polices. Learning curve theory will be used to define a temporal implementation horizon for improving delivery performance through the learning-based reduction in the variance of the delivery time distribution.

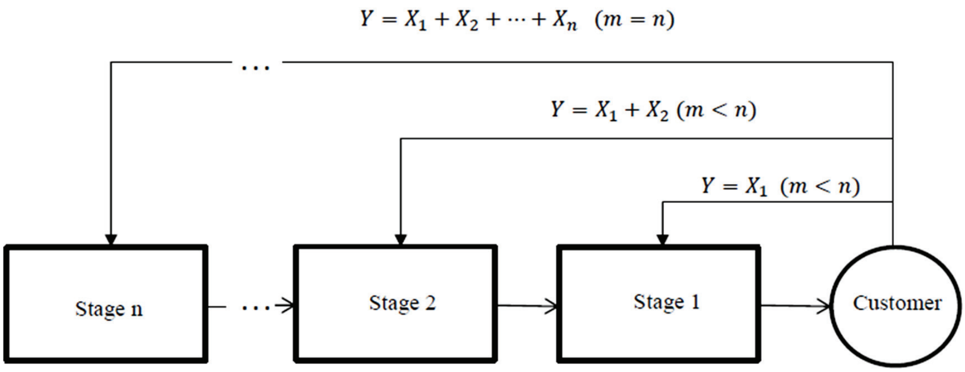
A GENERALIZED SIX SIGMA BASED SUPPLY CHAIN DELIVERY MODEL

A Supply Chain Delivery Model for Make-to-Order/Make-to-Stock Order Policies

Consider an N-stage serial supply chain operating under a make-to-order policy. Let X_i = the activity time of stage i ($i = 1, 2, \ldots, N$) with mean $E(X_i) = \mu_i$ and variance $V\left(X_i\right) = \sigma_i^2$. Under the assumption of independence between stage activity times, the total delivery time to the final customer is defined as $Y = \sum_i^N X_i$. Under a make-to-order operating policy, all N stages of the supply chain are required to fulfill the customer's order hence Y is a sum of independent random variables. Under a make-to-stock orientation, the number of stages required to fulfill the customer's order becomes a random variable with state space $N = (1, 2, \ldots, m)$. Under the assumption of independence between N and X_i the total delivery time Y is now defined as a *random sum* of independent random variables. When $N = m$ the supply chain operates in a make-to-order policy; when $1 \leq N < m$ the supply chain operates in a make-to-stock policy (see Figure 1).

The supply chain delivery models reviewed in Table 1 all assume a strict make-to-order policy where total delivery time Y is defined by a sum of independent random variables. By defining total delivery time Y as a random sum of independent random variables, the modeling structure of a supply

Figure 1. Illustration of make-to-order and make-to-stock supply chain deliveries



chain delivery performance model is generalized to allow for both make-to-order (all N stages visited) and make-to-stock environments (a sequential number of stages $N < m$ visited). When delivery time is defined as a random sum of independent random variables, the expected value and variance of delivery time Y are defined as follows. The expected value of delivery time Y is

$$E\left(Y\right) = E\left(\sum_{i=1}^{N} X_i\right) \tag{1}$$

$$= E\left[E\left(\sum_{i=1}^{N} X_i | N\right)\right] \tag{2}$$

$$= \sum_{n=1}^{m}\left(E\left(\sum_{i=1}^{N} X_i\right) | N = n\right) P\left(N = n\right) \tag{3}$$

$$= \mu_1 p_1 + \left(\mu_1 + \mu_2\right) p_2 + \ldots + p_m \sum_{i=1}^{m} \mu_i \tag{4}$$

$$= \sum_{i=1}^{m} p_i \left(\sum_{j=1}^{i} \mu_j\right) \tag{5}$$

The variance of delivery time Y is

$$V(Y) = E[V(Y|N)] + V[E(Y|N)] \tag{6}$$

where

$$E\left[V\left(\sum_{i=1}^{N} X_i | N\right)\right] = \sum_{i=1}^{m} V\left(\sum_{i=1}^{N} X_i | N = n\right) P\left(N = n\right) \tag{7}$$

$$= \sigma_1^2 p_1 + \left(\sigma_1^2 + \sigma_2^2\right) p_2 + \ldots + p_m \sum_{i=1}^{m} \sigma_i^2 \tag{8}$$

$$= \sum_{i=1}^{m} p_i \left(\sum_{j=1}^{i} \sigma_j^2\right) \tag{9}$$

and

$$V\left[E\left(Y|N\right)\right] = E\left[E\left(\sum_{i=1}^{N} X_i | N\right)\right]^2 - \left\{E\left[E\left(\sum_{i=1}^{N} X_i | N\right)\right]\right\}^2 \tag{10}$$

$$= \sum_{i=1}^{m} \left[E\left(\sum_{i=1}^{N} X_i | N\right)\right]^2 P\left(N = n\right) - \left[\sum_{i=1}^{m} p_i \left(\sum_{j=1}^{i} \mu_j\right)\right]^2 \tag{11}$$

$$= \sum_{i=1}^{m} p_i \left(\sum_{j=1}^{i} \mu_j^2\right) - \left[\sum_{i=1}^{m} p_i \left(\sum_{j=1}^{i} \mu_j\right)\right]^2 \tag{12}$$

Hence,

$$V(Y) = E[V(Y|N)] + V[E(Y|N)] \tag{13}$$

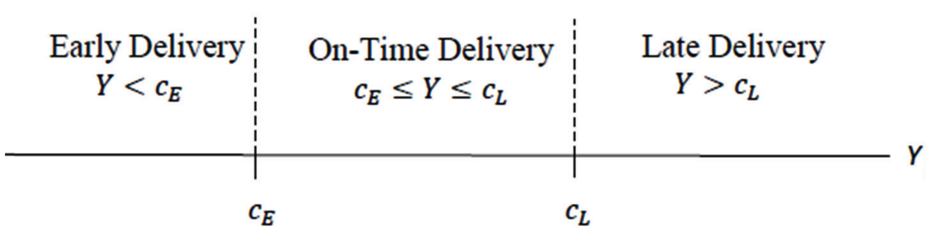
$$= \sum_{i=1}^{m} p_i \left(\sum_{j=1}^{i} \sigma_j^2\right) + \sum_{i=1}^{m} p_i \left(\sum_{j=1}^{i} \mu_j^2\right) - \left[\sum_{i=1}^{m} p_i \left(\sum_{j=1}^{i} \mu_j\right)\right]^2 \tag{14}$$

When X_i is distributed Gaussian, total delivery time $Y = \sum_{i=1}^{N} X_i$ is also Gaussian per the reproductive property of independent Gaussian random variables under addition. This is the case for the supply chain delivery models summarized in Table 1 where the activity time X_i at each stage of the supply chain is Gaussian under a strict make-to-order policy. However under the more generalized supply chain delivery model structure derived herein where Y is defined as a random sum of independent Gaussian random variables with mean and variance defined by equations (5) and (14), Y is no longer Gaussian. The convolution calculus to determine the exact distribution governing Y for the generalized modeling structure is extremely difficult and typically intractable.

An important metric in evaluating supply chain delivery performance measurement is the probability of on-time delivery (Hugos, 2011; Wang, 2010; Tan, Lyman, & Wisner, 2002; Gunasekaran, Patel, & Tirtiroglu, 2001). For a customer defined delivery window (see Figure 2) deliveries may be classified as early, on-time or late by comparing delivery time Y to benchmarks (c_E, c_L) which define early, on-time and late delivery. The delivery time benchmarks and penalty costs per unit time for early and late delivery are contractually stipulated in supply chains (Schneiderman, 1996). From a Six Sigma perspective, early and late deliveries are considered to be delivery process defects that contribute waste to the supply chain. Early deliveries $P(Y < c_E)$contribute to excess inventory holding costs; late deliveries $P(Y > c_L)$ contribute to production stoppage costs and loss of customer goodwill. The probability of on-time delivery, $P(c_E \leq Y \leq c_L)$, as characterized by Garg et al. (2006), is referred to as the *actual yield* of the supply chain delivery process.

When total delivery time Y is Gaussian with mean μ and standard deviation σ, Garg et al. (2006) defined the actual yield of a make-to-order supply chain in terms of the C_p and C_{pk} process capability indexes as

Figure 2. Illustration of supply chain delivery window



$$P(c_E \leq Y \leq c_L) = \Phi(3C_{pk}) + \Phi(6C_p - 3C_{pk}) - 1 \tag{15}$$

where:

$$C_p = \frac{c_L - c_E}{6\sigma}$$

$$C_{pk} = \frac{min\left(c_L - \mu, \mu - c_E\right)}{3\sigma}$$

$\Phi(\bullet)$ = the standard normal cumulative distribution function.

Under the more generalized modeling structure where the total delivery time Y is modeled as a random sum of independent Gaussian random variables, Y is no longer Gaussian and (15) no longer obtains. Given the complicated and typically intractable form of the probability density function of total delivery time when Y is defined as a random sum of independent Gaussian random variables, Monte Carlo simulation becomes a viable and useful methodology for establishing an empirical distribution to approximate Y. Given the empirical distribution, the actual yield for Y in the generalized delivery model now becomes

$$P\left(c_E \leq Y \leq c_L\right) = \sum_{i=c_E}^{c_L} P\left(Y_i\right) \tag{16}$$

Numerical Results

In this section we present a set of three numerical experiments that illustrate the generalized supply chain delivery model presented in the previous section. The following notation is introduced:

μ_Y = mean of empirical delivery distribution of total delivery time Y
σ_Y = standard deviation of empirical delivery distribution of total delivery time Y
δ = tolerance of delivery window
$c_E = \mu_Y - \delta$ = early delivery benchmark
$c_L = \mu_Y + \delta$ = late delivery benchmark
N = the number of stages in the supply chain

$P(N)$ = probability mass function for N
$E(N)$ = expected value of N
$V(N)$ = variance of N.

The probability mass function defining the probability of visiting stage N of the supply chain is varied to provide three numerical experiments to analyze the actual yield of the delivery process. Within each experiment, the tolerance of the delivery window was varied from 4 to 7 with a common set of normally distributed stage activity times. Time units are assumed to be days. By varying the probability mass function of N, the mix of make-to-order and make-to-stock deliveries occurring within the supply chain is varied thus capturing the key facet of the generalized supply chain delivery model presented in the previous section. Table 2 summarizes the parameter values used in the experiments. The Monte Carlo simulation procedure used to conduct the numerical experiments is available upon request from the authors.

The actual yields resulting from each experiment are summarized in Table 3. Actual yields were calculated for both the empirical delivery time distribution resulting from the Monte Carlo simulation of the generalized model and for a Gaussian distributed delivery time distribution. As expected, increasing the delivery tolerance increases the actual yield under either form of the delivery time distribution (see Figure 3). However, as the variance of the probability mass function of N increases, the difference (defined as empirical actual yield minus Gaussian actual yield) between the actual yield under the generalized model (which accommodates both make-to-order and make-to-stock delivery polices) and the Gaussian model (which is technically defined only for a make-to-order delivery policy) increases (see Figure 4). When the variance of N is largest (Experiment III), the largest net errors in the actual yield of the empirical and Gaussian deliveries occur. As the variance of N increases, the delivery process encounters a higher mixture of

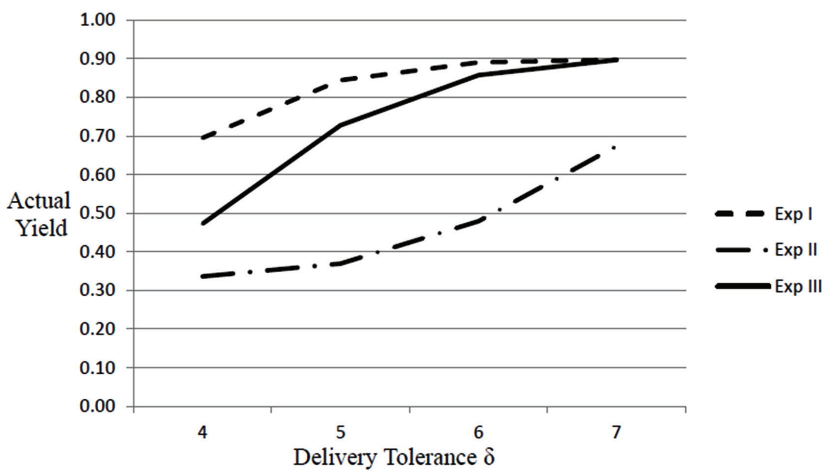
Table 2. Parameters for numerical experiments

Stage (N)	Activity Times (X_i)		Stage Probabilities $P(N)$		
	Mean	Variance	Experiment I	Experiment II	Experiment III
1	10.00	1.44	0.10	0.33	0.60
2	6.00	0.04	0.30	0.34	0.30
3	8.00	0.16	0.60	0.33	0.10
		$E(N)$	20.20	16.67	13.20
		$V(N)$	25.93	34.38	21.63

Table 3. Actual yield results from numerical experiments

Delivery Tolerance δ	Actual Yield (Probability of On-Time Delivery)					
	Experiment I		Experiment II		Experiment III	
	Empirical	Gaussian	Empirical	Gaussian	Empirical	Gaussian
4	0.695	0.607	0.336	0.505	0.473	0.570
5	0.844	0.714	0.369	0.606	0.727	0.676
6	0.890	0.800	0.479	0.694	0.857	0.764
7	0.897	0.865	0.673	0.768	0.896	0.833

Figure 3. Actual yield (probability of on-time delivery) vs. delivery tolerance

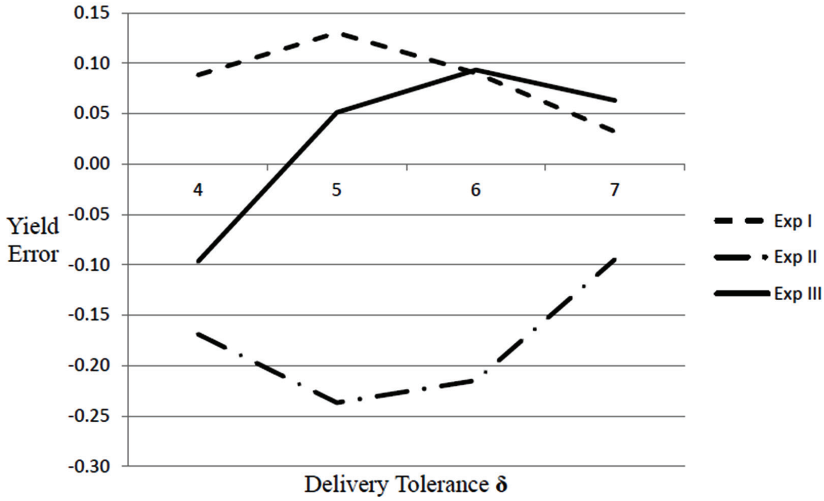


make-to-stock and make-to-order deliveries, and hence the actual yield (probability of on-time delivery) is better than the Gaussian which is technically valid for only make-to-order delivery realizations. In comparison to the empirical delivery time distribution resulting from the generalized delivery model, the assumed Gaussian model understated the actual yield in Experiments I and II (lower variance in *N*) and overstated the actual yield of the delivery process in Experiment III (higher variance in *N*).

Improving Delivery Performance through Delivery Time Variance Reduction

The delivery performance models summarized in Table 1 improve the actual yield of the delivery process by reducing the variance of the delivery time

Figure 4. Error in actual yield under Gaussian approximation



distribution. For a delivery time distribution with a fixed mean and constant delivery tolerance, reducing the variance of the delivery time distribution shifts more probability mass from the early and late portions of the delivery window into the on-time portion thus improving the actual yield of the delivery process. A limitation to these models is that the reduction in delivery variance occurs at only one point in time when in reality a continuous improvement program to improve the actual yield of the delivery process typically requires a planning horizon of several time periods in length with defined performance milestones. In this section we overcome this limitation and present a delivery variance reduction model for improving the actual yield of the delivery process that can be implemented over a defined time line with embedded performance milestones. The model is demonstrated for the case of a make-to-order Gaussian supply chain.

Applications of how learning curve models can be used to improve the performance of a process are abundant in the operations management and operations research literature (for a review of this literature see Jaber, 2011). A popular form of the learning curve is the Wright log-linear learning curve model which defines a functional relationship between cost and cumulative output. Under the Wright learning curve, each time cumulative output doubles the cost per unit decreases by a constant factor which is equal to the compliment of the learning rate. For example, a learning curve with an 80 percent learning rate will achieve a 20 percent reduction in cost each time cumulative output doubles.

Stata (1986) introduced the concept of the "half-life" as a predictive measure of system performance under conditions of learning. The half-life of a learning curve is the cumulative output level required to reduce the cost per unit to half its original value. Stata (1986) demonstrated the half-life concept as a tool for meeting performance improvement objectives for product quality, on-time delivery, lead time, yield, and new-product time to market. The half-life concept has inherent appeal to process improvements as it is common to speak of performance benchmarks such as "twice as much" or "half as much" (Badiru, 2011). The half-life milestone of a process can be generalized for a wider array of benchmarks (e.g., performance quartiles, performance deciles, etc.) for which the half-life model is a special case. By integrating delivery performance benchmarks based on the half-life concept into the variance-based improvement modeling of the actual yield of the supply chain delivery process, management can gain greater control and feedback in implementing improvements to the delivery process.

The actual yield for a Gaussian distributed delivery time distribution as a function of the variance of the delivery distribution can be stated as

$$P\left(\mu-\delta \le \mu \le \mu+\delta, \sigma^2\right) = 2\left(\frac{\delta}{\sqrt{\sigma^2}}\right) - 1 \tag{17}$$

where

μ = the mean of the delivery distribution
σ^2 = the variance of the delivery distribution
δ = the delivery tolerance
Φ = the standard normal cumulative distribution function.

Under the Wright form of the learning curve model, improvement in the variance of the delivery time distribution can be defined by

$$\sigma^2_{x_k} = \sigma^2_1 \left(x_k\right)^b \tag{18}$$

where

σ^2_1 = the initial variance of the delivery distribution
k = the performance milestone, $0 < k \le 1$ (note $k = 0.5$ is the half-life)
x_k = the cumulative delivery number for achieving performance milestone k

$\sigma^2_{x_k}$ = the delivery variance satisfying milestone k
$b = (ln\theta)/(ln2)$
θ = the learning rate ($0.5 < \theta < 1.0$)

Recognizing that $\sigma^2_{x_k} = k\sigma^2_1$ and substituting into (18) yields $k = (x_k)^b$. Taking the $(1/b)^{th}$ exponent of each side yields

$$x_k = (k)^{(1/b)} \tag{19}$$

when $k = \frac{1}{2}$ (19) is the half-life, e.g., the cumulative delivery number required to reduce the delivery variance time to half its original value. Since cumulative deliveries are integer, the ceiling function is introduced to insure that the milestone has been reached and (19) becomes

$$\lceil x_k \rceil = (k)^{(1/b)} \tag{20}$$

Numerical Illustration

Consider a make-to-order supply chain where the delivery time distribution is Gaussian distributed with mean $\mu = 20$ days and variance $\sigma^2 = 8.5$ days^2. Deliveries are made once per month and the delivery tolerance is $\delta = 3$ days. For these parameters the actual yield of the delivery process is 0.697. Table 4 illustrates the range of values for the delivery time variance and actual yield for delivery improvement milestones of $k = 0.10$ to $k = 0.90$ under learning-based improvement when the learning rate is $\theta = 0.80$.

Examining Table 4 we note that for a learning rate of 80%, the delivery variance can be decreased by 50 percent after the ninth cumulative delivery. With one delivery made per month, the actual yield of the delivery process increases from 0.697 to 0.857 in nine months. If management had targeted the actual yield to be 0.900, 18 months of improvement would be required to reduce the delivery variance from 8.500 to 3.352 to achieve this result.

DISCUSSION

The supply chain model presented in this chapter has overcome two limitations inherent to Six Sigma based supply chain delivery models found in

Table 4. Performance improvements in actual yield

Delivery Improvement Benchmark (*k*)	Delivery Number to Achieve Benchmark (x_k)	Variance of Delivery Distribution $\left(\sigma^2_{n_k}\right)$	Actual Yield $2\left(\dfrac{\delta}{\sqrt{\sigma^2_{x_k}}}\right)-1$
Current		8.500	0.697
0.90	2	6.800	0.750
0.80	3	5.968	0.781
0.70	4	5.440	0.802
0.60	5	5.063	0.818
0.50	9	4.190	0.857
0.40	18	3.352	0.899
0.30	43	2.533	0.941
0.20	149	1.697	0.979
0.10	1278	0.850	0.999

the literature. First, the model herein generalizes make-to-order Six Sigma supply chain delivery performance models to measure delivery performance for both make-to-order and make-to-stock supply chains. Second, the model has introduced learning curve theory as a means to achieve learning-based reduction in the variance of the delivery time distribution. Generalizing the half-life concept of the learning curve provides a methodology for implementing improvement in the actual yield of the delivery process using a planned time horizon with definable milestones for attaining targeted levels of improvement of the delivery process. By overcoming the limitations found in the Six Sigma supply chain delivery models reported in the literature, the generalized model provides management with the ability to measure delivery performance in supply chains operating under both make-to-order and make-to-stock ordering policies and to better manage programs to improve delivery performance.

There are several aspects of this research that can be extended. First, the model as presently defined is confined to measuring delivery performance in serial make-to-order and make-to-stock supply chains. Many supply chains are structured as networks with multiple retailers, manufacturers and raw material suppliers within each echelon of the supply chain. Measuring delivery performance in a network supply chain where delivery time to the final customer can be determined by multiple paths through the supply network would require a modeling strategy that could address this combinatoric aspect in defining total delivery time. Second, the model assumes that the total delivery time is the sum of independent upstage activity times. Expanding the model to allow for dependent stage activity times where the activity time of a predecessor stage impacts the activity time of a successor stage would further generalize the model. Third, reducing the variance of the delivery distribution to improve the actual yield of the delivery process is a widely accepted methodology for improving a process. Additional research is needed on how to model and coordinate improvements in the activity times of upstream stages of the supply chain so as to realize lower variability in the delivery time distribution. Fourth, case studies across a representative set of industries could be conducted to investigate and report on specific examples of managerial actions that have led to improvements in the delivery process. Lastly, total learning transmission between cumulative deliveries is assumed when improving the delivery process through learning-based reduction in the variance of the delivery time distribution. Disruptions in learning can occur between the stages of a supply chain hence the learning curve component of the model can be advanced by allowing for partial learning transfer.

CONCLUSION

The delivery process in a supply chain plays a fundamental role in the overall operation of the supply chain and is integral to promoting and maintaining long-term customer goodwill. Given this importance, research on the development of models to evaluate supply chain delivery performance is well represented in the literature on supply chain performance measurement. This chapter has contributed a delivery performance model which advances this literature by overcoming limitations found in current supply chain delivery performance models. The model presented herein is capable of measuring delivery performance in supply chains which are governed by make-to-order or make-to-stock ordering process. This model feature generalizes and extends the ability of supply chain managers to evaluate delivery performance within the supply chain. The model also supports the continuous improvement of supply chain delivery performance by providing a dynamic learning-based framework for improving delivery performance by reducing uncertainty in the delivery time distribution.

REFERENCES

Andersson, R., Eriksson, H., & Torstensson, H. (2006). Similarities and differences between TQM, six sigma and lean. *The TQM Magazine*, *18*(2), 282–296. doi:10.1108/09544780610660004

Azevedo, S. G., Carvalho, H., & Cruz-Machado, V. (2011). A proposal of LARG supply chain management practices and a performance measurement system. *International Journal of e-Education, e- Management Learning*, *1*(1), 7–14.

Badiru, A. B. (2011). Introduction to half-life learning curves. In M. Y. Jaber (Ed.), *Learning Curves Theory, Models and Applications* (pp. 129–161). Boca Raton, FL: CRC Press/Taylor and Francis Group. doi:10.1201/b10957-10

Beheshti, H. M., Oghazi, P., Mostaghel, R., & Hultman, M. (2014). Supply chain integration and firm performance: an empirical study of Swedish manufacturing firms. *Competitiveness Review: An International Business Journal Incorporating Journal of Global Competitiveness, 24*(1), 3–13.

Birou, L., Germain, R. N., & Christensen, W. J. (2011). Applied logistics knowledge impact on financial performance. *International Journal of Operations & Production Management*, *31*(8), 816–834. doi:10.1108/01443571111153058

Bititci, U. S., Suwignjo, P., & Carrie, A. S. (2001). Strategy management through quantitative modelling of performance measurement systems. *International Journal of Production Economics*, *69*(1), 15–22. doi:10.1016/S0925-5273(99)00113-9

Brady, J. E., & Allen, T. T. (2006). Six Sigma literature: A review and agenda for future research. *Quality and Reliability Engineering International*, *22*(3), 335–367. doi:10.1002/qre.769

Bushuev, M. A., & Guiffrida, A. L. (2012). Optimal position of supply chain delivery window: Concepts and general conditions. *International Journal of Production Economics*, *137*(2), 226–234. doi:10.1016/j.ijpe.2012.01.039

Byrne, G., Lubowe, D., & Blitz, A. (2007). Using a Lean Six Sigma approach to drive innovation. *Strategy and Leadership*, *35*(2), 5–10. doi:10.1108/10878570710734480

Chan, F. T. S., Chan, H. K., & Qi, H. J. (2006). A review of performance measurement systems for supply chain management. *International Journal of Business Performance Management*, *8*(2/3), 110–131. doi:10.1504/IJBPM.2006.009032

Chan, F. T. S., Swarnkar, R., & Tiwari, M. K. (2006). Synchronisation issue of supply chains: A six-sigma constrained random search approach. *International Journal of Services Technology and Management*, *7*(5/6), 552–567. doi:10.1504/IJSTM.2006.011287

Chapman, P., Beron, M., & Haggett, P. (2011). Applying selected quality management techniques to diagnose delivery time variability. *International Journal of Quality & Reliability Management*, *28*(9), 1019–1040. doi:10.1108/02656711111172568

Choudhary, A. K., Singh, D. A., & Tiwari, M. K. (2006). A statistical tolerancing approach for design of synchronized supply chains. *Robotics and Computer-integrated Manufacturing*, *22*(4), 315–321. doi:10.1016/j.rcim.2005.07.003

Christopher, M., & Lee, H. (2004). Mitigating supply chain risk through improved confidence. *International Journal of Physical Distribution & Logistics Management*, *34*(5), 388–396. doi:10.1108/09600030410545436

Cuthbertson, R., & Piotrowicz, W. (2011). Performance measurement systems in supply chains a framework for contextual analysis. *International Journal of Productivity and Performance Management*, *60*(6), 583–602. doi:10.1108/17410401111150760

Dasgupta, T. (2003). Using the six-sigma metric to measure and improve the performance of a supply chain. *Total Quality Management and Business Excellence*, *14*(3), 355–366. doi:10.1080/1478336032000046652

Forslund, H., Jonsson, P., & Mattsson, S. (2009). Order-to-delivery performance in delivery scheduling environments. *International Journal of Productivity and Performance Measurement*, *58*(1), 41–53. doi:10.1108/17410400910921074

Garg, D., Naraharai, Y., & Viswanadham, N. (2006). Achieving sharp deliveries in supply chains through variance reduction. *European Journal of Operational Research*, *171*(1), 227–254. doi:10.1016/j.ejor.2004.08.033

Gopal, P. R. C., & Thakkar, J. (2012). A review on supply chain performance measures and metrics: 2000-2011. *International Journal of Productivity and Performance Measurement*, *61*(5), 518–547. doi:10.1108/17410401211232957

Guiffrida, A. L. (2014). Recent trends in supply chain delivery models. *International Journal of Social, Management, Economics and Business Engineering*, *8*(4), 1809–1812.

Guiffrida, A. L., Chen, L., Liang, H., Ngniatedema, T., & Tanai, Y. (2013). Modeling supply chain delivery performance: A literature review. In *Proceedings of the 2013 International Academy of Business and Economics Conference*, (pp. 11-20). Academic Press.

Guiffrida, A. L., & Nagi, R. (2006). Cost characterizations of supply chain delivery performance. *International Journal of Production Economics*, *102*(1), 22–36. doi:10.1016/j.ijpe.2005.01.015

Gunasekaran, A., & Kobu, B. (2007). Performance measures and metrics in logistics and supply chain management: A review of recent literature (1995-2004) for research and application. *International Journal of Production Research*, *45*(12), 2819–2840. doi:10.1080/00207540600806513

Gunasekaran, A., Patel, C., & McGaughey, R. (2004). A framework for supply chain performance measurement. *International Journal of Production Economics*, *87*(3), 333–347. doi:10.1016/j.ijpe.2003.08.003

Gunasekaran, A., Patel, C., & Tirtiroglu, E. (2001). Performance measures and metrics in a supply environment. *International Journal of Operations & Production Management*, *21*(1/2), 71–87. doi:10.1108/01443570110358468

Hellsten, U., & Klefsjö, B. (2000). TQM as a management system consisting of values, techniques and tool. *The TQM Magazine*, *12*(4), 238–244. doi:10.1108/09544780010325822

Hsu, B.-M., Hsu, L.-Y., & Shu, M.-H. (2013). Evaluation of supply chain performance using delivery-time performance analysis chart approach. *Journal of Statistics and Management Systems*, *16*(1), 73–87. doi:10.1080/09720510.2013.777568

Hugos, M. H. (2011). *Essentials of Supply Chain Management* (vol. 62). Wiley.

Huo, B. (2012). The impact of supply chain integration on company performance: An organizational capability perspective. *Supply Chain Management: An International Journal*, *17*(6), 596–610. doi:10.1108/13598541211269210

Jaber, M. Y. (2011). *Learning Curves Theory, Models, and Applications*. Boca Raton, FL: CRC Press/Taylor and Francis Group. doi:10.1201/b10957

Johnson, M., & Templar, S. (2011). The relationships between supply chain and firm performance. *International Journal of Physical Distribution & Logistics Management*, *41*(2), 88–103. doi:10.1108/09600031111118512

Kim, S. W. (2009). An investigation of the direct and indirect effect of supply chain integration on firm performance. *International Journal of Production Economics*, *119*(2), 328–346. doi:10.1016/j.ijpe.2009.03.007

Kleijnen, J. P. (2005). Supply chain simulation tools and techniques: A survey. *International Journal of Simulation and Process Modeling*, *1*(1/2), 82–89.

Knowles, G., Whicher, L., Femat, J. H., & Canales, F. D. C. (2005). A conceptual model for the application of Six Sigma methodologies to supply chain improvement. *International Journal of Logistics: Research and Applications*, *8*(1), 51–65. doi:10.1080/13675560500067459

Kokkranikal, A. J., Kosgi, H., & Losekoot, E. (2013). Barriers and challenges in the application of Six Sigma in the hospitality industry: Some observations and findings. *International Journal of Productivity and Performance Management*, *62*(3), 317–322. doi:10.1108/17410401311309203

Lee, K. L. (2002). *Critical Success Factors of Six Sigma Implementation and the Impact on Operations Performance*. (Dissertation). Cleveland State University, Cleveland, OH.

Lee, M. C., & Chang, T. (2010). Developing a lean design for Six Sigma through supply chain methodology. *International Journal of Productivity and Quality Management*, *6*(4), 407–434. doi:10.1504/IJPQM.2010.035891

Leuschner, R., Rogers, D. S., & Charvet, F. F. (2013). A meta-analysis of supply chain integration and firm performance. *Journal of Supply Chain Management*, *49*(2), 34–57. doi:10.1111/jscm.12013

Lin, L.-C., & Li, T.-S. (2010). An integrated framework for supply chain performance measurement using six-sigma metrics. *Software Quality Journal*, *18*(3), 387–406. doi:10.1007/s11219-010-9099-2

Lockamy, A., & McCormack, K. (2004). Linking SCOR planning practices to supply chain performance: An exploratory study. *International Journal of Operations & Production Management*, *24*(12), 1192–1218. doi:10.1108/01443570410569010

Magnusson, K., Kroslid, D., Bergman, B., Häyhänen, P., & Mills, D. (2003). *Six Sigma: The Pragmatic Approach*. Lund: Studentlitteratur.

Martin, P. R., & Patterson, J. W. (2009). On measuring company performance within a supply chain. *International Journal of Production Research*, *47*(9), 2449–2460. doi:10.1080/00207540701725604

Nabhani, F., & Shokri, A. (2009). Reducing the delivery lead time in a food distribution SME through the implementation of six sigma methodology. *Journal of Manufacturing Technology Management*, *20*(7), 957–974. doi:10.1108/17410380910984221

Pepper, M. P. J., & Spedding, T. A. (2010). The evolution of lean Six Sigma. *International Journal of Quality & Reliability Management*, *27*(2), 138–155. doi:10.1108/02656711011014276

Ramaa, A., Subramanya, K. N., & Rangaswamy, T. M. (2013). Performance measurement of supply chain – an empirical study. *International Journal of Business Performance and Supply Chain Modelling*, *5*(4), 343–360. doi:10.1504/IJBPSCM.2013.058202

Rao, C. M., Rao, K. P., & Muniswamy, V. V. (2011). Delivery performance measurement in an integrated supply chain: Case study in batteries manufacturing firm. *Serbian Journal of Management*, *6*(2), 205–220. doi:10.5937/sjm1102205M

Roy, M., Gupta, R. K., & Dasgupta, T. (2013). A technique for determining the optimal mix of logistics service providers of a make-to-order supply chain by formulating and solving a constrained nonlinear cost optimization problem. *Decision Sciences Letters*, *2*(1), 1–14.

Safaei, M., Issa, S., Seifert, M., Thoben, K.-D., & Lang, W. (2013). A method to estimate the accumulated delivery time uncertainty in supply networks. In H.-J. Kreowski, B. Scholz-Reiter, & K.-D. Thoben (Eds.), *Dynamics in Logistics, Lecture Notes in Logistics* (pp. 337–347). Berlin: Springer-Verlag. doi:10.1007/978-3-642-35966-8_28

Salah, S., Rahim, A., & Carretero, J. A. (2011). Implementation of Lean Six Sigma (LSS) in supply chain management (SCM): An integrated management philosophy. *International Journal of Transitions and Innovation Systems*, *1*(2), 138–162. doi:10.1504/IJTIS.2011.039622

Sambasivan, M., Mohamed, Z. A., & Nanden, T. (2009). Performance measures and metrics for e-supply chains. *Journal of Enterprise Information Management*, *22*(3), 346–360. doi:10.1108/17410390910949751

Schneiderman, A. M. (1996). Metrics for order fulfillment process (part I). *Journal of Cost Management*, *10*(2), 30–42.

Schroeder, R. G., Linderman, K., Liedtke, C., & Choo, A. S. (2008). Six Sigma: Definition and underlying theory. *Journal of Operations Management*, *26*(4), 536–554. doi:10.1016/j.jom.2007.06.007

Shepherd, C., & Günter, H. (2006). Measuring supply chain performance: Current research and future directions. *International Journal of Productivity and Performance Management*, *55*(3/4), 242–258. doi:10.1108/17410400610653219

Shi, M., & Yu, W. (2012). Supply chain management and financial performance: Literature review and future directions. *International Journal of Operations & Production Management*, *33*(10), 1283–1317. doi:10.1108/IJOPM-03-2012-0112

Stata, R. (1986). Organization learning – the key to management innovation. *Sloan Management Review*, (Spring): 63–74.

Suwignjo, P., Bititci, U. S., & Carrie, A. S. (2000). Quantitative models for performance measurement system. *International Journal of Production Economics*, *64*(1), 231–241. doi:10.1016/S0925-5273(99)00061-4

Tan, K. C., Lyman, S. B., & Wisner, J. (2002). Supply chain management: A strategic perspective. *International Journal of Operations & Production Management*, *22*(6), 614–631. doi:10.1108/01443570210427659

Tetteh, E. G., Eyob, E., & Amewokunu, Y. (2013). *Evaluation of Key Metrics for Performance Measurement of a Lean Deployment Effort*. Hershey, PA: IGI Global.

Vachon, S., & Klassen, R. D. (2002). An exploratory investigation of the effects of supply chain complexity on delivery performance. *IEEE Transactions on Engineering Management*, *49*(2), 218–230. doi:10.1109/TEM.2002.803387

Wagner, S. M., Grosse-Ruyken, P. T., & Erhun, F. (2012). The link between supply chain fit and financial performance of the firm. *Journal of Operations Management*, *30*(4), 340–353. doi:10.1016/j.jom.2012.01.001

Wang, F. K., & Du, T. C. (2007). Applying capability index to the supply chain network analysis. *Total Quality Management*, *18*(4), 425–434. doi:10.1080/14783360701231807

Wang, F. K., Du, T. C., & Li, E. Y. (2004). Applying Six-Sigma to supplier development. *Total Quality Management and Business Excellence*, *15*(9/10), 1217–1229. doi:10.1080/1478336042000255596

Wang, I. (2010). The application of third part logistics to implement the Just-In-Time system with minimum cost under a global environment. *Expert Systems with Applications*, *37*(3), 2117–2123. doi:10.1016/j.eswa.2009.07.030

Yang, H. M., Choi, B. S., Park, H. J., Suh, M. S., & Chae, B. (2007). Supply chain management six sigma: A management innovation methodology at the Samsung Group. *Supply Chain Management: An International Journal*, *12*(2), 88–95. doi:10.1108/13598540710737271

Zhang, W., Hill, A. V., & Gilbreath, G. H. (2011). A research agenda for Six Sigma research. *Quality Management Journal*, *18*(1), 39–53.

ADDITIONAL READING

Abd El-Aal, M. A. M., El-Sharief, M. A., El-Deen, A. E., & Nassr, A.-B. (2011). Supply chain performance evaluation: A comprehensive evaluation system. *International Journal of Business Performance and Supply Chain Modelling*, *3*(2), 141–166. doi:10.1504/IJBPSCM.2011.041376

Arnheiter, E. D., & Maleyeff, J. (2005). The integration of lean management and Six Sigma. *The TQM Magazine*, *17*(1), 5–18. doi:10.1108/09544780510573020

Beamon, B. M. (1999). Measuring supply chain performance. *International Journal of Operations & Production Management*, *19*(3), 275–292. doi:10.1108/01443579910249714

Cao, M., & Zhang, Q. (2011). Supply chain collaboration: Impact on collaborative advantage and firm performance. *Journal of Operations Management*, *29*(3), 163–180. doi:10.1016/j.jom.2010.12.008

Carvalho, H., Azevedo, S. G., & Cruz-Machado, V. (2010). Supply chain performance management: Lean and green paradigms. *International Journal of Business Performance and Supply Chain Modelling*, *2*(3), 304–333. doi:10.1504/IJBPSCM.2010.036204 da Silveira, G. J. C., & Arkader, R. (2007). The direct and mediated relationships between supply chain coordination investments and delivery performance. *International Journal of Operations & Production Management*, *27*(2), 140–158. doi:10.1108/01443570710720595

Danese, P., Romano, P., & Formentini, M. (2013). The impact of supply chain integration on responsiveness: The moderating effect of using an international supplier network. *Transportation Research Part E, Logistics and Transportation Review*, *49*(1), 125–140. doi:10.1016/j.tre.2012.08.002

Elgazzar, S. H., Tipi, N. S., Hubbard, N. J., & Leach, D. Z. (2012). Linking supply chain processes' performance to a company's financial strategic objectives. *European Journal of Operational Research*, *223*(1), 276–289. doi:10.1016/j.ejor.2012.05.043

Fawcett, S. E., Calantone, R., & Smith, S. R. (1997). Delivery capability and firm performance in international operations. *International Journal of Production Economics*, *51*(3), 191–204. doi:10.1016/S0925-5273(97)00051-0

Forslund, H., & Jonsson, P. (2010). Integrating the performance management process of on-time delivery with suppliers. *International Journal of Logistics: Research and Applications*, *13*(3), 225–241. doi:10.1080/13675561003712799

Golini, R., & Kalchschmidt, M. (2010). Global supply chain management and delivery performance: a contingent perspective, In: G. Reiner (Ed.), Rapid Modelling and Quick Response (pp. 231-247), Springer-Verlag, London Limited. doi:10.1007/978-1-84996-525-5_16

Goodrich, P. L. (2010). *Delivery Time Variance Reduction in the Military Supply Chain*, Thesis, Department of the Air Force Air University, Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio.

Guiffrida, A. L. (2009). A probability based model for evaluating delivery performance. *Journal of the Academy of Business and Economics*, *9*(3), 95–104.

Guiffrida, A. L., Rzepka, R. A., & Jaber, M. Y. (2007). A convolution algorithm for evaluating supply chain delivery performance. *Proceedings of the 40th Hawaii International Conference on System Sciences (HICSS-40)*, 9 pages, CD-ROM, IEEE Computer Society, January 3-6, 2007. doi:10.1109/HICSS.2007.12

Huehn-Brown, W. J., & Murray, S. L. (2010). Are companies continuously improving their supply chain? *Engineering Management Journal*, *22*(4), 3–10.

Jaber, M. Y., Bonney, M., & Guiffrida, A. L. (2010). Coordinating a three-level supply chain with learning-based continuous improvement. *International Journal of Production Economics*, *127*(1), 27–38. doi:10.1016/j.ijpe.2010.04.010

Kerber, B., & Dreckshage, B. J. (2011). *Lean Supply Chain Management Essentials: A Framework for Materials Managers*. Boca Raton, FL: CRC Press/Taylor and Francis Group.

Ma, J., Wang, K., & Xu, L. (2011). Modelling and analysis of workflow for lean supply chains. *Enterprise Information Systems*, *5*(4), 423–447. doi:10.1080/17517575.2011.580007

Malik, A., & Blumenfeld, S. (2012). Six Sigma, quality management systems and the development of organizational learning capability: Evidence from four business process outsourcing organisations in India. *International Journal of Quality and Reliability Analysis*, *29*(1), 71–91.

Mishra, P., & Sharma, R. K. (2014). A hybrid framework based on SIPOC and Six Sigma DMAIC for improving process dimensions in supply chain network. *International Journal of Quality and Reliability Analysis*, *31*(5), 522–546.

Morgan, C. (2004). Structure, speed and salience: Performance measurement in the supply chain. *Business Process Management Journal*, *10*(5), 522–536. doi:10.1108/14637150410559207

Morgan, C., & Dewhurst, A. (2008). Multiple retailer supplier performance: An exploratory investigation into using SPC techniques. *International Journal of Production Economics*, *111*(1), 13–26. doi:10.1016/j.ijpe.2006.11.018

Neely, A., Gregory, M., & Platts, K. (1995). Performance measurement system design: A literature review and research agenda. *International Journal of Operations & Production Management*, *15*(4), 80–116. doi:10.1108/01443579510083622

Nieminen, P., & Takala, J. (2006). Achieving better on-time-delivery performance with the help of internal dependencies in the production. *International Journal of Management and Enterprise Development*, *3*(1/2), 181–190. doi:10.1504/IJMED.2006.008249

Paul, M. C., Babu, A. V., Reddy, D. M., & Perati, M. R. (2013). Analytical models for delivery performance of a supplier or a service provider. *American Journal of Industrial and Business Management*, *3*(6), 39–42. doi:10.4236/ajibm.2013.36A005

Safaei, M., Seifert, M., & Thoben, K. D. (2010). Proposed a method for increasing the delivery performance in dynamic supply network. *World Academic of Science*. *Engineering and Technology*, *70*, 620–623.

Salvador, F., Forza, C., Rungtusanatham, M., & Choi, T. Y. (2001). Supply chain interactions and time-related performances: An operations management perspective. *International Journal of Operations & Production Management*, *21*(4), 461–475. doi:10.1108/01443570110381372

Soepenberg, G. D., Land, M., & Gaalman, G. (2008). The order process diagram: A supportive tool for diagnosing delivery reliability performance in make-to-order companies. *International Journal of Production Economics*, *112*(1), 495–503. doi:10.1016/j.ijpe.2007.06.001

Soni, G., & Kodali, R. (2009). Performance value analysis for the justification of the leagile supply chain. *International Journal of Business Performance Management*, *11*(1/2), 96–133. doi:10.1504/IJBPM.2009.023802

Vunjak, N. M., Buha, J., Zulfiu, V., & Tangiri, P. P. (2013). An empirical study on efficiency, effectiveness and performance measurement in supply chain management. *Strategic Management*, *18*(4), 27–34.

Whicker, L., Bernon, M., Templar, S., & Mena, C. (2009). Understanding the relationships between time and cost to improve supply chain performance. *International Journal of Production Economics*, *121*(2), 641–650. doi:10.1016/j.ijpe.2006.06.022

KEY TERMS AND DEFINITIONS

Actual Yield: Is the proportion of supply chain deliveries that arrive within the on-time portion of the supply chain delivery window.

Ceiling Function: The ceiling function for variable *X* is denoted as $\lceil X \rceil$ and is defined as the smallest integer not less than *X*.

Delivery Window: A specified time interval in which a delivery to the end customer in a supply chain is to be made. In the statement of the delivery window milestone benchmarks in time are used to classify a delivery as being early, on-time or late. Under a delivery window, deliveries that are classified as early or late are subject to contractually agreed upon penalty costs. No penalty costs are assigned for on-time deliveries.

Learning Curve Theory: Is a relationship between the unit production time (production cost) and the cumulative number of units produced. As a result of learning the unit's production time (cost) declines by a fixed percentage each time cumulative output doubles. The most widely adopted mathematical form of the learning curve defines a log-linear relationship between unit production time and cumulative output.

Monte Carlo Simulation: Is a technique used to incorporate uncertainty into decision models when the model form is difficult to represent in a closed form expression. Monte Carlo simulation uses repeated random sampling from user defined probability distributions which represent the uncertain facets of the model to generate a set of numerical solutions of the model. The resulting set of numerical solutions is then statistically analyzed to provide insight of the probabilistic behavior of the model.

Make-to-Order Policy: A production strategy where a customer order for an end product is manufactured on a unique basis. The end product is manufactured only when a customer order for it is received. A make-to-order policy is found in a pull-type supply chain.

Make-to-Stock Policy: A production strategy where a customer order is matched to existing capacity and inventoried components of the end product. A make-to-stock policy is found in a push-type supply chain.

Random Variable: In probability and statistics a random variable is a function that assigns a real number to each possible outcome in a sample space of an experiment. Random variables can be either continuous or discrete. Outcomes for a continuous random variable are governed by a probability density function; outcomes for a discrete random variable are governed by a probability mass function.

Random Sum of Random Variables: Is the addition of a series of random variables where the number of random variables being summed in the series is also a random variable.

Chapter 5
An Assessment of Lean Communication at a Nuclear Power Plant

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ABSTRACT

Communication is the sharing of information between individuals or groups to reach common understanding or goals. Ensuring effective and efficient communication is important when dealing with complex structures such as a nuclear power generation environment. This calls for a need for partnership and dialogue between major stakeholders in government, industry, employees, and the public at large. Even though communication can alarm people to seek safety, it can be used to calm employees as well as generate a sense of urgency. This chapter uses a survey to investigate the relationship between communication and 13 critical factors of lean management principles in an organization where safety is the fundamental component of the process. Data was collected and analyzed using Pearson's correlation coefficient and regression analysis. The results show that friendliness, willingness, guarantee, criticism, self-esteem, and acceptance are positive predictors of a lean communication while responsibility is negative.

DOI: 10.4018/978-1-4666-7320-5.ch005

INTRODUCTION

Lean philosophy is the ideology of reducing or eliminating waste. Its purpose is to promote a more successful and profitable business. Currently, many businesses are indulging in lean production or lean manufacturing. They focus on eliminating waste in all parts of their production process. This minimizes the amount of sitting inventory and encourages "as needed" production. If they only produce what is demanded by customers, fewer resources would be wasted on maintaining or storing extra inventory. Lean manufacturing also involves input from the workers who work directly with the production process. As a result, they are able to fix problems and make improvements as needed, rather than, having to report those problems and wait until handled through higher authority. Lean manufacturing is "the key to achieve sustainable development" (Upadhye, Deshmukh, & Garg, 2010). Throughout the years, the principles of lean have been successfully applied to other areas by both researchers and practitioners.

Communication is one of the areas prone to what lean enterprise can offer. Downs and Hazen (1977) defines communication as an "intervening variable that leads to (1) productivity, (2) satisfaction, (3) labor-management relations, and (4) profit." In any business or work place, communication is crucial, especially efficient communication. Communication can "facilitate the exercise of the functions of forecasting, organization, coordination, empowerment or control, and the participation of the members of the organization to achieving the objectives…" (Emanoil, Ramona, & Lucia, 2013). Most of the time spent within a business is used communicating.

Efficient communication is the sharing and receiving of information in a timely manner and without waste. Information should be transmitted straight to the point to be efficient. Efficiently communicating will save time, energy, and confusion; therefore, leading to the possibility of having lean communication.

This research aims to apply lean principles to communication. The goal is to find what factors can be improved to increase efficient communication. If waste can be reduced in manufacturing and production to create a more successful processes and procedures, it is possible to apply the same principals to communication needs.

LITERATURE REVIEW

Lean Philosophy

Lean is minimizing or eliminating waste. Waste can be categorized in eight processes: "over production, waiting, motion, transportation, inventories, over-processing, defects, and other which includes underutilized worker creativity and resource, application of non-adequate equipments and systems, wasted energy and water, (and) damage of environment" (Kovacs, 2012). Kovacs (2012) also defines lean thinking as "thinking that focuses on value added flow and the efficiency of the overall system. The goal is to keep product flowing and add value as much as possible. The focus is on the overall system and synchronizing operations. Bhasin (2011) argued why lean should be considered as an ideology.He explained that "Lean explores the conventional wisdom behind situations, identifying the root cause of issues and then proceeding to solve problems, often in a unique and spectacular fashion."

Standard and Davis (2000) breaks down lean into three parts: lean philosophy, lean principles, and lean practices. Lean philosophy focuses on "total system efficiency, continual improvement, value-added activity, and respect for people" (Standard & Davis, 2000). Lean principles emphasizes the reorganization of" the flow of production material throughout the entire enterprise" (Standard & Davis, 2000). This is supported by lean practices by decreasing the variability of production.

In order to make lean applicable, an organization must not include one of the previously mentioned elements, but all of them. Research conducted by Bhasin (2011) "attempts to establish that Lean is a total system supporting and encouraging its employees to continuously improve the processes they work on." This goes back to why communication and its factors are important. Continually carrying out an efficient and accurate system of communication will make the lean system beneficial. When viewing and implementing lean, Bhasin (2011) mentions that one should not look at it in a narrow sense but analyze the entire organization. This would include the employees, the management, and production. This chapter examines a list of concepts to determine whether an organization views lean as an ideology or a philosophy, some included:

- Lean is continuous and becomes a way of thinking;
- An appreciation that Lean is an integration of a complete system;
- A recognition that Lean is not synonymous with religion;
- In every circumstance, Lean has to produce profits;

- The importance of developing people is fully acknowledged;
- An implementation program of the appropriate tools; a simultaneous application of five or more of the technical tools depending on the stage of implementation;
- Tools are considered to be mechanisms to see problems and not solutions;
- Lean should be extended to the entire value chain, including outsourcing;
- The organization needs to have a clear clarity of vision in relation to Lean;
- Make numerous cultural changes embracing empowerment and sponsor the Lean principles throughout the value chain; and
- Make substantial organizational changes such as remuneration systems, links with marketing and logistics and the training culture (Bhasin, 2011).

In order for a business to be able to embrace being lean, it must consider the above mentioned. The organization must adopt being lean into its company's practices, vision, and mission. Every aspect and division of the business must operate based on being Lean, including outsourcing.

In the study Bhasin (2011) conducted, he discovered that the organizations that displayed the best performances involved: "higher profitability; improved employee performance; improved market share; increased competitiveness; and constant waste reduction." "The base line is that markets, technology, people and money all need to be attended to for a business to be successful" (Bhasin, 2011). The companies used in Bhasin's study used Lean as a business philosophy, thus demonstrating the above results. This leads to the implication that applying the lean philosophy to an organization can better the company in all areas that judges a company's performance level. Stone (2012) suggested that the definition of lean should consist of three terms that describes the end of the process, what occurred to achieve the ending goal, and what was used to carry out the process.

Bhasin (2011) came to the conclusion that lean would make planning and processing easier while shortening the lead time through the supply chain. He also concluded that Lean should be viewed as a developing discipline and dynamic since it its constantly improving. Organizations should use Lean as a "long-term commitment" (Bhasin, 2011) that is both physical and financial. The more it is practiced, the simpler it would be to lead the business into obtaining its benefits.

Lean Manufacturing

The idea of lean production did not begin with the Toyota Production System (TPS) or the Just in Time Production (JIT). It began as far back as Eli Whitney's interchangeable parts of the cotton gin in 1799 and the thousands of muskets he manufactured for the U.S. Army at an unbelievably low price. Fredrick W. Taylor developed the idea of Scientific Management, which led to Lillian Gilbreth studying workers and involving psychology. This began the idea of eliminating waste. Then came Henry Ford who became known as the first practitioner of Just In Time and Lean Manufacturing (Sun, 2011). It wasn't until the 1950s and 1960s that Eiji Toyoda and Taiichi Ohno of Toyota began developing more approaches of lean manufacturing (Upadhye et. al., 2010).

In the late 1990s, the introduction of Lean Thinking encouraged organizations to come to a better understanding of planned change throughout the organization as a whole (Stone, 2012). According to Standard and Davis (2000), productivity has risen by 35% between 1995 and 2000 and is continuously increasing. In order for manufacturers to keep up with competition, they must make sure they are continuously improving.

Lean production, also known as lean manufacturing, is eliminating or minimizing waste in every area of an organization's or business's production system. "Waste is anything that does not contribute to transforming a part of your customer's needs" (Kovács, 2012). Lean manufacturing "… has been credited as the standard production management approach in the 21st century" (Sun, 2011). For a company to achieve lean production or manufacturing, it must reach a high-volume of production while using the least amount of resources, ongoing processes, and completed products. Lean focuses on the idea to produce product as it is needed or as customers demand it. Lean manufacturing also aims to reduce costs by "eliminating non-value added activities" and by optimizing quality and costs to gain a competitive advantage (Kovács, 2012). It aims to meet the expectations of its current and potential customers. "Lean has become accepted by academics and practitioners as the dominant approach in manufacturing management" (Boyle & Scherrer-Rathje, 2011). Sun (2011) quoted that the Lean Aerospace Initiative definition of Lean as: "The dynamic, knowledge-driven, and customer-focused process through which all people in a defined enterprise continuously eliminate waste with the goal of creating value."

Steinlicht (2010) classifies the techniques of lean into three views. He calls the first view "benchmarking," or imitating other organizations to keep up with competition. The second view is called "bolt-on," where an organization adapts its local conditions to lean principles. The third view is called "adaptation." This means to "completely reinvent the organization (using the principles of lean instead of the tools and practices)…This approach uses lean to achieves cultural change" (Steinlicht, 2010).

Stone (2012) suggested that the principles of lean are related to the "tools used to execute" the process. Kovács (2012) identifies five principles of lean manufacturing: "Value, the value stream, flow, pull, and perfection." Sun (2011) lists a more in depth description of Kovács' principles:

- Understanding the customers' wants and producing to meet their expectations;
- Aim to be perfect by identifying and getting rid of waste;
- Make employees a part of the analyzing and improving process;
- Introduce a "plan-do-check-act" system to achieve goals effectively and efficiently;
- Use statistics and adequate feedback to solve issues in a timely manner; and
- Carry out activities for improvement from a company-wide perspective.

"Some lean organizations also rely heavily on Six Sigma, which includes a set of statistical techniques for identifying and reducing process variation" (Sun, 2011). Krause (2009) states that Lean Six Sigma focuses on: "Delighting your customers with speed and quality; improving your work processes; working together for maximum gain; basing decisions on facts and data." Compared to the basics of Lean philosophy itself, lean production and manufacturing not only emphasizes increasing profits, competitiveness in the global market, and employee involvement, it focuses on the customers as well.

Sun (2011) characterizes lean production into three traits:

1. "Aggressive efforts to satisfy customers,
2. Lean operations throughout the entire delivery system (producing the outputs that customers want with the minimum possible direct costs for labor, materials, and tools), and
3. Tight integration of resource networks (integrating inputs through extensive use of technology)."

According to Kovács (2012), applying lean manufacturing comes with many advantages such as shorter production lead times, operation timing imbalances are more obvious, mistakes become more obvious and their source can be identified quickly, there is a continuous drive to improve, and part handling and inventory costs are at a minimum. The transformation to using a lean strategy has been proven to be more successful when the entire organization is aligned along the same strategy (Stone, 2012). Upadhye, Deshmukh, and Garg (2010) stated that in reference to JIT, "…a work culture that allows: the worker to become a participant in decision making and thus necessary putting trust and responsibility in the hands of the workers…" In other words, having worker participation can lead to efficiency in the work place and can help accomplish the goals of lean manufacturing. "…it is not surprising that successfully implementing lean is a complex task that has led to disappointing results for many" (Boyle & Scherrer-Rathje, 2011). The awareness of lean can be maintained through a variety of external and internal information sources.

Lean Communication

Emanoil, Ramona, and Lucia (2013) define communication as "the process of exchanging messages with the view of achieving the individual and common objectives of its members." Regardless of how it is done, communication is mandatory and important within an organization. Communication is the "key to organizational excellence and efficiency" (Emanoil, Ramona, & Lucia, 2013). The process or systems in which a company chooses to communicate depends on the kind of organization and the capacity of it. Emanoil, Ramona, and Lucia (2013) organize organizational communication in two types:

1. "Communication defined formally among those that occupy various positions in an organization; and
2. Communication defined informally, among persons as individuals (separate from their position in the organization)."

"Communication scholars argue that communication is necessary for the organizing of any organization to take place and that we should not assume that more communication is equated with better communication" (Keyton et al., 2013). Therefore, keeping communication direct and to the point can get the message across as efficiently as possible. Keyton et al. (2013) go on to discuss that communication behaviors contribute to work being accomplished. To get a better understanding of this, they argue that the focus should be on behaviors or tasks, the smallest unit of communication to complete work. Focusing on this can lead to creating more efficient trainings and evaluations. Therefore, diminishing unnecessary aspects of communication. Without communication, the employees will not be able to comprehend the organization itself and what is going on within it. Being aware of what is happening and what can spark motivation can contribute to the company as a whole. To have a better understanding of communication on building and sustaining relationships in a business, various channels of communication should be looked at from "the viewpoint of interactant consciousness" (Olkkonen, Tikkanen, & Alajoutsijarvi, 2000). Different interactants create different interpretations.

Emanoil, Ramona, and Lucia (2013) found that majority of communication in this time are done through electronics. Managers are choosing to communicate throughout their company through phone calls, fax, and through the internet. The disadvantage to electronic communication is the inability to collect visual clues and non-verbal messages as feedback which includes "everything from voice tone and facial expressions" (Spinks & Wells, 1995). Although these may seem minor, these can make a difference between positive and negative feedback. The advantage to communicating electronically is its efficiency. Messages can be transmitted quickly, at lower costs, and on a vast scale.

Communication is not only about giving information, but it is about receiving it as well. Spinks and Wells (1995) stated that two-way communication build teamwork, encourages feedback, and promotes productivity.

Kongchan (1985) defines communication satisfaction as satisfaction of an employee's perception with his total communication environment in the organization. Goris (2007) provided a similar definition but also added that communication satisfaction refers to the accuracy of information available as well. Downs and Hazen (1977) connects the satisfaction of communication with the efficiency of a business. After a factor analysis they concluded that eight factors supported the hypothesis that the satisfaction of communication is multidimensional. These factors include satisfaction with communication climate, satisfaction with superiors, satisfaction with organizational integration, satisfaction with media quality, satisfaction with horizontal and informal communication, satisfaction with general organizational perspective, satisfaction with communication with subordinates, and personal feedback (Kongchan, 1985). Of these seven, the most important factor was communication climate. When the appropriate mix and amount of upward, downward, and lateral communication are accomplished, satisfaction with communication may be attained. (Goris, 2007).

Emanoil, Ramona, and Lucia (2013) discussed studies they found on the importance of communication in an organization and the factors that lead to efficient communication. This included: "The satisfaction of the employees as regards to communication in their organization is connected to the commitment of their organization to them, to the productivity and performance of the positions and to the work satisfaction and other important effects." (Emanoil, Ramona, & Lucia, 2013)

Berger and Iyengar (2013) discussed how channels of communication can determine communication satisfaction. Different modalities of communication differ in their synchronicity. Oral communication is more synchronous than written communication. In oral conversation, there is a constant discussion without interruptions or delays. It tends to be consistent and allows for less time to be used to think about what will be said next. Written conversation is more asynchronous. Whether the communication is through letters, emails, or instant messaging, people are able to take breaks and ponder on responses. Thus, allowing time to "construct and refine communication…people can take the time to formulate what to say or edit their communication until it is polished" (Berger & Iyengar, 2013). Written communication also generates less recurrence of ideas and prevents irrelevant ideas from being presented. Words are chosen more cautiously rather than speaking on impulse. How one communicates and how he or she presents oneself can be a factor of communication satisfaction.

The satisfaction of communication goes hand in hand with lean communication. Being sure everyone is satisfied with the transmission of information can ensure clarity and consistency.

Quality Communication

Lean communication is a factor of efficient communication. Many authors have discussed how lean communication effects organization. "Lean communication is the avenue by which leaders clarify their visions and foster participative management within the organization" (Spinks & Wells, 1995). Having quality communication makes it clear what the leaders' mission and vision are for the company, its employees, and its customers. Upholding the quality in communication builds trust and consistency. This is necessary to avoid unnecessary confusion or misunderstood messages. Emanoil, Ramona, and Lucia (2013) named another benefit of an efficient communication. They explained that a positive climate of communication and an efficient communication with the employees consolidates the identification of the employees with their organization, which contributes to financial performance and lasting success–efficient communication facilitates the commitment and builds trust, which represents a vital ingredient for strong and reliable organizations.

In the above studies, a positive environment, commitment, and work satisfaction are all factors that lead to efficient communication. Thus, leading to a more productive and efficient company as a whole. Emanoil, Ramona, and Lucia (2013) concluded that efficient communication in an organization is accomplished when the right people receive the correct information in the right time. Schoop, Kohne, and Ostertag (2010) conducted studies on the quality of communication in negotiations. Because negotiations are necessary in communication in a general aspect, their findings can be applied to communication in general. Schoop, Köhne, and Ostertag (2010) argued that the communicative and strategic actions and interactions determine the efficiency of the process as well as the effectiveness of the joint outcome.

Spinks and Wells (1995) classify the effectiveness of communication based on the levels of leadership: upper, middle, or lower level. In the upper level, the leaders are responsible for making sure the information they are receiving and giving is correct and sufficient. Doing so will ensure that they are consistently viewing the company from every perspective so decisions can be made accordingly. Those in the middle level must be a representation of the upper level and the lower level at the same time. Policies and business plans must be carried out while retaining the employees' best interest. Middle level managers must build and uphold the trust between them and those below them to consistently be able to transfer accurate and adequate information. Having this open and trusting environment makes way for a better communication system.

Lower level managers must focus on moving the information they get up the management hierarchy. These leaders work closest to the workers and customers. Therefore, they are initially responsible for making sure the customers and employees' voices are heard clearly. "If quality communication is in place, the organization will achieve delighted customers, empowered employees, higher revenues, and lower costs" (Spinks & Wells, 1995). In other words, the company will essentially become more effective and efficient as a business.

Schoop, Kohne, and Ostertag (2010) divided quality communication into three proportions: effectiveness, efficiency, and relationship. The effectiveness represents the development and achievement of a shared understanding on all semiotic layers. The efficiency encompasses mutual structuring efforts, coherence, and transparency. Finally, the relationship portion is defined by the ability "to build trust and shared identities. Trust and communication quality are directly related; greater trust leads to higher communication quality.

NUCLEAR POWER SAFETY RELATION TO COMMUNICATION

History of Nuclear

Research into the uses of nuclear elements or materials in the United States first started at the end of World War II. The Atomic Energy Commission was formed from the United States Atomic Energy Act of 1946 (Ruebhausen, Oscar; von Mehren, June 1953). The Atomic Energy Commission assigned Argonne National laboratory to develop the US commercial nuclear energy program. Currently there are 104 commercial nuclear reactors in service all of which were built on or before 1974 (Wald, 2010). The US Navy was instrumental in leading the US into the nuclear age. The Navy engineered, tested, and deployed the first nuclear power plant on the submarine, USS Nautilus (SSN 571) in 1954 (Nautilus, 1970). Nuclear reactors on US Navy submarines and ships were built to not only provide steam for propulsion but also to power turbine generators for the production of electrical power. To ensure the safe and reliable operation of these nuclear power plants the US Navy established the regulator project called Naval Reactors. To this day Naval Reactors still oversees and regulates training of US Naval nuclear operators, repairs to nuclear equipment/plants, and operation of the US Navy's nuclear power plants (LaMonica, 2011).

Due to the success of the US Navy to safely engineer, build and operate its nuclear reactors the door was opened for establishment of a commercial nuclear power program. In 1958 the Shippingport nuclear power plant was brought on line, in Beaver County, Pennsylvania. The reactor reached criticality on December 2, 1957, and remained in operation until October 1982. The first electrical power was produced on December 18, 1957. This reactor was capable of producing 60 mega watts of power and over its life time produced 7.4 billion kilowatts of electricity (Clayton, 1993).

One major difference between commercial and military reactors is the Navy chose a design and utilizes it almost exclusively while the commercial industry uses multiple types of reactors. Of the commercial reactors in service today, 69 are Pressurized Water while 35 are Boiling Water Reactors (NUREG-1350, 2012). The common design principle shared by all type of nuclear power production systems is that steam is generated then flows to and turns turbines which power the generators that produce electricity. Once the steam passes through the turbines it is directed to a component called a condenser. Pumps circulate water from lakes or rivers through tubes in the condenser. In the condenser the water travels inside the tubes while the steam passes over the tubes and is cooled. Pumps then circulate the cooled water back to the steam generator and the cycle repeats (Bradford, 2013).

There have been major accidents involving both types of reactors such as 1979 Three Mile Island accident in Pennsylvania and Japan's 2011 Fukushima accident. Ethics in nuclear power is pivotal in providing the direction nuclear power will head in the future. Through the use of nuclear power, the US will have the ability to greatly lower energy costs for government, businesses and the population. As with any complex systems, this powerful energy generating technology contains inherent risks. Without very careful consideration for design, safety, and environmental impacts, the construction of new plants could cause more problems than is deemed to be an advantage to community. The government and nuclear power industry must utilize a systems thinking approach to the expansion of nuclear power.

It is a fact that the amount of power that can be produced from nuclear power plants eclipses that of solar or wind power. The environmental impact and amount of radioactivity released from coal power plants is far more extensive than that of a nuclear power plant. But the main question is its impact on the population if an accident occurs. Whether the accident is a result of nature (Fukushima, Japan), personnel error (Three Mile Island PA, US), or design failure (Chernobyl, Russia) the industry has the obligation to ensure the safety of the public. The Fukushima nuclear accident was initially caused by an earthquake and tsunami (Nature). Many believe the accident could have been contained with little to no radioactive release. At the same nuclear facility the newer nuclear plants were cooled and containment remained intact. This was due to the placement of the emergency generators at a higher elevation. The Japanese nuclear industry and regulatory branch knew there were risks with the generators being located to low at the older plants. The decision to leave the older plant emergency generators in the lower, more vulnerable, location was made based on budget concerns. Had the emergency generators been moved to the safer elevation, impact of the disaster could have been reduced.

The Chernobyl nuclear accident was primarily due to personnel error and a questionable plant design. The Chernobyl design was agraphite-moderated nuclear power reactor. This design is solely a Russian design and is not utilized in the United States based on serious design and safety flaws. The environmental impacts from this melt down are still very significant with large areas of land remaining uninhabitable. Even though this design will not be utilized in the US it is still important to show how poor design and a lack of detailed research can result in catastrophe. As the US moves it nuclear technology forward it is imperative they thoroughly test and prove all new designs. The worst nuclear accident in the US was the partial melt down at Three Mile Island. Before the nuclear plant could be stabilized the reactor did sustain damage. Because of casualty actions to protect the core and good engineering design for the containment buildings and systems there was no significant increase in radiation levels to the population or release to the environment. Other than the cost to clean-up the accident, the largest impact from this disaster was the shaken confidence of the American population. The impact to the psyche of the American people is still prevalent to date, 30 years later.

The Energy of Choice

The major environmental impact from nuclear power is the storage of the radioactive waste generated from the fleet of nuclear plants across the US. Around 20–30 tons of high-level waste are produced per year per nuclear reactor (Sovacool, 2011). The world's nuclear fleet creates about 10,000 metric tons of high-level spent nuclear fuel each year (Harrell, 2011). To date the US has not established a policy for the long term storage of this radioactive waste. Currently, there is 65,000 tons of radioactive waste in temporary storage facilities throughout the US. Recently President Obama stopped the construction of a permanent repository at Yucca Mountain in Nevada (Harrell, 2011) due to lingering legal ramifications.

Another environmental concern from nuclear power is the release of gaseous and liquid radiological effluents. These gases and radiological effluents are strictly monitored in the US by the Environmental Protection Agency and the Nuclear Regulatory Commission. The effects to personnel living within a 50 miles radius of the nuclear power plant will receive fewer radioactivities from the power plant than eating one banana. A numerical prospective of the impact of radioactive release is: Civilians living within 50 miles (80 km) of a nuclear power plant typically receive about 0.1micro Sievert per year. For comparison, the average person living at or above sea level receives approximately 260 micro Sieverts from cosmic radiation (American Nuclear Society, 2012). A major health concern from exposure to radiation is cancer. Based on studies performed from the nuclear attack on Japan and data correlated to date from nuclear power plant operations the risks of personnel getting cancer from nuclear power is 0.04%. Of 10,000 persons 2,000 will get some kind of cancer. If this population were exposed to.001 Sieverts an additional 4 persons would get cancer. This results in an increase of approximately.04%. Therefore, the risks associated from nuclear power are small compared to everyday hazards. Data to date has failed to identify any genetic or long term effects from personnel that are exposed within the limits of the federal government. A comparison of coal plants to nuclear plants shows that humans living near coal plants are subjected to 100 times the radioactivity of nuclear plants (Gabbard, 1993). The National Council on Radiation Protection and Measurements (NCRP Reports No. 92 and No. 95) estimated the dose to the population from 1000 Mega Watt coal and nuclear plants is 4.9 micro-Sievert per year and 0.048 micro-Sievert per year respectively (a typical Chest x-ray gives a dose of about 0.06 micro-Sievert for comparison). Additionally, the Environmental Protection Agency estimates that civilians living within 50 miles of coal or nuclear plants receive a dose of 0.3 micro Sieverts per year and 0.00009 micro Sieverts respectively (Gabbard, 1993).

The Political Challenges

The US currently has the world's largest nuclear power industry with over a hundred commercial nuclear reactors in operation. The United States depends on nuclear power to meet "only'' about one-fifth of its demand for electricity. That share (20 percent) is still greater than the worldwide average (17 percent). Even though nuclear power generates only one-fifth of US energy, it is still equal to the combined total of the world's two other nuclear giants, France and Japan (Nivola, 2004). In 2003, the Bush administration and House of Representatives enacted legislation that would allow for more nuclear licenses to be approved, enabling energy power giants the opportunity to expand nuclear power generation through construction of new power plants. With this break through legislation, one would think revitalization of the nuclear power industry was under way. In reality, after ten years, the nuclear industry in the US has not constructed or operated a new nuclear power plant since 1974. The nuclear industries inability to jump on obtaining new licenses and build new nuclear power plants may have inadvertently put the "nail in the coffin" for nuclear power. In addition, the natural gas industry has become a power house in the energy production field. Newly discovered natural gas resources, combined with cheaper construction and operating costs, have enabled the natural gas industry to excel.

Even with the advanced of natural gas industry next to the nuclear industry nuclear power is still the power source of choice. Furthermore, despite the negative publicity from the most recent nuclear accident in Japan, the US public still approves highly the use of nuclear power for energy. Americans favoring nuclear power has grown from half the public in 1983 to two-thirds in the fall of 2012. This equates to an average of 66% of the US population has a favorable view of nuclear power (Bisconti, 2012). In a poll conducted by the Nuclear Energy Institute for perceived safety of nuclear power plants, 69% polled indicated they think nuclear power has a high safety rating while 17% said the safety rating is low (Bisconti, 2012). Across the political spectrum nuclear power has over a 68% approval rating. The following is a breakdown of how the different political parties weighed in on nuclear power: Democrats 64%, Republicans 75%, and Independents 63%. This poll was conducted by the Bisconti Research Inc. and GFK Roper (Bisconti, 2012). In 2011, the public and political acceptance of building new nuclear power plants at existing sites had a 67% favorability rating which is down from 2005 which had a favorability rating of 75%. In the fall of 2012 the public's view of nuclear power rose to a favorability of 69% (Bisconti, 2012). This slight increase in the public's sentiment towards nuclear power is promising for the industry. The reduction in this favorability trend can be attributed to the Fukushima nuclear accident in 2011.

Nuclear power has been safely utilized in the US since the Three Mile Island accident in 1979. To give a perspective of how safe nuclear power is compared to other energy industries worldwide studies have shown the following: Between 1969 and 2000, there were 20,276 and 20,218 in the coal and oil energy chains respectively. Hydropower was responsible for 29,924 deaths in one incident in China. In contrast, there have been two severe accidents in nuclear power plants over this period of time (Chernobyl and Fukushima) which resulted in 31 fatalities (All of these were from Chernobyl) (Gordelier & Cameron, 2010).

Radiation exposure to the general public from operating nuclear power plants is extremely small compared to exposure from other sources such as medical procedures, the earth and sun. The average nuclear energy facility worker receives 115 mrem. The average member of the public receives less than 0.5 mrem per year from the entire nuclear energy fuel cycle combined, including uranium mining, fuel fabrication, nuclear power generation and waste disposal (Nuclear Regulatory Commission, 2012). In comparison, U.S. Average environmental radiation exposure is 45 mrem to cosmic rays, 25 mrem to ingested radioactivity from food, and 70 mrem from x-rays (Bushong, 1977). From these statistics it is clearly seen that the public has been kept safe from nuclear power. The challenge of the nuclear power industry is getting the information to the public and reassuring them that nuclear power is safe and focus on the study of the non technical factors such as efficient internal communication that impact the safe operation of these plants.

METHODOLOGY

Participants

The participants of this research consist of 1639 employees at a nuclear power plant located in the United Stated of America. They were between 18 and 67 years of age and were not paid for participating in the survey, but were on business time.

Multiple Regression Modeling

The purpose of the multiple regression analysis is to learn more about the relationship between several body composition parameters. In addition to the main effects of these variables, effects of the interactions were included in the analysis (see Table 1). The model was expressed Equation 1:

$$R = \beta_0 + \beta_1 R + \beta_2 O + \beta_3 F + \beta_4 W + \beta_5 G + \beta_6 C + \beta_7 S + \beta_8 F + \beta_9 D + \beta_{10} E + \beta_{11} A + \beta_{12} T + \beta_{13} P \tag{1}$$

where:

Table 1. Variables and descriptions

	Variable	Description
1	Lean Communication	Management condones quality in communication
2	Responsibility	Responsible to identify problems
3	Openness	Openly challenge decisions made by management
4	Friendliness	Free to approach management with any concerns
5	Willingness	Willingness of listening to problems by management
6	Guarantee	Management ensuring that concerns raised are addressed
7	Criticism	Helpful criticism is encouraged
8	Self-esteem	People are treated with dignity and respect by the management
9	Flexibility	Dialogue is encouraged when evaluating safety issues
10	Differences	Differing professional opinions are welcomed and respected
11	Empowerment	Responsible to raise safety concerns
12	Acceptance	Raise safety concerns without fear of retaliation
13	Timeliness	Decisive actions when safety concerns are raised
14	Promotion	Encouragement and expectation to report safety concerns

R- Responsibility
O- Openness
F- Friendliness
W- Willingness
G- Guarantee
C- Criticism
S- Self-Esteem
F- Flexibility
D- Differences
E- Empowerment
A- Acceptance
T- Timeliness
P- Promotion
β_i - Linear Constants

With the significance level set to ($\alpha = 0.05$), the null hypothesis and alterative hypothesis for the model were:

$\mathbf{H_0}$: $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = \beta_8 = \beta_9 = \beta_{10} = \beta_{11} = \beta_{12} = \beta_{13} = 0$

$\mathbf{H_1}$: at least one of the predictors does not equal to zero. (2)

Findings

The mean and standard deviation among the lean communication subscales are shown in Table 2.

Data analysis was performed using the Statistical package of Minitab. First, a correlation was conducted to see whether the measurement variables covary, and to measure the strength of any relationship between the predictor variables and the predicted variable. Correlations of the predictor variables with the predicted variable were reported as Pearson correlation coefficients in Table 3.

The results show that R-squared is equal to 68.89%. This means that 68.6% of the variation in Y is explained by the regression line. The adjusted R-squared value of the regression coefficients was 0.68, which indicated high association of the R-squared with variances in the predictor values. This evidence showed a strong linear relationship between the predictor variables and the predicted variable for the model (see Table 5).

The fitted regression model found from the output is:

Table 2. Descriptive for the measures lean communication

	Variable	Mean	StDev
1	Quality	5.1296	1.8690
2	Responsibility	5.8858	1.7884
3	Openness	4.6093	1.8382
4	Friendliness	5.1828	1.9017
5	Willingness	4.9599	1.8201
6	Guarantee	4.8173	1.7654
7	Criticism	4.7383	1.7688
8	Self-esteem	5.0437	1.7624
9	Flexibility	5.2689	1.7082
10	Differences	4.9184	1.7083
11	Empowerment	5.9312	1.7933
12	Acceptance	5.5009	1.7752
13	Timeliness	5.3716	1.7330
14	Promotion	5.4094	1.8134

Note: N =1639

Table 3. Pearson correlation coefficient between the variables and lean communication

Variable	R	O	F	W	G	C	S	F	D	E	A	T	P
Total Score	0.43*	0.59*	0.56*	0.49*	0.45*	0.46*	0.52*	0.45*	0.52*	0.84*	0.62*	0.65*	0.64*

* Significant at the 0.05 level of probability

Communication Quality = 0.359 - 0.0590 Responsibility + 0.0637 Friendliness + 0.1330 Willingness + 0.0877 Guarantee + 0.0834 Criticism + 0.2727 Self-esteem + 0.2253 Acceptance (3).

The results of analysis of variance (ANOVA) of the model also supported strong linear relationships in the models (Equation 3). The F value of the regression is 2.73 shown in Table 6. The high F values indicated a great significance ($\alpha<.05$) for the model in rejecting the null hypothesis (H_0) that every coefficient of the predictor variables in the model was zero. Instead, the alterative hypothesis, at least one of these coefficients did not equal to zero, was accepted.

Table 4. Results of multiple regression with highlighted non-significance ($\alpha = 0.05$)

	Variable	DF	F-Value	β	P-Value
2	Responsibility	1	4.35	- 0.0590	0.037
3	Openness	1	1.72	0.0314	0.190
4	Friendliness	1	3.91	0.0637	0.048
5	Willingness	1	11.92	0.1330	0.001
6	Guarantee	1	7.31	0.0877	0.007
7	Criticism	1	9.90	0.0834	0.002
8	Self-esteem	1	81.65	0.2727	0.000
9	Flexibility	1	0.49	0.0229	0.484
10	Differences	1	1.30	0.0385	0.254
11	Empowerment	1	0.54	- 0.0224	0.462
12	Acceptance	1	54.32	0.2253	0.000
13	Timeliness	1	0.30	0.0167	0.585
14	Promotion	1	2.61	0.0537	0.106

Table 5. Summary results of multiple regression with significance ($\alpha = 0.05$)

	Variable	DF	F-Value	β	P-Value
2	Responsibility	1	4.35	- 0.0590	0.037
4	Friendliness	1	3.91	0.0637	0.048
5	Willingness	1	11.92	0.1330	0.001
6	Guarantee	1	7.31	0.0877	0.007
7	Criticism	1	9.90	0.0834	0.002
8	Self-esteem	1	81.65	0.2727	0.000
12	Acceptance	1	54.32	0.2253	0.000

Table 6. ANOVA table of the regression models

Source	DF	Sum of Squares	Mean Square	F-Value	Pr>F
Regression	13	1541.22	1.198	2.73	0.000
Residual	1498	1634.16	1.091		
Total	1511	5252.36			

Therefore, the linear relationship between the predicted variable (R) and predictor variables significantly existed. The coefficients of all predictor variables and the constants of the model are listed in Table 4.

DISCUSSION

The results of this study showed that information shared should be more precise and specific as opposed to following a systematic approach (Pfeiffer, 1998). Information should be tailored to each organization needs. Information as we know it involves a chain of events that start with raw data that will go through a specific process to become value added final product (Graebsch., 2005). For example, rank-and-file employees may contribute data on what they perceive as errors or data for improvement in a production process. Second, the raw data will be gathered to generate knowledge. Third, this knowledge is transferred through encoding. The encoded knowledge is information that can add value to the production process and to the organization of the company as a whole. Communication may be enhanced through augmented element such as videos and emails as shown by the favorable response of employees. Therefore, the same care should apply the augmented element to ensure superior communication. Observing email etiquette is part of clear and proper communication. Employees have to be direct to the point and stay on the topic at hand while communicating through emails. The use of courteous language and not offensive tone need to be promoted with messages being specific to the group or person it is intended (Essex & Kany, 1999).

The results show that the only negative factor with a negative relation with the lean communication is responsibility. It is surprising that the employees are wishing to be less responsible to identify problems within the company. This attitude stems from the fact that manager should let people assume responsibility only when they are able (Goldsmith, 2010). It does appear that the employees do not have the necessary preconditions to desire more responsibility. Some of the things senior management can do to build an environment that empowers employees are to giving power to those who have demonstrated the capacity to handle the responsibility, creating a favorable environment in which people are encouraged to grow their skills, refraining from second-guessing others' decisions and ideas unless it is absolutely necessary, and giving people discretion and autonomy over their tasks and resources (Goldsmith, 2010). This ties into the notion of responsibility with corresponding authority. Even though people have to empower themselves, management role is to encourage and support a decision-making environment, and to give employees the tools and knowledge they need to make and act upon their own decisions. By doing this, employees will reach an empowered state where their confidence will not be undermined and they will seek more responsibility and the daily management of the organization (Gallo, 2013).

The results also show that acceptance factor as a positive predictor of lean communication with employees raising safety concerns without fear of retaliation. One of the most important lean principles calls for an open line communication that facilitates the participation of all levels of employees, managers, and management/administration (Puvanasvaran, Megat, Hong, & Razali, 2008). A good implementation of lean effort requires effective communication at all times and at all job position levels (Puvanasvaran, Megat, Hong, & Razali, 2008) with the commitment of both employees and managers in all aspects of their jobs is necessary. Workers' empowerment helps improve lean implementation, communication, and all phases of work and the organization as a whole. Workers' empowerment means letting each worker participate, contribute, be responsible for, and control in the manufacturing or production process, inasmuch as they are the first to note errors and first at hand in the manufacturing process (Puvanasvaran, Megat, Hong, & Razali, 2008). The results show that employees who have worked for the company for 16 years to 20 years ranked the lowest among all employee groups with respect to communication and those employees who did not identify themselves were the least agreeable pertaining to knowledge of their group's plans. The management must see to it that communication proceedings per employee group and department must be on a regular basis. Communication channels should be bi-directional on a vertical and horizontal process, meaning between co-employees and up and down the employee-to-manager-to-administration levels. All matters such as knowledge or information regarding manufacturing or product process, organizational concerns, and employee concerns will affect business. Lean implementation demands problem-solving in all these concerns in order to eliminate waste and add value to the processes (Kilpatrick, 2003).

Helpful criticism is an important factor needed to implement open communication channels for employees to communicate their ideas and concerns to higher level managements. As mentioned above, front-line employees know more about what is happening at the manufacturing ground floor than do the higher level management. It is obligatory for all employees to communicate their concerns regarding the production or manufacturing line to their managers so that immediate, proper, and complete problem-solving process may be initiated before worst things can happen.The methods of communication used by supervisors or managers to communicate with employees need to be uniformed and equally implemented throughout the entire plant. Lean communication requires networking among employees and managers, and standardization of the information and communication process (Graebsch., 2005). Information communicated must have "form (concrete stored form), fit (information must be in a form "useful to downstream processes and provided seamlessly), function (information in a design form), and timeliness (providing the right information at the right time)" (Graebsch., 2005).

Willingness of management to listen to problems and concerns in general is needed to keep the momentum going, since all employees share the same ideas concerning safety issues in particular. Although occupational safety requirements are dictated by labor laws in most States, improvements in occupational safety such as monitoring of unsafe activities or areas in a company, design of safety gagdets and attires/uniforms/helmets for employees, and proper occupational safety procedures are routinely audited or checked for further improvement. These kinds of information can be gleaned from the rank-and-file employees. In a lean situation, continuous system improvement is achieved by permitting rank-and-file employees the timeline and freedom to determine improvements and remove waste in a climate of trust and worker empowerment (Jones, Medlen, Merlo, et al., n.d.). Company policy formation should be performed wherein the ideas and experiences of all employees are solicited, and solutions discussed (Jones, Medlen, Merlo, et al., n.d.). Communication is about "ensuring the delivery of information to those who need it in a timely manner, and in a form that is easily understood by them" (Khan, 2011). Information delivery is for purposes of proer decision-making (Khan, 2011). The need to maximize communication means that the communication provided must see it from the receiver's point-of-view (Khan, 2011). The usefulness of information for people is when they have to use it for decision-making (Khan, 2011). The factors influencing information usefulness are, as follow: "quality (accuracy and completeness of information), quantity (too much or too little), reusability (right language, tone, amount of detail, and complexity level), and timeliness (right information at the right time)" (Khan, 2011). Root cause analysis can be used to facilitate this process by identifying the recurrent root problems in any aspect of the organization using "structured and unstructured: techniques such as problem tree or fishbone diagrams (Jones, Medlen, Merlo, et al., n.d.). Management must be continuously asking the employees what improvement measures can be implement for better processes (Noonan & Panebianco, 2013). Training in communication skills of all levels of employees and management must be performed to ensure that communication at the managerial level is not limited to just by sending information and memos down, but requires physical contacts with regular staff and thresh matters out and for purposes of direct visual management or ocular inspection of actual progress of work and manufacturing or production processes in the company Management guaranteed that all concerns raised are effectively addressed on a regular basis. The attention doesn't need to be on only technical concerned, but also human resources. Four factors that affect organizational communication are job satisfaction, job stress, teamwork, and employee commitment (Khot, Nahmens, & Ikuma, n.d.). Job satisfaction refers to job monotony, job type, control over one's work, and work methodologies. Job satisfaction is dependent on the skill level of an employee for a certain job type. Incapability to exert control over one's work also contributes to job satisfaction. Teamwork means working with one's own group at one's employment area. Job stress is due to job dissatisfaction, excessive work but little pays, occurs when there is incongruent fit of a worker's skills to the job he has. Consistent and constant commitment by a worker is a source of motivation for him and his co-workers and he performs better. All these factors affect organizational communication which in turn affects the state of the business or the company. Work productivity and quality goes hand in hand with organizational communication. The company's human resource management division must look into these matters in order to improve organizational communication and the whole business process.

Further, differences in communication quality among managers and employees must be addressed. In many instances, managers should not be better informed by the upper management level staff, where other employees will have less agreement of knowledge of their group's activity. This situation may reflect that communication from the upper management is not being fully disseminated downwards or concerns have not been communicated adequately. These factors may shed light to the probable root causes of the differences in communication quality and satisfaction among the lower level employees. Therefore, transparency in the communication process in any level of the company organization should be warranted. Transparency in communication involves proper, complete, and honest information or data flow to favor learning.

CONCLUSION

This study used multiple regression analysis to investigate communication predicted by thirteen lean concepts. The results show that among the thirteen factors, five were connected to communication. Communication within an organization seems to be straight forward to many. To be lean, however, communication must have some essential factors which this study tried to reveal. Lack of communication tends to hinder the creation of an environment where people come together to work and learn. Furthermore, employees' self actualization can depend on many factors. Delegating more responsibilities, conveying clear expectations, giving useful feedback, and creating a climate free of fear and anxiety will surely encourage employees to have a desire to take on more responsibilities.

Although, this study explores the nature of the relationship between communication and thirteen lean factors, some inevitable limitation were gleaned during the course of the study. Therefore, it is advised that the results be considered cautiously. One limitation is the characteristics of the instrument used to measure the variables and sample. Data collected from questionnaire can be very basic. The use of other complementary tools such as interviews can add more complexity to the information collected. Further, limiting this study to only one nuclear plant is another constraint. The study can benefit greatly from data collected from multiple sites. Therefore, survey can be extended to other locations similar to where this study was conducted.

REFERENCES

American Nuclear Society (2012). *ANS dosechart*. Author.

Anonymous,. (1994). What is communication? *International Journal of Bank Marketing*, *12*(1), 19. PMID:7746874

Berger, J., & Iyengar, R. (2013). Communication channels and word of mouth: How the medium shapes the message. *The Journal of Consumer Research*, *40*(3), 567–579. doi:10.1086/671345

Bhasin, S. (2011). Performance of organisations treating lean as an ideology. *Business Process Management Journal*, *17*(6), 986–1011. doi:10.1108/14637151111182729

Bisconti, A. S. (2012). *Nuclear Energy: Upward Trends in U.S. Leadership*. Innovative Reactors.

Boyle, T. A., Scherrer-Rathje, M., & Stuart, I. (2011). Learning to be lean: The influence of external information sources in lean improvements. *Journal of Manufacturing Technology Management*, *22*(5), 587–603. doi:10.1108/17410381111134455

Bradford, B. (2013). *Are Mini-Reactors The Future Of Nuclear Power*. Academic Press.

Bushong S. C (1977). *Radiation Exposure in Our Daily Lives*. Academic Press.

Clayton, J. C. (1993). *The Shippingport pressurized water reactor and light water breeder reactor*. Westinghouse Electric Corporation.

Cohen, S. (2011). *The Political Demise of Nuclear Power in the U.S*. Academic Press.

De Feo, J. A., & Early, J. F. (2010a). Continuous innovation using design for six sigma. In J. M. Juran & J. A. De Feo (Eds.), *Juran's quality handbook: The complete guide to performance excellence* (6th ed., pp. 407–438). New York, NY: McGraw Hill.

De Feo, J. A., & Early, J. F. (2010b). Six sigma: Improving process effectiveness. In J. M. Juran & J. A. De Feo (Eds.), *Juran's quality handbook: the complete guide to performance excellence* (6th ed., pp. 355–385). New York, NY: McGraw Hill.

Doerman, S. M., & Caldwell, R. K. (2010). Lean techniques: Improving process efficiency. In J. M. Juran & J. A. De Feo (Eds.), *Juran's quality handbook: the complete guide to performance excellence* (6th ed., pp. 327–354). New York, NY: McGraw Hill.

Downs, C. W., & Hazen, M. D. (1977). A factor analytic study of communication satisfaction. *Journal of Business Communication*, *14*(3), 63–73. doi:10.1177/002194367701400306

Early, J. F., & Stockhoff, B. A. (2010). Accurate and reliable measurement systems and advanced tools. In J. M. Juran & J. A. De Feo (Eds.), *Juran's quality handbook: The complete guide to performance excellence* (6th ed., pp. 583–672). New York, NY: McGraw Hill.

Emanoil, M., Ramona, T., & Lucia, F. (2013). Efficient organizational communication- A key to success. *Studies In Business & Economics*, *8*(2), 74–78.

Eriksson, O. (2000). *Communication quality: Towards an intersubjective understanding of quality.* Report on Business and Informatics 2000.

Essex, L., & Kany, M. (1999). *Fast forward leadership.* Guildford, UK: Kings Lynn.

Gallo, A. (2013). *Act like a leader before you are one*. Harvard Business Review.

Goldsmith, M. (2010). *Empowering your employees to empower themselves. Harvard Business Review*.

Gordelier, S., & Cameron, R. (2010). *Comparing Nuclear Accident Risks with Those from Other Energy Sources*. Academic Press.

Goris, J. (2007). Effects of satisfaction with communication on the relationship between individual-job congruence and job performance/satisfaction. *Journal of Management Development*, *26*(8), 737–752. doi:10.1108/02621710710777255

Graebsch, M. (2005). *Information and communication in lean product development.* (Diploma thesis). Technical University of Munich, Munich, Germany.

Harrell, E. (2011). Bury Our Nuclear Waste-Before It Buries Us: Belfer Center Programs or Projects: Managing the Atom. *Time*.

Hasle, P., Bojesen, A., Per, L. J., & Bramming, P. (2012). Lean and the working environment: A review of the literature. *International Journal of Operations & Production Management*, *32*(7), 829–849. doi:10.1108/01443571211250103

Helper, S. (1996). Lean thinking. *Sloan Management Review*, *38*(1), 114.

Jones, C., Medlen, N., Merlo, C., et al. (n.d.). *The lean enterprise.* Retrieved June 5, 2014, from CiteSeer: http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.26.8316

Juran, J. M., & De Feo, J. A. (2010). *Juran's quality handbook: the complete guide to performance excellence* (6th ed.). New York, NY: McGraw Hill.

Keyton, J., Caputo, J., Ford, E., Fu, R., Leibowitz, S. A., & Liu, T. etal. (2013). Investigating verbal workplace communication behaviors. *Journal of Business Communication*, *50*(2), 152–169. doi:10.1177/0021943612474990

Khan, S. (2011). *A lean communication model for product management.* Retrieved June 5, 2014, from http://onproductmanagement.net/wp content/uploads/2011/03/Lean-Communication.pdf

Khot, D., Nahmens, J., & Ikuma, L. (n.d.). *The impact of lean methods on organizational communication in homebuilding*. Retrieved June 5, 2014, from Associated Schools of Construction: ascpro.ascweb.org/chair/paper/CPRT124002010.pd

Kilpatrick, J. (2003). *Lean principles.* Retrieved June 5, 2014, from Utah Manufacturing Extension Partnership: http://yourcareeracademy.com/yca/assets/uploads/lib_file/Lean%20Principles%20-%20overview.pdf

Kongchan, A. (1985). Communication satisfaction, job satisfaction, and organizational commitment of business college faculty. (Order No. 8602582, Arizona State University). ProQuest Dissertations and Theses, 267-267.

Kovács, G. (2012). Productivity improvement by lean manufacturing philosophy. *Acta Technica Corviniensis - Bulletin of Engineering, 5*(1), 41-45.

Krause, T. (2009). Facilitating teamwork with lean six sigma and web-based technology. *Business Communication Quarterly*, *72*(1), 84–90. doi:10.1177/1080569908330374

LaMonica, M. (2011). *A reality check on nuclear fusion at MIT*. Academic Press.

Matthew, L. W. (2010, December 7). Nuclear 'Renaissance' Is Short on Largess. *The New York Times*.

Maurer, R. (2013). Will lean work in your organization? *Journal for Quality and Participation*, *36*(2), 27–31.

Monroe, D. J. (2010). Root cause analysis to maintain performance. In J. M. Juran & J. A. De Feo (Eds.), *Juran's quality handbook: The complete guide to performance excellence* (6th ed., pp. 387–405). New York, NY: McGraw Hill.

Nautilus. (1970). *Dictionary of American Naval Fighting Ships*. Naval History & Heritage Command.

Nivola, P. (2004). *The Political Economy of Nuclear Energy in the United States*. Academic Press.

Noonan, M., & Panebianco, J. (2013, March). *9 ways leaders' actions can sustain lean progress.* Retrieved June 5, 2014, from TBMCG: http://www.tbmcg.com/whitepaper_assets/managementbriefing_9ways_leaders_actions.pdf

Nuclear Regulatory Commission. (2012). *Occupational Radiation Exposure at Commercial Nuclear Power Reactors*. NUREG.

Olkkonen, R., Tikkanen, H., & Alajoutsijarvi, K. (2000). The role of communication in business relationships and networks. *Management Decision*, *38*(6), 403–409. doi:10.1108/EUM0000000005365

Pfeiffer, W. (1998). *Conditions that hinder effective communication. The Pfeiffer Library, 6 (2).*

Puvanasvaran, P., Megat, H., Hong, T. S., & Razali, M. M. (2008). The roles of communication process for an effective lean manufacturing implementation. In *The roles of communication process for an effective lean manufacturing implementation*, (pp. 128-152). Academic Press.

Ralson, J. E. (2010). Using national awards for excellence to drive and monitor performance. In J. M. Juran & J. A. De Feo (Eds.), *Juran's quality handbook: The complete guide to performance excellence* (6th ed., pp. 387–405). New York, NY: McGraw Hill.

Ruebhausen, O. M., & von Mehren, R. B. (1953, June). The Atomic Energy Act and the Private Production of Atomic Power. *Harvard Law Review*, *66*(8), 1450. doi:10.2307/1336868

Schoop, M., Köhne, F., & Ostertag, K. (2010). Communication quality in business negotiations. *Group Decision and Negotiation*, *19*(2), 193–209. doi:10.1007/s10726-008-9128-8

Sovacool, B. (2011). *Second Thoughts About Nuclear Power*. National University of Singapore.

Spinks, N., & Wells, B. (1995). Quality communication: A key to quality leadership. *Training for Quality*, *3*(2), 14–19. doi:10.1108/09684879510087486

Standard, C., & Davis, D. (2000). Lean thinking for competitive advantage. *Automotive Manufacturing and Production*, *12*, 1–3.

Steinlicht, C. L. (2010). Lean production and the organizational life cycle: A survey of lean tool effectiveness in young and mature organizations (Order No. 3412450, Capella University). *ProQuest Dissertations and Theses,*, 218-n/a.

Stockhoff, B. A. (2010). Core tools to design, control, and improve performance. In J. M. Juran & J. A. De Feo (Eds.), *Juran's quality handbook: The complete guide to performance excellence* (6th ed., pp. 583–672). New York, NY: McGraw Hill.

Stone, K. B. (2012). Four decades of lean: A systematic literature review. *International Journal of Lean Six Sigma*, *3*(2), 112–132. doi:10.1108/20401461211243702

Sun, S. (2011). The strategic role of lean production in SOE's development. *International Journal of Business and Management*, *6*(2), 160–168. doi:10.5539/ijbm.v6n2p160

Upadhye, N., Deshmukh, S. G., & Garg, S. (2010). Lean manufacturing for sustainable development. *Global Business and Management Research*, *2*(1), 125–137.

Wood, B., & Janssen, A. (2010). Bookmarking: Defining best practices for market leadership. In J. M. Juran & J. A. De Feo (Eds.), *Juran's quality handbook: The complete guide to performance excellence* (6th ed., pp. 439–466). New York, NY: McGraw Hill.

World Nuclear Association. (2013). *Nuclear Power in the USA*. Author.

KEY TERMS AND DEFINITIONS

Communication: The transfer of information from a transmitter to a receiver.

Communication Satisfaction: The employee's perception of the overall communication environment in the organization. It also refers to the accuracy of the information available to the employee.

Information Quality: The quality of information refers to the relevance, accuracy, and reliability of the information.

Lean Communication: The practices of identifying and eliminating friction and waste in the process of communication.

Lean Philosophy: The ideology of the reduction or elimination of waste. Its purpose is to promote a more efficient and profitable business.

Lean Production: Internal process that use fewer resources to deliver greater value to customers.

Productivity: A measure of the effectiveness of a person, machine, plant, system, etc., in converting inputs into outputs.

Feedback: Useful information and criticism given to someone on what can be done to improve performance, product, etc.

Effectiveness: The degree to which objectives are achieved or the extent to which targeted problems are resolved.

Organizational Commitment: the psychological attachment of an employee to the company.

Job Satisfaction: How happy an individual is about his/her work.

Chapter 6
Lean Continuous Improvement Builds Excellence and Engagement

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ABSTRACT

The current management literature is replete with advocates for employee engagement. Not many would argue that engendering ownership and responsibility along with the reported organizational benefits are worth aspiring to achieve. However, the actual results of workplace surveys report disengagement appears to be more the norm in spite of management best efforts. As organizational success and growth come, things start falling apart, resulting in missed deliveries, waste, worker frustration, dissatisfied customers, and lower profit margins. Lean best practices, heralded by many marketplace leaders, demonstrate results-oriented and proven ways of gaining employee engagement from extraordinary process performance to everyone's satisfaction (customers, owners, employees, community). This chapter is a cataloguing of the employee engagement characteristics matched to prevalent Lean processing principles. Lean is promoted in this work as providing a mature and proven system for advancing engagement even while improving processes.

DOI: 10.4018/978-1-4666-7320-5.ch006

INTRODUCTION

Today's competition demands excellence and responsiveness if a customer is going to stay loyal to a particular firm. Effective managers must find ways to meet both the essentials of being competitive while remaining profitable in the new world of relational customization – aka Market 2.0 (Palacios-Marques, Saldaña, & Vila, 2013). Gary Hamel's Wall Street Journal commentary in Management's Dirty Little Secret sums it up perfectly: in a world where customers wake up every morning asking, "what's new, what's different and what's amazing?" (Hamel, 2013) success depends on a company's ability to unleash the initiative, imagination and passion of employees at all levels (Cooke & Buckley, 2008).

Further, employees want to know they are part of the team and making a difference (Hamel, 2012). Interestingly, both good employees and good customers have a myriad of choices in deciding which firm to build a relationship with today (Cooke & Buckley, 2008). Managers must have proven ways of developing both their employee ownership, in concert with their operational effectiveness, as their entire enterprise works to serve their market. Lean Continuous Improvement equips individuals at every level of the organization to have meaningful impact. Success in engendering an engaged workforce with Lean Continuous Improvement commonly results in (Ransom, 2012):

- Waste reduction up to 80%
- Production cost reduction by 50%
- Processing cycle times decreased by 50%
- Labor reduction by 50% while maintaining or increasing throughput
- Inventory reduction by 80% while increasing customer service levels
- Capacity in current facilities increase by 50%
- Higher quality
- Higher profits
- Higher system flexibility in reacting to changes in requirements improved
- More strategic focus
- Improved cash flow through increasing shipping and billing frequencies

Here are three ways for unlocking each individual's desire to be engaged that Lean Continuous Improvement facilitates (Hamel, 2012): Give them cool stuff to work on; Recognize their accomplishments; and Ask them for input. At its heart, Lean is respecting the worth and creativity of people as they work together developing their processes and themselves. These team-based approaches are akin to world-class athletes working together, synergistically creating something far better than any individual. Essentially, their championship results come from members giving their input and effort for the betterment of the team. Their winning record and fan following consequentially recognizes this excellence. And finally, no matter what the sport, winning team members will tell you that it is a "cool feeling or rush" to work with a great team. Those managers that can tap into the proven winning team ways as coaches, translating the principles into their workplaces, will get the same engaging outcomes. Lean best practices draw on the best of human nature in getting results while building an engaging work environment for the team associates.

A Strong Employee Engagement Culture Not Only Results in Extraordinary Performance but is a Great Place to Work

Today's frenetically changing market place has companies scrambling for ways to be the preferred provider in their market. Further, the social-media connected community provides a ready and immediate platform for any contrary story to adversely impact an otherwise solid position in customer's hearts and souls (Shanley, 2014). All the stakeholders within the domain of the company must be not only considered, but turned into raging fans of the company to ascend to and remain the market leader within their field. The employee engagement movement contains impactful insights on improving company performance (Yalabik, Popaitoon, Chowne, & Rayton, 2013) along with strategies to enhance their own employees' commitment to the enterprise (Yadav, 2013).

Workers are looking for more than a good job; they are looking for a good place to work. They will actually accept less pay if they are working in a positive environment where they are making a positive contribution, Managers and professionals routinely leave stressful positions with higher pay and benefits for more positive team-oriented workplaces. The business news regularly ranks the best and worst companies with, interestingly correlated, the valuation of "bad workplaces" suffering in the stock market (Ransom, 2012).

No one would argue with the desire of wanting the best for people, customers and owners. Unfortunately, for so many, the workplace experience turns out to be unfulfilling and in their own expression dehumanizing. EE advocates promise the quintessential better way that appeals to every stakeholder (Vragel, 2013).

The characteristics of the best workplaces include positive perceptions by workers concerning management credibility, overall job satisfaction, and team camaraderie. The culture of these places are typically rated high when it comes to benefits, hiring practices, employee communications, training, recognition and diversity programs (Yalabik, Popaitoon, Chowne, & Rayton, 2013).

Enlightened owners and managers want more than profit for their enterprises. In line with their more noble purpose, they are looking for the edge in attracting and keeping the best people as the extra ingredient to business success. As the most-favored-workplaces are studied, the findings reveal a recurring pattern of customer focus, efficiency, and an engaged workforce–all of these coalescing into a high performance workplace with extraordinary results for all stakeholders (Paul, 2012).

Employee Engagement Looks Like an Olympic Team on a Quest for the Gold to Give Glory to their Country

Employee engagement (EE) is the concept of the work force being fully committed and even enthusiastic about their work and the organization itself (Kahn & Fellows, 2013). EE manifests as an overwhelmingly positive collection of activities (including work, of course) to advance the efforts, interests, and even the reputation of the organization. The conceptual label originated with William Kahn (1990) and has since been greatly advanced by many other organizational behaviorists. Kahn's work defined EE as "the harnessing of organisation members' selves to their work roles; in engagement, people employ and express themselves physically, cognitively, and emotionally during role performances" (Kahn & Heaphy, 2014).

Most recently the Gallup organization has led the advancement of a system of assessing and developing EE as a management discipline. Their reach along with their strengths for surveying has generated a large body of empirical evidence indicating a significant benefit to companies with advanced EE cultures.

Responsible managers are always on a quest to improve their results and make things better for their employees. In today's social communities, workers expect to be treated more like colleagues than the historical "worker commodity" of previous generations. Business leaders fully cognizant of their vulnerability to the whims of the networked market chatter want positive reinforcement of their presence and contributions to the community (Kahn & Fellows, 2013).

Even as the typical workplace does not give the least glimmer of hope to satisfy the deeper and broader needs of workers, there are some businesses exhibiting remarkable examples of an engaged workforce. The results of engaged employee cultures are (Ransom, 2012):

- Increased market share price (16% over study period)
- Operating profits up by 4%
- Outperform competitors by 28%
- Better safety records
- Lower employee turn-over

Gallup asserts that disengaged workers cost American companies an estimated $300 billion annually in lost productivity. This doesn't include the other costs that are literally polar opposites of the benefits for EE as cited (Kahn & Heaphy, 2014).

In Every Important Measure for Business EE Cultures Do Better: Economics, Health, Jobs, and Community

In order to put the idea of employee engagement to work, the essential criteria for nurturing EE must be well catalogued in practical ways. The growing body of literature points to very positive outcomes in returns on investment, customer satisfaction, and employee loyalty for organizations willing to do the work to figure out how to get their workforce more engaged.

As evidenced by the Olympic fervor routinely surfacing around medalists, everyone wants to be part of a winning team. Managers thrill at leading in the marketplace. Owners wish that everyone within their enterprise would act like they do in taking responsibility, developing relationships and in getting the results outlined in their plans (Crabtree, 2013). The company with higher values of engagement does not demonstrate the mutually exclusive expressions of people-care and profits as aired out by frustrated managers when challenged to lead their teams in more engaging ways (Sorenson, 2013). Gallup has taken the noble ideas of employee engagement and translated them into a very practical and personal assessment methodology with their 12 questions (Abraham, 2012):

1. Do you know what is expected of you at work?
2. Do you have the materials and equipment to do your work right?
3. At work, do you have the opportunity to do what you do best every day?
4. In the last seven days, have you received recognition or praise for doing good work?
5. Does your supervisor, or someone at work, seem to care about you as a person?
6. Is there someone at work who encourages your development?
7. At work, do your opinions seem to count?

8. Does the mission/purpose of your company make you feel your job is important?
9. Are your associates (fellow employees) committed to doing quality work?
10. Do you have a best friend at work?
11. In the last six months, has someone at work talked to you about your progress?
12. In the last year, have you had opportunities to learn and grow?

Obviously, engagement is very personal. It really does not matter if the owner or manager believes everything is OK or that people should appreciate their special opportunity. Employee engagement is in the eye of the beholder. Leaders that want to leverage the more tactile investments in their company stand to gain enormously by learning how to engage their team members in the "proverbial quest for the gold" within their own industry playing field. What has to be acknowledge in light of the research outcomes is that Employee Engagement does make a significant difference (Abraham, 2012). If that is not enough, managers are always in a competition for the best "players" in the marketplace. An engaging workplace recruits winners.

The Better Continuous Improvement Methodologies Work Elevating the Human Spirit

There are a number of scientific management methods that have been developed with the advent of the professional corporate business model. Certainly, human nature itself is a quest for the betterment of situations and processes. What is being considered here are the larger management movements of the previous century. Their advocates promote these toolsets as worthwhile approaches to improving the way companies create value in the marketplace (Giannantonio & Hurley-Hanson, 2011). For context, they will be briefly mentioned highlighting why the focus of this work is on Lean and Employee Engagement.

Unfortunately, many of the so-called management movements have been perceived by the worker as manipulations to "squeeze blood out of the proverbial turnip" as evidence by the simultaneous rise of the employee unions. Interestingly, a quick survey of the principal contributors to these efforts reveal their sincere commitment to making the worker's lot better. The best of these efforts crafted win-win, balanced strategies to make every aspect of the work better including the workers' situation, the processes' effectiveness, and the overall profitability of the organization.

The history of scientific management and process improvement has bright spots of breakthroughs, but overall does not show that well. In a nut shell, scientific management is about working smarter not harder according to the major contributors (Tayor, Gilbreths, Gantt, Weber) in a quest for improvement (Burton, 2012) outlined by:

- Individual productivity, efficiency
- Overall process work stream
- Worker ergonomics and safety
- Economic systems (job, business, community, national)
- Organizational behavior
- Engagement of worker

With the advent of Scientific Management and its various evolutionary incarnations, management has evolved from being considered an art into a science (Giannantonio & Hurley-Hanson, 2011). The conception of a scientific system means that there is now a replicable model of success that can be learned. This has been proven out over and over again. Even so, so many of the systems are so work/process oriented; i.e., tools based; along with the old-school management model of command and control that workers find the entire idea of process improvement dehumanizing. Such an attitude does not promise anything positive to any endeavor. Thus, once again, a positive culture of creating value for everyone is the key factor in achieving the key outcomes being sought in any business (Burton, 2012) (Singh, & Singh, 2013).

Prevalent toolsets for today's process improvement and management methods can be seen in Table 1.

Lean's Framework Principles on Creating Customer Value along with its Toolbox for Improving Process and People Give Natural Expression to Engagement

Contained within Lean's fundamentals of "respect for people and continuous improvement" is the unflinching focus on creating customer value. This pursuit, according to many behaviorists, is hardwired into the psyche of everyone and is therefore the lynch pin between EE and Lean. Ultimately, this is also the make or break component to any EE initiative which so many campaigns heartily assert. Unfortunately, this is also the flaw causing so many miserable failures in workplace reality– (Kahn & Fellows, 2013) EE's feedback from many is "great theory but short on tactics."

Table 1. Leading process improvement toolsets

Process Improvement Method	Chief Architect/Promoters	Continuous Improvement Sweet Spot
Lean Processing	Taichi Ohno, Shigeo Shingo; Toyota	Customer Value Focus; Engage entire process team in creating increasing value while eliminating waste, unreasonableness, and unevenness.
Six Sigma	Shewhart; Motorola, Honeywell, GE	Variation Identification, Analysis, Elimination; use statistical quality control to manage with data while analyzing causes and priorities to eliminate variation.
Theory of Constraints	Goldratt; Bethlehem Steel, General Motors, National Semiconductor, United Airlines, Boeing, ITT, US Military Logistics	ID & Eliminate Constricting Steps in Overall Process; Focus resources in orderly fashion to mitigate greatest constraint to bring in line with process normal throughput; Achieve, sustain go to next highest constraint
Total Quality Management	Feigenbaum, Ishikawa, Demming; Malcolm Baldridge (US Dept of Commerce), Westinghouse	Holistic Management System; Recognizes interdependencies with ongoing assessment of each aspect of business using statistical measurement, analysis, management and improvement.

No one, especially the workers, would disagree with the primary pursuits of EE. Everyone wants the fulfillment and meaningful pursuit that EE asserts. Is any manager against having everyone on the same page pursuing the business goals? Everyone wants EE but the daily demands dictate get the work done and the product out the door; that “individual, self-actualization stuff be damned or you won’t have a job.” Any meaningful conversation about Employee Engagement or Lean will quickly turn to culture. The truth whether verbalized or not, is that business managers are more immediately and continuously held to performance results as their success measures. What is needed is a Business Operating System that blends these two synergistically rather than one that is at odds with each other. Every company has a culture. It is recognized by (O’Reilly, Chatman, & Caldwell, 1991):

- **Mission:** Strategic Direction and Intent, Goals and Objectives and Vision.
- **Adaptability:** Creating Change, Customer Focus and Organizational Learning.
- **Involvement:** Empowerment, Team Orientation and Capability Development.
- **Consistency:** Core Values, Agreement, Coordination/Integration.

Implicit in the culture discussion is the expectation that a positive culture engenders positive outcomes for a business. That said, a company's leaders should pursue the building of an "employee engagement" culture by advancing proven workplace enhancement qualities of their enterprise (Vragel, 2013):

1. Hiring People Who Fit Your Culture
2. Having Employees Know the Values and the Mission of the Company
3. Knowing That Good Decisions Can Come from Anywhere
4. Realizing You're a Team and Not a Bunch of Individuals

Leans Foundations are Respect for People and Continuous Improvement with a Very Large Proven Collection of Tools, Methods, and Benchmarks

From start to finish Lean is about value creation, and very quickly asserts that the culture nor management is truly respecting people if they are not tapping into the innate creativity of each value stream team member. Part of the power of Lean is that it works at every level utilizing the same basic ideas and tools. The individual can clearly articulate his effort within the framework and terms of Lean lingo. Managers can plan and assess the process working backwards from customer focus and see the process step by step throughout the value stream. Ultimately, the customer can see the difference as promises are kept while the value propositions are realized ahead of other providers (Nicholas, 2012).

All of the principles, methods, tools and systems of Lean (aka Lean Management Operating System) emanate from the foundation of respect for people and continuous improvement. Lean is simply developing processes and people for maximum customer satisfaction. The foundation principles of Lean from which all the tools, methods, and best practices derive are (Marodin & Saurin, 2013):

Five fundamental principles of lean correlated to the Q12 are shown in Table 2.

As stated, the tools, methods and best-practices derive from the basic principles of Lean. Further, the principles provide the flexibility for tailoring the actual implementation to the specialty processing and to the unique characteristics of business types and specific corporate environments (Cottyn, Van Landeghem, Stockman, & Derammelaere, 2011).

Table 2. Lean framework chart for continuous process improvement

Lean Principle	Best Practice Application	Expected Outcome
Creating Customer Value	Key performance indicators – meaningful goals with continuous scorekeeping and feedback	1. Clear understanding of value in customer terms
Functioning as Value Streams	Value Stream Mapping – customer focus with supporting process clarity and accountability Spaghetti diagram – movement of materials and people	2. With visual management and pull systems we rarely don't have what we need; VM always gives us alternatives, also 3. As a team we are developing and learning from each other; my strengths are part of our success 4. Feedback is continuous with meaningful incentives 5. Team and roles are clearly defined with position cross training ongoing, "my part clearly matters" 6. Lean is development of people and process; needs are assessed with development plans
Increasing Flow to One Piece Production	5S – optimizing the workplace for process efficiency and people effectiveness Single-Minute Exchange of Die – quick change-over, start-ups/shut downs Overall equipment effectiveness - Total Productive Maintenance – operator involvement as subject-matter expert	7. Team briefs, improvement ideas are routine 8.Work activities and outcomes are clearly connected with value known and highlighted
Producing On-Demand	Kanban – visual management; on-demand replenishment	9. Continuous improvement is ongoing and at all levels 10. My team needs me and we care for each other
Pursuing Perfection	Poka-yoke – error proofing and point-source quality Ishikawa diagram – root cause analysis	11. Team and personal goals are set with continuous feedback; team and personal improvement are built in

The Gallup Organization is the Leader in Expressing the Qualifications and Measures for Engagement

The Gallup organization's twelve-question survey implies the tenets engendering a healthy employee engagement culture (Sorenson, 2013). The thesis being advance here is that Lean satisfies these essential components while directly connecting engagement-building activities to high-valued outcomes for the market place. Across all industries and services Lean has proven to be an extraordinary and sustainable enabler of value creation even as it fully engaging workers, leaders, and customers. As alluded, the proven Lean concepts are applicable for the individual, teams, and enterprises.

Since Gallup is the accepted engagement leader with its Q12 surveys (Sorenson, 2013), this work will utilize their basic structure to demonstrate how Lean engenders engagement within the business purpose framework while creating optimum customer value (Cottyn, Van Landeghem, Stockman, & Derammelaere, 2011). Table 3 will utilize the Lean Framework Principles to both outline and compare the common engagement Gallup Q12 question with most common Lean operating concepts. This table, in fact, asserts that the matched Lean concept put into practice can facilitate a positive answer to the Gallup challenge question.

Gallup Engagement Questions Framework with each answered utilizing the prevalent Lean processing management/improvement methods (see Table 3).

An essential aspect of Lean's success across so many types of business and specific corporations is that it strongly considers the personal perspective while aligning business strategic and tactical processes. The overall organizational goals are defined in the same terms as the value stream team's goals along with each team member's goals (Nicholas, 2012). Further, most of the basic tools for identifying, analyzing, and improving the work are the same at each process level. This Lean process and problem-solving language is as practical at describing front-line issues, market place strategies, or personnel cultural issues.

Leaders Desiring the Outcomes Routinely Reported by Lean Market Leaders must Transform to a Culture of Respect for People while Teaching the Tools for Value Creation

As the saying goes, "there is nothing more useless than a theoretical plumber when the toilet is overflowing and the basement is filling with water." How

Table 3. Lean and employee engagement alignment

Lean Principle	Employee Engagement Question (Refer to Q12 Questions)	Answer in Lean Best Practices Outcomes from Framework Chart
Create Customer Value	Do you know what is expected of you at work? 4. In the last seven days, have you received recognition or praise for doing good work? 8. Does the mission/purpose of your company make you feel your job is important?	1. Clear understanding of value in customer terms 4. Feedback is continuous with meaningful incentives 8. Work activities and outcomes are clearly connected with value known and highlighted
Map the Value Stream	5. Does your supervisor, or someone at work, seem to care about you as a person? 7. At work, do your opinions seem to count? 10. Do you have a best friend at work? 11. In the last six months, has someone at work talked to you about your progress?	5. Team and roles are clearly defined with position cross training ongoing, "my part clearly matters" 7. Team briefs, improvement ideas are routine 10. My team needs me and we care for each other 11. Team and personal goals are set with continuous feedback; team and personal improvement are built in
Flow the Processes	3. At work, do you have the opportunity to do what you do best every day?	3. As a team we are developing and learning from each other; my strengths are part of our success
Produce on Demand	2. Do you have the materials and equipment to do your work right?	2. With visual management and pull systems we rarely don't have what we need; VM always gives us alternatives also
Pursue Perfection	6. Is there someone at work who encourages your development? 9. Are your associates (fellow employees) committed to doing quality work? 12. In the last year, have you had opportunities to learn and grow?	6. Lean is development of people and process; needs are assessed with development plans 9. Continuous improvement is ongoing and at all levels

do we get the desired employee engagement agreeing that the Lean methodology seems to give the same overall desired outcomes? The challenge for working managers is to sort through the on-going requirements to learn the Lean-tools focus simultaneous to maintaining a Lean-culture priority. The need is to balance a successful Lean employee engagement transformation as not an either/or proposition but a both/and implementation of development of process and people.

Experience along with organizational behavior surveys have shown that workers want what EE and Lean promises. They want to have meaningful work and be treated as creative human beings. Most managers do not like being thought of as the proverbial slave drivers. Owners of companies do not care to be called robber barons caricatured across the community.

Lean's framework principles blend both the bottom-up and top-down desires of engaged team members. A properly balanced approach provides congruence toward the same ultimate objectives of ever-increasing customer value creation. There is an order for transforming from a traditional "batch and cue" process to an on-demand, pull (Lean) processing system (Marodin & Saurin, 2013):

1. The first step is ensuring absolute clarity and focus on customer value creation
2. Establish visual management of the producing process with full accountability of the value stream team
3. Work to create flow end to end while eliminating waste, unreasonableness and unevenness
4. Produce according to customer demand with internal pull processing and on-demand supply systems
5. Continuously improve the lean system design with collective scientific thinking and root cause analysis

These foundation principles are easily learned along with the specific tools and methods of implementation. The challenge is to have the discipline to progressively implement the practices along with the discipline to sustain the practices. Even though individuals can always apply the Lean principles in some measure, the manager must coach and facilitate the interactions between team members and other functional teams. The managing coach must ensure daily consistency and discipline, adhering to the Lean tools known as Leader Standard Work.

The Goal of Every Organization Must be Satisfying Customers While Creating Value--Profitably

Once again, the inherent ethos of Lean is to meet customer demand at both the strategic level and the operational level. This "cultural focus" serves to align perspectives that routinely seem at odds in many organizations. The survivability of any business is determined by sustained customer appreciation of the company's value contribution to the market place. Employees want to be a part of a good company delivering appreciated customer value. Managers want to lead good teams producing extraordinary results, while owners delight in profitability and accolades for their contributions to the community.

One of the reinforcing strengths of Lean is the common language of process management and improvement. As both the strategic goals and operational goals are defined in the same terms of creating customer value, there is an automatic alignment of the big picture with the daily front-line activities of the work streams. The principal goals of business and Lean are the same: produce for ultimate customer satisfaction at a profit. Lean's pragmatic best-practice methods have evolved into three primary ways of making the process better at achieving the aforementioned objectives (Marodin & Saurin, 2013):

- **Eliminate Waste:** Defects, overproduction, waiting, non-value add, transportation, inventory, motion, employee engagement (lack of)
- Improve process capability (eliminate unreasonableness)
- Optimize process efficiency (eliminate unevenness)

A Organizational Checkup and Process Maturity Assessment Will Identify Pathologies while Clarifying Process Wellness Program Needs

To maintain our own health we rely on annual checkups which objectively inform where more attention is needed for interventions or remediation. Further, wellness programs enable getting ahead of the curve to sustain health and vigor through ongoing fitness programs. These same sort of assessment strategies are built into Lean. Assessments have proven useful to give focus, discipline, and priority to the Lean employee engagement and continuous improvement efforts. The Shingo organization has a rigorous review process that can be used to determine not only where the opportunities for improvement are but help establish order and priority for the process wellness effort (Singh & Singh, 2013).

Front-line producers should be given immediate and on-going feedback on their work. Managers appreciate the visual management components of process flow and status of work. Visitors and owners appreciate the orderliness and obvious discipline of the engaged value stream teams. Interestingly, understanding and awareness of needs has proven therapeutic in lieu of the frustrating unknown and hopelessness common to many of life's environs.

In order to have a healthy process, regular checkups are required in the areas of culture, process efficiency/effectiveness and benefit/effort exercises to establish priorities for initiatives. All improvement efforts are not equal just as all personnel programs are not perceived of value to employees. Only with assessment and benchmarking can leaders and the value stream teams see the entire organization and culture holistically to sort out the best choices for continuous improvement initiatives.

A Noble Purpose Empowered by Value-Creation Learning Will Radicalize Your Organization

After some straightforward education on the Lean principles including the concepts of waste identification, unevenness, and unreasonableness; the number of things that need to be fixed can be absolutely overwhelming. At this juncture, some basic Lean tools help to sort out where team members should start.

Once work and opportunities are made visible, workers have no problem making choices on specific activities and priorities. The visual workplace further helps managers and team members know status of work while flagging areas requiring extra attention. Finally, senior management's routine presence in the workplace dialoguing with front-line workers using the visual controls and feedback keep strategic objectives solidly linked to the frontline operations.

Meaningful contribution and personal growth are commonly reported as key job satisfiers in workplace surveys. Each of these are inherent characteristics of a mature and engaging Lean culture.

As the invisible nature of the process is now made visible to all, agreement can be reached on the priorities of waste elimination and work improvement. The order of priority tracks the themes of first stabilizing the work processes, standardizing work and its flow, and implementing systems to sustain continuous improvement gains.

As more process problems are resolved the same tools that helped remedy those are applied to proactively improve the processes and culture of the enterprise. As a company's process maturity is stepped up, a momentum of value creation and success engenders infectious high-performance work teams delivering extraordinary customer value along with an engaging work culture.

A Real Employee Engagement Culture Makes Coming to Work a Challenging, Soul-Satisfying Adventure

Contained within the frameworks of Lean and employee engagement are ownership and personal responsibility. Lean actually provides details within the framework where empowerment is managed from the bottom up while being managed from the top down within an overall orchestrating, customer-focused structure. Both culturally and personally, empowerment is built in.

The concepts of the value stream are easily (assumed) to extend forward into the customer domain and backward into the supplier domain for full supply chain consideration. The front-line team member becomes holistically aware while intimately committed to making value flow end-to-end. This should sound like solid "employee engagement" to anyone paying attention. This is a far cry from the "it's not my job" mentality that prevails in non-Lean workplaces.

As a customer-focused, value-creating culture of respect and continuous improvement matures, people find their workplace one of their primary life fulfillment environments.

Unfortunately, company managers start programs that quickly wither leading to "program of the month" cynicism often heard around the water cooler. Suffice it to say that Lean can work the same way. The recipe that has proven successful for transformation to Lean includes (Deflorin & Scherrer-Rathje, 2012):

- Teach everyone to take a process/systems view
- Provide problem solving skills to everyone; expect them to use them
- Put in place "measures that matter" along with real-time feedback; i.e., visibility in "What I Do Matters"
- Make everything visible, especially problems and their resolution
- Place responsibility in the hands of the people on the front-line of the process

Certainly, this all is a radical change to the workplace norm. There must be real investment in training and development. Take note; beyond the investment in training and development is the require transformation from top-down command and control to a more collaborative work place. For most work places this is a sea change that takes patience and persistence. The workforce must get belief which can only come by taking steps of ownership and responsibility that are reinforced by seriously committed leaders. The good news and the bad news is the same: this change of mind and heart must first come from leaders. Such a radical commitment to change must be proved over and over again on the front line if a real and lasting culture shift of positive (and profitable) employee engagement is to occur.

A Lean Employee Engagement Culture and Operational Framework Welcomes any Proven Toolset that Can Make Things Better

Each component of the continuous improvement movement contains proven and valuable tools for making things better within the modern complex organization. Further, even many of the more specialized tools appropriate to specific industries have been tailored to efficiently meet their own specialized needs.

As processes and work is improved and refined within an organization, new opportunities and technology from the "House of Lean" will be drawn into the work. Workers today must be on a continual quest for development and learning new skills. Lean's foundation of respect for people and continuous improvement along with its focus on customer value allows for any proven tool or technique to be incorporated into the Lean mix of best practices. Some common tools that are regularly blended into the Lean value creation culture are (Nicholas, 2012; Burton, 2012):

- **Six Sigma:** Finding and eliminating variation (quality).
- **Quality Function Deployment:** Clearly articulating the satisfiers and dis-satisfiers of the customer.
- **Theory of Constraints:** Finding and eliminating the production limiters and removing.
- **TRIZ-Theory of Inventive Problem Solving:** Systematic innovation seeking the "ideal final result."

As stated, Lean does not preclude or interfere with other proven analytical or specialty toolsets. For example, Six Sigma's statistical modeling tools for identifying and eliminating variation is commonly linked with Lean. Others such as Theory of Constraints and Quality Function Deployment also play-well with Lean as they actually delve more deeply into some aspects of analyzing the value stream that Lean doesn't. The technologies of many specialized industries mandate some specialty toolsets which generally fit rather well into the Lean value creation framework (Singh & Singh, 2013).

Trust is the Secret Sauce of Lean and Engagement

As articulated, Lean best practices are a proven way of gaining Employee Engagement along with extraordinary performance to every stakeholders' satisfaction (customers, owners, employees, community) (Wang & Hsieh, 2013). There is one other significant factor that needs to be addressed for the sake of legitimately advancing employee engagement and any form of Lean transformation desired. The profound truth underlying everything expressed thus far is that people must trust enough to try (Gerst, 2013). If what is being asked is not worth the risk because the work environment does not engender openness, things will be very difficult to change and ultimately will not sustain. Unfortunately, the majority of workers do not trust their management (Wang & Hsieh, 2013).

Workers that don't trust their managers will cover up concerns and issues. Team members that don't trust their teammates will not freely share insights or ask for help. Managers working under a cloud of distrust must monitor everything leaving no discretionary time to develop or improve anything (Wang & Hsieh, 2013). Profits from untrustworthy companies suffer due to "distrust taxes" also known as hidden spoilage, extra overhead to check things, lost opportunity, extra risk bonding, etc. (Dan-Shang & Chia-Chun, 2013).

Without trust workers will not take a chance while even resisting the most positive of changes desired. They just don't believe. However, when trust is pervasively a characteristic of the work environment, as David Horesager asserts, there is a culturally engaging advantage for organizations he has labeled the "Trust Edge." His Trust-Edge pillars model describes a workplace where leaders are aspiring to consistency, clarity, compassion, character, contribution, competency, connection and commitment. Succinctly, managers can change a distrustful environment by building off of the Eight Pillars of the Trust Edge (Horsager, 2012). The Trust Edge is actually greatly reinforced by continuous improvement Lean principles and tools which further tie to Lean process improvement as follows:

1. **Consistency:** The Lean principles and tools advance a common continuous improvement language focused on creating customer value.
2. **Clarity:** The clear mission of value creation for the customer with a common quest in the pursuit of perfection unifies and inspires.

3. **Compassion:** Establishing value stream teams with both ownership and responsibility tied to award and appreciation builds camaraderie and trust.
4. **Character:** Advancing value stream team work and team betterment is a win-win service mentality with on-going feedback and public score-keeping promotes transparency and integrity.
5. **Contribution:** Lean visual management with continuous, immediate feedback both drives and recognizes team and individual contribution.
6. **Competency:** Inherent to the plan-do-check-act scientific thinking/improvement model is making things and people better.
7. **Connection:** The common language culture of Lean promotes community and team goals along with the shared victories or challenges of accomplishment.
8. **Commitment:** Value stream team membership with commitment to common objectives presumes and builds trust.

Trust does not start with the economy or government. It starts with individuals becoming trustworthy. That trust takes a long time to earn; is very fragile; and can be lost in an instant. The reason most companies cannot immediately implement Lean or any other improvement program is because their current culture reeks of distrust (Wang & Hsieh, 2013) (Horsager, 2014). This will be the first place to start on the Lean Employee Engagement journey. The pilgrimage can have enormous payoff for those leaders willing to honestly assess themselves and their organization. The proven best-practice tools of process improvement are readily accessible. The real question is what will it take for the enterprise to build a Lean Employee Engagement culture? As the game show exclaims: “the answer is -- Trust!” and training to use the Lean Employee Engagement tools.

SUMMARY: BEHAVIOR-BASED LEAN TRANSLATES THEORY INTO A GREAT WORKPLACE

A GOATHERD had sought to bring back a stray goat to his flock. He whistled and sounded his horn in vain; the straggler paid no attention to the summons. At last the Goatherd threw a stone, and breaking its horn, begged the Goat not to tell his master. The Goat replied, “Why, you silly fellow, the horn will speak though I be silent.”– ÆSOP

It is said that the aphorism: "actions speak louder than words" comes from this classic fable of wisdom. We can study and preach and desire, but Lean is about doing things on the front line where the value is created. Even so, how are leaders to implement the broad concepts of Lean, Engagement, and Trust in a way that can make a positive difference in the work place. As expressed numerous times in this work and regularly reported in the business literature, there is a great gap between the aspirations of treating people well and the actuality of a positive work culture. Further asserted in this work is the notion that Lean was developed in the workplace not in a theoretical social science lab. The greatest contributors to the Lean body of knowledge were business innovators on a quest to do better for all the stakeholders of the enterprise: customers, workers, stockholders and the business host community.

We do know from the plethora of surveys in the literature that people will respond in kind to a positive (and challenging) workplace. They want to feel like they are making a contribution to their team and doing work that makes a difference. The majority of people do want to be a part of a great workplace doing good work for a customer community. Along with building in ways to learn Lean concepts for yourself and your front line workers, as follows are a half dozen questions to meaningfully engage in dialogue with front line workers eliciting challenges to make your business better:

- Do we know what our customer really wants?
- What seems wasteful about this work?
- How could we get rid of this waste?
- Does this particular step (or thing) we are doing really add-value?
- What really bugs me about this work?
- How could we improve this process step cycle time by just 2 seconds?

Each of these questions can be answered at a superficial level very quickly and easily. However, each can be delved into very deeply by using the Lean tool set to make the invisible issues and opportunities, visible. In line with gaining more insight (and involvement by asking), leaders will discover that each team member has a perspective along with an unending stream of good ideas for making things better. Here is the "dirty little secret" to making a difference. A lot of little improvements generated by the team that can be put into action will make a huge difference over time versus the great big idea from the experts that we must delay pending the next budget cycle. Besides seeing ready results by implementing these improvements, each team member will see that their own idea is what is making a difference in their own work. It doesn't take much imagination to see how this very simple set of questions with follow-up quick action leads to engagement, ownership, appreciation and respect as the leader demonstrates trust in the front-line team members.

Start basic and simple at the front line. Set up daily routines to ask questions from those on the frontline, and finally, let them make quick, straightforward improvements. Start a "coffee-break" Lean development program for you and your team to learn the Lean best practices. If you will do these simple things (i.e., modify your leadership behavior), in the not too distant future, your organization will be known as a Lean leader within your market with everyone in the area wanting to come to work for you. Beyond being a very good process improvement tool set, Lean presupposes a people-centric leadership behaviors for the practical development of a very engaging work culture for your employees, your managers, your customers and your bank account.

Since this summary began with a fable of Lean wisdom, it will also be closed with one asserting the need to take consistent action:

A man who had traveled in foreign lands boasted very much, on returning to his own country, of the many wonderful and heroic feats he had performed in the different places he had visited.
Among other things, he said that when he was at Rhodes he had leaped to such a distance that no man of his day could leap anywhere near him as to that, there were in Rhodes many persons who saw him do it and whom he could call as witnesses.
One of the bystanders interrupted him, saying: "Now, my good man, if this be all true there is no need of witnesses. Suppose this to be Rhodes, and leap for us." - AESOP

Moral: Don't let your words be larger than your deeds.

REFERENCES

Abraham, S. (2012). Job Satisfaction as an Antecedent to Employee Engagement. *SIES Journal of Management*, *8*(2), 27–36.

Burton, T. (2012). The generations of improvement. *Industrial Engineer, 44*(8), 46-50.

Cooke, M., & Buckley, N. (2008). Web 2.0, social networks and the future of market research. *International Journal of Market Research*, *50*(2), 267–292.

Cottyn, J. J., Van Landeghem, H. H., Stockman, K. K., & Derammelaere, S. S. (2011). A method to align a manufacturing execution system with Lean objectives. *International Journal of Production Research*, *49*(14), 4397–4413. doi:10.1080/00207543.2010.548409

Crabtree, S. (2013). *Northern America Leads the World in Workplace Engagement*. Gallup Poll Briefing.

Dan-Shang, W., & Chia-Chun, H. (2013). The effect of authentic leadership on employee trust and employee engagement. Social Behavior & Personality. *International Journal (Toronto, Ont.)*, *41*(4), 613–624. doi:10.2224/sbp.2013.41.4.613

Deflorin, P., & Scherrer-Rathje, M. (2012). Challenges in the transformation to lean production from different manufacturing-process choices: A path-dependent perspective. *International Journal of Production Research*, *50*(14), 3956–3973. doi:10.1080/00207543.2011.613862

Gerst, R. (2013). Understanding Employee Engagement and Trust. *Journal for Quality and Participation*, *35*(4), 32–36.

Giannantonio, C. M., & Hurley-Hanson, A. E. (2011). Frederick Winslow Taylor: Reflections on the Relevance of The Principles of Scientific Management 100 Years Later. *Journal Of Business & Management*, *17*(1), 7–10.

Hamel, G. (2012). What Matters Now. *What Matters Now, 1*.

Hamel, G. (2013). High Engagement? *Leadership Excellence*, *30*(2), 3–4.

Horsager, D. (2012). Author shares 8 pillars to getting ‘The Trust Edge’. *Inside Tucson Business, 22*(14), 14.

Horsager, D. (2013). Employee Trust. *Leadership Excellence*, *30*(1), 5.

Horsager, D. (2014). The Trust Edge. *Trust Edge, 1*.

Kahn, W. A., & Fellows, S. (2013). Employee engagement and meaningful work. In B. J. Dik, Z. S. Byrne, & M. F. Steger (Eds.), *Purpose and meaning in the workplace* (pp. 105–126). Washington, DC: American Psychological Association. doi:10.1037/14183-006

Kahn, W. A., & Heaphy, E. D. (2014). Relational contexts of personal engagement at work. In Employee engagement in theory and practice (pp. 82-96). Academic Press.

Marodin, G., & Saurin, T. (2013). Implementing lean production systems: Research areas and opportunities for future studies. *International Journal of Production Research*, *51*(22), 6663–6680. doi:10.1080/00207543.2013.826831

Nicholas, J. (2012). An Integrated Lean-Methods Approach to Hospital Facilities Redesign. *Hospital Topics*, *90*(2), 47–55. doi:10.1080/00185868.2012.679911 PMID:22671435

Palacios-Marques, D., Saldaña, A., & Vila, J. (2013). What are the relationships among Web 2.0, market orientation and innovativeness? *Kybernetes*, *42*(5), 754–765. doi:10.1108/K-03-2013-0057

Paul, G. (2012). Creating an Excellence Oriented Post-merged Organisational Culture through a Structured Approach to Employee Engagement. *Africa Insight*, *42*(2), 136–156.

Ramakrishnan, S. (2013). Vital missing link in organizational transformation. *Industrial Management (Des Plaines)*, *55*(1), 8–9.

Ransom, C. (2012). Why lean? In *Proceedings of Lean Alliance Annual Meeting*. Greenville, SC: Lean Alliance.

Shanley, C. (2014). Minding Your Social Media Ps and Qs. *Illinois Banker*, *99*(1), 28–29.

Singh, J., & Singh, H. (2013). Continuous Improvement Strategies: An Overview. *IUP Journal of Operations Management*, *12*(1), 32–57.

Sorenson, S. (2013). How Employee Engagement Drives Growth. *Gallup Business Journal, 1*.

Vragel, P. (2013). Creating an Employee Engagement Culture. *Ceramic Industry*, *163*(10), 27–28.

Wang, D., & Hsieh, C. (2013). The effect of authentic leadership on employee trust and employee engagement. *Social Behavior and Personality*, *41*(4), 613–624. doi:10.2224/sbp.2013.41.4.613

Wong, W., Ignatius, J., & Soh, K. (2014). What is the leanness level of your organisation in lean transformation implementation? An integrated lean index using ANP approach. *Production Planning and Control*, *25*(4), 273–287. doi:10.1080/09537287.2012.674308

Yadav, L. (2013). The Commitment Conundrum. *IUP Journal of Soft Skills*, *7*(3), 23–30.

Yalabik, Z. Y., Popaitoon, P., Chowne, J. A., & Rayton, B. A. (2013). Work engagement as a mediator between employee attitudes and outcomes. *International Journal of Human Resource Management*, *24*(14), 2799–2823. doi:10.1080/09585192.2013.763844

KEY TERMS AND DEFINITIONS

5S: 5S is a method used by front-line workers to optimize the workplace for work processes characterized by visual management, performance indicators, a designated place for everything, and everything in its right place.

6σ (Six Sigma): Six Sigma is a business management strategy focused on identifying and removing variability within processes. It uses statistical modeling to objectively qualify and quantify quality issues along with a full suite of methods for measuring and controlling processes. A six-sigma process is one in which 99.99966% of the products manufactured are statistically expected to be free of defects (3.4 defects per million).

A3: The A3 is a structured problem-solving methodology where process problems are captured, sorted, analyzed capturing essential information on an 11x17 sheet that everyone can see, understand, and comment on.

Bottlenecks: A bottleneck is a constraint within a process limiting the overall output of a process line. It comes from the Theory of Constraints continuous improvement approach to process management.

Cellular/Flow Manufacturing: On-piece flow is a fundamental principle of Lean and is frequently achieved by breaking complex/constraining processes into cellular subassembly areas to match flow rates or takt time thereby equalizing each process step.

Continuous Flow: This Lean idea seeks to remove queuing and batching within production processing. This basic Lean concept is proven to eliminate all kinds of waste and quality problems.

Continuous Improvement (CIP): Continuous Improvement follows a "Plan-do-check-act" (PDCA) cycle: ID/define the problem, capture the current situation, plan improvements; prototype or implement the improvement ideas; use objective metrics to monitor and report on the process; adjust the process based on the analysis of the feedback and continue the PDCA loop.

Culture of Engagement: An organizational culture where everyone understands their function and what they can do to make the organization succeed along with being committed in word and deed to the success of the enterprise.

Cycle Time and Lead Time: Cycle-time is the amount of time that value-added work is performed within a process step or overall process line. The Lead time is the time it takes from the customer request to the final delivery.

Defect: A defect is a flaw or missed specification in the product or service.

Employee Engagement: Describes relationships between associates and the company that on the mutual commitment and passion for success for the enterprise and its constituents.

Engagement Scores: Objective feedback on the assessment of employee commitment to the organization.

Gallup Q12: The distilled assessment criteria developed by the Gallup organization that ferrets out a company's engagement rating compared to other organizations and their own previous assessments. This rating correlates to a number of other standard business success criteria.

Just-in-time (JIT) Manufacturing: Producing and developing supply systems that deliver materials on-demand eliminating extra handling and inventorying of process materials.

Kaizen: Kaizen is the Lean term for continuous improvement originating in Japanese and literally meaning a change for good. The term is used both for a mindset of always seeking a better way or a short-cut term for improvement projects/events.

Kaizen Event: A Kaizen Event is a focused, short-term set of activities following a very controlled path to make sweeping and rapid improvements within a process area.

Kanban: A Kanban is a visual signal to indicate materials needs or status. It can simply be a flag on a bin, a re-order card or the position of an item itself that triggers signals a need thereby triggering an on-demand-pull replenishment system.

Lean: Lean is the description of a process of focused on creating maximum customer value while eliminating all forms of waste within a process.

One-Piece Flow: The concept of making one/moving one. Lean seeks to achieve end-to-end processing visibility/accountability with no stopping or starting to produce the product or service. This objective has proven to be the most reliable cost-effective method for process intensive activities.

Poke-Yoke/Mistake Proofing: Mistake proofing or murphy-proofing consisting of front-line, very direct and reliable methods that will prevent errors or detect off-normal situations before they occur. Autonomation is the part of poke-yoke that will automatically shut the process down if a mistake occurs.

Problem-Solving Process: A repeatable and reliable systematic set of methods that consistently surface all the issues within a problem situation, facilitate root cause understanding while leading to a solution to implement (A3 and 8D are common).

Pull vs. Push: Push is the traditional batch and queue process method bent on reducing costs through economy-of-scale production. Pull is the Lean concept of producing on-demand; when one is moved or consumed another is produced to replace it.

Pull/Kanban System: Kanbans are “supermarkets” for process materials. More than just storage, the inform of materials status and replenishment needs as they are implemented off of the Lean foundation of Pull or on-demand/ just in time fulfillment.

Quality at the Source: AKA point-source quality is the idea that everyone is responsible for verifying work entering a process step and produced in that step. There is no separate quality control–it is built into the process work.

Quick Changeover, Setup Reduction: Focus on reducing non-producing process setup and changeover time akin to a well-rehearsed race car pit stop.

Single Minute Exchange of Dies (SMED): Originated as the idea of doing stamp-die changes in less than 10 minutes. It is now applied to Lean process change quick change-over efforts as a short hand concept.

Standardized Work: Presumes there is at any state of process maturity a current one best way to do things that needs to be captured and practiced by everyone. It also allows for a disciplined process of continuous improvement as part of the standardized work cycle.

Takt Time: Takt Time is the rate that we must produce product to meet customer demand. This steady rate of production is what we optimize the process to fulfill. Further, as customer demand changes, our process should be flexible to change accordingly.

Teams: Lean presumes team-based approaches focused on a common goal or maximizing customer value through the pursuit of perfection (continuous improvement).

Total Productive Maintenance (TPM): A Lean concept to synthesize equipment maintenance into the process operations as a component of process quality and reliability. TPM trains the operator to be a maintainer greatly improving productivity while eliminating equipment-related waste.

Value Stream Mapping (VSM): Is the tool to make the process value stream visible. Once the AS-IS state is captured and validated by all stakeholders, a future state is envisioned by the expert stakeholders. The gap between the two states surfaces opportunities for kaizen; either projects or blitz-type events.

Visual Controls/Visual Management: Visual management means that everything within the process or workplace is obvious, whether it is a process step, the location of tools and equipment, the status of work, and of course, the process effectiveness score.

Waste: Waste is anything that uses resources that doesn't add real value. It further presumes a minimalist approach to time and materials sued within a process. The Eight Wastes of Lean are: Defect, Overproduction, Waiting, Non-value add processing, Transportation, Inventory, Movement, Employees that are not engaged.

WIP: Acronym for Work in Process.

Workflow Analysis: Carefully analyzing physical process flow with the intent of reducing distance and eliminating steps/time while improving communication and quality.

Chapter 7
Manufacturing Production Companies Can Gain Strategic Global Advantage Using Lean Six Sigma

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ABSTRACT

How the implementation of Lean Six Sigma in manufacturing production companies in the global environment can positively affect innovation, quality, education, productivity, standard of living, and ethics is discussed in this chapter. Examples by notables like Dr. W. Edwards Deming and the Chegg Study point out a serious misalignment between what is actually needed in manufacturing production worker skill sets and what is available. The chapter demonstrates the interconnectivity of, and responsibility for, the welfare of citizens of the world. It shows how Lean Six Sigma implementation can influence Gross National Product and Gross Domestic Product, which in turn determine quality of life for a nation's citizens. The chapter offers solutions like fostering industry, academics, and government relationships for the abatement of problems such as less government funding for public education and equipping college students with the right skill sets for more complex jobs in manufacturing production industries.

DOI: 10.4018/978-1-4666-7320-5.ch007

ATTAIN GLOBAL MANUFACTURING SUCCESS: MAXIMIZE LEAN SIX SIGMA

Manufacturing production companies are concerned about maximizing productivity. Because a nation's standard of living and its quality of life are driven by its productivity, Shaw (2009). According to Economic Snapshot (2000) labor productivity is a measure of the amount of goods and services that the average worker produces in an hour of work. According to Shaw, of the many factors that influence a country's standard of living, by far the most important is productivity (2009). The Bureau of Labor Statistics (BLS) (n.d.) says that productivity equals output which is measured in units of whatever a company is producing, divided by input, which is measured in man hours (mh). The resulting output, or productivity, is units/mh. Implementing Lean Six Sigma has the potential to greatly increase a nation's productivity.

This chapter will focus on innovative solutions for productivity issues and challenges facing manufacturing production companies globally. Its theme will be Lean Six Sigma and how these principles and practices can provide solutions to the aforementioned problems. The purpose of these solutions is to make manufacturing production companies able to effectively meet and exceed the competition's productivity anyplace in the world.

This chapter will explain ways that manufacturing organizations may learn to strategically use and implement Lean Six Sigma principles and practices to ethically increase productivity, exceed customer and provider expectations, and cut production costs. The result of these innovative changes should increase productivity and bottom-line company profits. The experience of learning and successfully implementing Lean Six Sigma should provve to be enjoyable, rewarding and exciting for people in manufacturing organizations as well as for those in educational institutions who wish to partner with manufacturing organizations.

WHAT IS LEAN SIX SIGMA? AND WHAT BENEFITS CAN ORGANIZATIONS EXPECT FROM IMPLEMENTING LEAN SIX SIGMA?

There appear to be varying descriptions and much discussion among manufacturing industry leaders as to what exactly Lean Six Sigma is. Also, as to what is the difference between "Lean" and "Six Sigma" Strupe (2009)? According to Strupe (2009) the term Lean Six Sigma is a methodology that combines process speed with quality. However, the term Lean Six Sigma can be reduced to its individual parts, which are Lean and Six Sigma, and each separate part has its own definition. Lean Six Sigma is about continuous improvement to drive up quality and drive cost down. It's about the relentless pursuit of perfection. Conventional wisdom seems to state that the organization that comes closest to perfection in product or service, at the lowest cost, will dominate the industry. Over the last few centuries manufacturing production innovations have made tremendous progressive contributions to the industry.

Historical Innovative Milestones in Manufacturing

During the course of history people have strived and changed manufacturing dramatically. From the water wheel to the spinning wheel, and into the First Industrial Revolution, it was people who made dramatic changes along the way. A customer focus for quality in products seems to have always driven productivity though innovations.

The Industrial Revolution, covering the period from 1760 to 1830, is usually credited with the most significant increase in productivity up until the time of its introduction (Industrial Revolution, 2014). This initiative is believed to have started in Great Britain. Its main innovative feature of productivity improvement was the process of change from an agrarian, handicraft economy to one dominated by industry and machine manufacture (2014). The invention of the cotton gin and the steam engine characterized innovations of the Industrial Revolution.

Early Lean Six Sigma Thinking

I have found it useful to think about the history of lean thinking at the Ford Motor Company, going back nearly 100 years. I believe it offers many useful lessons for our current-day lean journey and Ford's immediate choices (Crate, 2006, p.1).

The historical record is clear. Henry Ford was the world's first systematic lean thinker. His mind naturally focused on the value creation process rather than assets or organizations. And he was the first to see in his mind's eye the flow of value from start to finish, from concept to launch and from raw material to customer. In addition, Ford was history's most ferocious enemy of waste. (Except, possibly, Taiichi Ohno at Toyota who claimed that he learned what to do from reading Henry Ford's books. [Crate, 2006]) Even then Henry Ford was thinking in terms of Lean Six Sigma although the terms "Lean" and "Six Sigma" weren't formally introduced into manufacturing until 1986 at the Motorola Corporation.

Lean Manufacturing Quality

Quality Defined and Quantified

Quality is the feeling that one gets when performance (product or service) exceeds expectation. Quality can be quantified by using the formula:

Quality (Q) = Performance (P)/Expectation (E) or Q = P/E.

Lean Manufacturing Focus

Lean manufacturing primarily focuses on speed. It emphasizes reducing the amount of time between activities, events, and cycles. The shorter the cycle time, the more cycles you can complete in a given amount of time. Lean also identifies areas where process waste and bottlenecks can be eliminated, Strupe (2009). Lean experts vary as to how many forms of wastes exist. Using the following commonly used acronym, TIMWOODS, this chapter will identify eight types of wastes that lean practices can reduce or eliminate.

T – Transportation: Moving people, products, and information.
I – Inventory: Storing parts, pieces, documentation ahead of requirements.
M – Motion: Bending, turning, reaching, lifting.
W – Waiting: For parts, information, instructions, equipment.
O – Over Production: Making more than is immediately required.
O – Over Processing: Tighter tolerances or higher grade materials than are necessary.
D – Defects: Rework, scrap, incorrect documentation.
S – Skills: Underutilizing capabilities, delegating tasks with inadequate training.

Lean Manufacturing Goals

According to Carreira & Trudell, (2006),

The basic goals of Lean are high quality, low cost, short cycle times, flexibility, relentless efforts to drive waste out of the organization, and all value being defined by the customer. Waste is anything a customer is not willing to pay for. Value is anything the customer is willing to pay for.

Six Sigma Quality

Six Sigma methodology is a quality tool that emphasizes reducing the number of errors in a process. It focuses on identifying variation in the types of data inputs, and looks at Root Cause Analysis to determine the source of errors (Strupe, 2009).

Six Sigma's Focus

Six Sigma is a strategic and tactical system for managing the total business enterprise (Harry, Mann, Hodgins, Hulbert, & Lacke, 2010, p. 13). From this perspective, Six Sigma has the ability to concurrently deliver customer and provider satisfaction (p. 13). In its most elemental form, Six Sigma represents 3.4 defects per million opportunities for defects. Harry, Mann, Hodgins, Hulbert, and Lacke (2010) also found….Given that Six Sigma is primarily a business initiative that contains metrics and is not just a quality program, one can see that it is more closely aligned with risk abatement than with defect detection. In other words, when businesses apply Six Sigma to reduce exposure to risk, customers increase their confidence of achieving entitlement performance in everything they do (p.13). Essentially, like Lean Manufacturing, Six Sigma's primary goals are to increase quality and productivity.

THE PRODUCTIVITY ISSUE

Measuring Productivity

Most countries use Gross Domestic Product (GDP) to measure productivity, which is sometimes referred to as standard of living, or economic health. GDP is the primary measure used by the U.S. Department of Commerce's Bureau of Economic Analysis (BEA). Although, up until 1991 the BEA used Gross National Product (GNP) as its primary measure. The difference between GDP and GNP is: GDP is the market value of everything produced within a country by a country's residents, no matter where they live. Gross National Product (GNP) is the total market value of goods and services produced by the residents of a country, even if they're living abroad, FactCheck.org (2008).When it made the switch, the BEA noted that GDP was already being used by "virtually all other countries," so making comparisons between the U.S. and other nations would be easier if the U.S. switched to GDP. The use of GDP is also consistent with other economic indicators, such as employment (FactCheck.org, 2008).

Manufacturing's GDP Positions

While manufacturing's portion of GDP of global advanced economies continues to decline, Perry (2012), it continues to climb in emerging economies, though not as dramatically as in recent years (The Economist, 2013). According to The Economist, the most impressive growth in recent history was in four of the biggest emerging economies: Brazil, Russia, India and China, countries whose names were acronymed into the BRICs in 2001. Though the BRICs economies continue to grow, the world is not likely to witness, ever again, growth like the growth of the BRICs from the late 1990's through the early 2000's (2013).

Employing Lean Six Sigma principles and practices may help manufacturing production companies strategically increase their productivity through effective leadership and constant innovation. Innovation includes different aspects of change or improvement. Although innovation includes inventions, innovation is not all about inventions. Sometimes innovation may comprise a clever modification or the tweaking of a process to make it more efficient. Can innovation be taught in institutions such as community colleges and four-year higher learning institutions? The issue of industry, academic, government relationships will be addressed later in this chapter.

Labor Productivity in GDP Calculations

The cost of labor to produce goods and services is a factor used in calculating a country's GDP. Another factor to consider when computing productivity or GDP is Unit Labor Cost (ULC) or cost per hour to produce a unit of labor. According to the Bureau of Labor Statistics (BLS)'s Handbook of Methods (2014), the following formula is used for the computation of ULC:

Unit of Labor Cost = Cost/Hour divided by Output/Hour or ULC = (C/H)/(O/H).

This formula highlights the relationships between unit labor costs, hourly compensation, and labor productivity. This formula also computes labor compensation per hour which parallels the computation of output per hour. This may provide a better understanding of why manufacturing production companies find it advantageous to offshore manufacturing in South American, Central American or Asian countries where productivity labor is relatively cheap when compared to the U. S. labor and labor markets in more developed countries (Shorr & Wong, 2013). However, along with cheap labor comes other ethical labor issues i.e. sweatshops.

Ethical Issues with Sweatshops

Shorr & Wong (2013) say a sweatshop is any factory which may have unreasonably authoritative overseers, dangerous and unhealthy (both physically and psychologically) working conditions, and enforces long hours with low pay, and, also frequently employs child labor. The two essayists go on to say that:

Many developed nations, including the United States, have at some point engaged sweatshop production facilities on a large scale, and a major segment of the world's remaining sweatshops are located in Asia. As the West continues its long-standing tradition of fostering what many would liken to slave labor, an ethical examination of these business practices becomes increasingly important. (32)

Brands such as Nike, Gap, Converse and Levi's all have U. S. corporate headquarters and customer bases, while the manufacturing component of their production processes are in Asian countries, often using sweatshops (Shorr & Wong, 2013). Sweatshops are also notorious for underpaying their workers, (2013).

According to Shorr & Wong (2013),

The U.S. minimum wage is $7.25 per hour, it is $1.48 dollars in Thailand, 69 cents in the Philippines, and 67 cents in China with some workers frequently paid less than these estimates suggest–amounts barely enough to survive on even considering the lower cost of living in these regions (p. 32). And yet because of their dire need for these meager earnings, the closing of these sweatshops in some Asian countries are met with hostility by the workers who, because of the sweatshop closings, are now without any income.

How to resolve the issue of sweatshops is no easy matter as The practical problem revolves around the fact that sweatshops are mutually beneficial, making both employees and workers better off, even if the latter is not as much better off as critics think they ought to be, thereby making it more difficult to give force to the normative arguments against sweatshops (Shorr

& Wong, 2013). If Lean Six Sigma principles were taught in institutions of higher education in emerging economies, in any economy, it could alleviate the need for sweatshop conditions.

The Need for Industry, Academic, Government Relationships

Why not teach Lean Six Sigma to students in institutions of higher education? If taught, it could prove advantageous to higher education students, administrators and teachers, as well as to manufacturing industries. Two-year and four-year public institutions of higher education face dwindling government, especially state government, financial support creating a perfect storm for state-funded higher education institutions to eventually reach zero state funding. Thomas Mortenson (2012), a senior scholar at The Pell Institute for the Study of Opportunity in Higher Education in Washington, D.C., wrote an article in the Winter 2012 Edition of American Council on Education (ACE) entitled "State Funding: A Race to the Bottom." The article states, "Based on the trends since 1980, average state fiscal support for higher education will reach zero by 2059, although it could happen much sooner in some states and later in others. [Eventually] public higher education [will] gradually [become] privatized" (p. 27).

Lean Six Sigma at the University of Arizona

Campus teams at the University of Arizona that were organized to streamline operations and make them more efficient are using Lean Six Sigma in conjunction with the campus's own "Mosiac" initiative (Martinez, 2009). According to Martinez (2009) Lean Six Sigma which was originally developed to streamline manufacturing companies, is now being used to help identify ways to make both the academic and the business sides of the University function more efficiently. So, if Lean Six Sigma can be implemented to help the University of Arizona increase its operational efficiencies, why not teach it to university students as a tool to carry with them when they leave the halls of academia and enter the business world, enabling them to hit the ground running.

Fostering Industry, Academic, Government Relationships

Fostering collaborative working relationships for the purpose of innovating has become a subject of great interest to industry, academics and policy makers as evidenced by President Barack Obama and the Department of Energy

(DOE)'s January 15, 2014 foray into North Carolina (NC) State University (Obama, 2014). During his January 15, 2014 visit to NC State University President Obama selected NC State to lead a $140 million advanced manufacturing institute that will unite academic, government and industry partners in an effort to revolutionize energy efficiency across a wide range of applications, including electronic devices, power grids and electric vehicles. According to President Obama (2014) The mission of the Next Generation Power Electronics National Manufacturing Innovation Institute is to develop advanced manufacturing processes that will enable large-scale production of wide bandgap (WBG) semiconductors, which allow electronic components to be smaller, faster and more efficient than semiconductors made from silicon.

Need for Collaboration

There appears to be an ever-widening gap between the skills that higher education graduates are acquiring and the skill that the manufacturing production companies are demanding. In fact, Yashchin (2014) says the days are gone when one could graduate college, knowing that rewarding work was available in one's field of study, according to a recent study by Chegg. In fact, only 27% of college graduates are hired for a job related to their major. Higher college enrollment rates, combined with falling job creation rates, have created a daunting and competitive job market. Even triple-threat applicants with direct experience, applicable degrees, and network connections express difficulty with finding well-paying, rewarding jobs (Yashchin, 2014).

Apparently recent college graduates are having difficulty finding jobs to match their skill sets. According to Yashchin (2014), Failure to equip rising generations with the knowledge and skills required for available jobs could lead to further disintegration of our nation's economy as well as increased unemployment. However, one solution has been put forward: combine the hands-on approach of a vocational program with the convenience and cost-effectiveness of an online education to gear modern learning towards addressing the skills gap (2014).

In the words of the Chegg study,

We live in an era of massive cultural change, and the institution of higher education has not escaped these forces. The popular imagination has been captured by technology moguls who pride themselves on having dropped out of college. The ease of access to information and, some say, education via the Internet is causing students and academic institutions alike to experiment with every element of the college experi-

ence. The President himself has signaled a future in which a school's eligibility for federal funding will be tied to the data documenting its students' post-collegiate successes – and struggles – in the workplace. Among student populations, there is a grave concern about paying for college and being unable to find work after graduation. Something at the intersection of higher education and workforce preparedness is misaligned. (Chegg, 2013)

FUTURE FUNDING FOR PUBLIC HIGHER EDUCATION

With an undetermined future for state funding, higher education administrators are working in the unknown territory of a skill set, collaboration with business, which could come to be commonly used in industry.

Mortenson (2012 states that,

The longer-term issues of higher education funding are being addressed in some states and at some public institutions. If these public institutions are no longer state supported who owns them? Who should govern them? Who should they serve? Should states be contracting for quite specified outcomes? The defunding of public higher education by the states inevitably inaugurates a new conversation about who controls them and whose interests are to be served. The states will play a diminished role in finding answers to these questions if public higher education is to survive and thrive. (p. 29)

Current Funding for Public Higher Education

Two-year higher education institutions face the same challenges as traditional four-year institutions, dwindling government support. The federal government's stimulus money temporarily delayed the inevitable end, or great decrease, in government funding for higher education.

In June 2012 the Center for American Progress released an article by Stephen Steigleder and Louis Soares entitled, Let's Get Serious About Our Nation's Human Capital-A Plan to Reform the U.S. Workforce Training System. In the article the writers proposed a plan to overhaul and reform the workforce training and counseling system. Steigleder and Soares (2012) emphasized, "Programs would be implemented with private-sector partners and linked to projected job openings in high-growth regional industries. Participants would earn associate degrees, technical certificates, and industry-recognized credentials" (p. 5). This may suggest there is a paradigm shift from higher education for general purposes, or liberal arts education, at least in part, to education for specific jobs and career occupations.

Desirable Outcomes for Four-Year Higher Education

Four-year institutions of higher education and industry employers may favor a two-pronged approach to a college education, according to a December 28, 2006 study by Peter D. Hart Research Associates, Inc. entitled, How Should Colleges Prepare Students to Succeed in Today's Global Economy? Hart (2006). Hart prepared the study for The Association of American Colleges and Universities, which includes community colleges. Hart's study concluded that a majority of employers and a majority of recent college graduates reject a higher education approach that focuses narrowly on providing knowledge and skills in a specific field; the Hart study indicates that majorities of employers and recent college graduates believe that an undergraduate college education should provide a balance of a well-rounded education and knowledge and skills in a specific field (p. 4).

The Hart study article further explains,

A key area of concern for both employers and recent college graduates is the degree to which college students are given the opportunity to put learning outcomes into practice. They believe that higher education should give students more experience with real-world applications of their knowledge and skills through hands-on learning. (p.3)

Key Findings of Peter D. Hart Research Associates, Inc.

Fifty-six percent of business executives think that our nation's colleges and universities should focus on providing all students a balance of both a well-rounded education with broad knowledge and skills that apply to a variety of fields and knowledge and skills in a specific field and 11 percent favor a focus primarily on providing a well-rounded education. Just 22 percent of employers endorse a narrow focus on providing skills and knowledge in a specific field (Peter D. Hart Research Associates, 2006). Upon hearing a description of liberal education, large majorities of employers and recent graduates endorse it as important for colleges and universities to provide this type of education. In identifying collegiate level skills needed by manufacturers versus what is actually being taught to college graduates, one wonders what the state of manufacturing is.

State of U. S. Manufacturing Compared to other Countries' Manufacturing

Greg Galdabini is Senior Director of Editorial Communications, U.S. Chamber of Commerce and Editor-in-Chief of FreeEnterprise.com and Free Enterprise magazine. In a February 12, 2013 FreeEnterprise.com article Galdabini (2013) states, "During the recent recession, many observers wrote American manufacturing's obituary, claiming that it could no longer be a world leader because of intense competition from low-cost competitors" (p. 1). According to Galdabini (2013), The U.S. manufacturing sector generates $1.7 trillion in value each year–equivalent to nearly 12% of GDP. It supports over 17 million U.S. jobs. About 12 million Americans–or 9% of the workforce–are directly employed in the manufacturing industry (p. 1).

In comparing U.S. manufacturing to some other nations, based upon a study of U.S. Manufacturing by Dr. Mark J. Perry, Professor of Economics at the Flint campus of The University of Michigan, Dr. Perry (Perry, 2013) emphasized the following three points in American manufacturing (p. 1):

1. The combined sales revenue (including global sales) of only the top 500 US-based manufacturing firms in 2012 was $6.01 trillion, which was a 17.2% increase over 2011 sales of $5.13 trillion. To put those sales in perspective, if those 500 US manufacturers were considered as a separate country, their revenue last year of $6.01 trillion would have ranked as the world's third's largest economy behind No. 1 US and No. 2 China, and slightly ahead of No. 4 Japan's entire GDP of $5.98 trillion in 2012.
2. The sales revenue from the top ten US manufacturing industries totaled $4.83 trillion in 2012 (see figure 4.), which was 44% more than Germany's entire GDP of $3.36 trillion last year.
3. Annual sales of $1.62 billion in 2012 for America's single largest manufacturing industry – petroleum and coal products – was larger than the GDP of Australia last year of $1.54 trillion, and almost as much as Canada's $1.77 trillion in GDP in 2012.

United States Chamber of Commerce Chief Operating Officer David Chavern addressing the Greater Elkhart (IN) Chamber of Commerce, stated:

With the thriving manufacturing sector driving growth in our economy and sharpening our competitive edge, there's no reason America can't reemerge as an undisputed global economic leader…. We don't need to fear competition. In fact, the international arena represents much *more of an economic opportunity than a threat. We can and should win in the world…. He warned, though, that government needs to enact policies to support manufacturing.*

In that address Chavern shared some interesting figures:

- Manufacturers in the U.S. generate $1.7 trillion in value each year, 12 percent of the country's gross domestic product.
- Manufacturing provides 17 million U.S. jobs, 12 million of them in engineering and production. Those jobs are well above average income levels.
- For every 100 direct jobs in manufacturing, they support another 58 non-manufacturing jobs.
- Manufacturing drives more innovation than any other sector of the U.S. economy, responsible for two-thirds of all research and development in the country.
- The U.S. share of global manufacturing output hasn't changed over the last 40 years. "We make a lot in America," he said.
- The U.S. remains the world's largest manufacturer, accounting for 21 percent of world manufacturing value added in 2010. That's more than China, Russia, Brazil and India combined.

According to Chavern (2013):

Manufacturing jobs have dropped – a lot. U.S. manufacturing jobs peaked at 19.5 million in 1979. But by 2010, the number of Americans directly employed in manufacturing fell to a new low of 11.4 million. Where did those jobs go? Mostly to a country called "productivity." Technological change, automation, and widespread use of information technologies have enabled firms to boost output even as some have cut payrolls. These advancements are also allowing us to make high-value-added products that drive growth, innovation, and competitiveness (p.1). However, the need to educate/train the workforce to better align with the skills required remains a daunting task.

SOLUTIONS AND RECOMMENDATIONS

A recent employer survey by Hart Research Associates for The Association of American Colleges and Universities shows that 95 percent of responding employers said that "they give hiring preference to college graduates with skills that will enable them to contribute to innovation in the workplace… "and 92 percent agree that "innovation is essential" to their organization's continued success ("Employer Survey," 2014). As universities struggle to remain competitive and produce well-prepared graduates for the workforce, Lean Six Sigma coursework would seem to be a necessary standard.

Another recent survey by the National Association of Colleges and Employers (NACE) indicates that employers place the highest importance on skills such as "ability to make decisions and solve problems," "ability to communicate," and "ability to obtain and process information." High values were also given to the "ability to plan, organize, and prioritize work," and "ability to analyze quantitative data" ("The Skills and Qualities Employers Value Most in Their New Hires," 2014). Each of these skills from the top of the survey results would be developed or enhanced with a structured exploration of Lean Six Sigma concepts in a University setting.

The Value of Disruptive Innovation

Lean Six Sigma principles, practices and implementation may involve disruptive innovation sometimes referred to as disruptive technology. Disruptive innovation is a term of art coined by Harvard Professor Clayton Christensen (Christensen, 2014). The term describes a process by which a product or service takes root initially in simple applications at the bottom of a market and then relentlessly moves up market, eventually displacing established competitors (2014). The personal computer (PC) and the cellular phone are two examples of disruptive innovations. In today's global economy, disruptive innovation may well be the catalyst that determines whether a manufacturing or service organization even exists. Waiting, by business and government leaders, until disruptive technologies exert their full influence on the economy will be too late to capture the benefits or react to the consequences (Manyika et al., 2013).

Innovators must learn to connect the dots of significant events and times in their lives. Lean Six Sigma is about looking at what's happening now, analyzing root causes, and devising a solution based upon what you have observed during the previous phases. It's about looking back over the events of your life and making some sense of things that you observed. Steve Jobs, Jobs (2005), one of the greatest innovators of all times, said it this way:

Again, you can't connect the dots looking forward; you can only connect them looking backwards. So you have to trust that the dots will somehow connect in your future. You have to trust in something – your *gut, destiny, life, karma, whatever. This approach has never let me down, and it has made all the difference in my life. Of course Steve Jobs, who dropped out of Reed College in Portland, Oregon after 6 months and hung around the college another 18 months picking up odd classes (2005). One of those odd classes was a calligraphy class which he would later use, by connecting the dots, to design the font for the famous McIntosh personal computer. (2005)*

The sports drink Gatorade is an example of how a university can innovate by connecting the dots. Then University of Florida (UF) assistant football coach Dwayne Douglas questioned (UF) kidney disease specialist Robert Cade about why players lost so much weight during practices and games but urinated so little, Hayes and Phillips-Hahn (2003). According to Hayes and Phillips (2003) Douglas, who had a stellar career with the Gators and then the NFL's Philadelphia Eagles until he injured his knee, told Cade he had lost as much as 18 pounds during a game, but never felt the need to visit the restroom. Dr. Dade would later state that that question changed his life, Block (2007). Dr. Cade and his colleagues went on to invent a concoction to ward off heat-related distress and fatigue for the UF football team. The UF football Gators went on to achieve national acclaim and recognition. The rights to the Gatorade formula was sold to private industry and earned billions of dollars for the UF all because someone cared enough to connect the dots. Students at other universities, with proper training, can learn to innovate and invent solutions analysis for manufacturing production problems and advancements by connecting dots identified by methods such as root cause.

Elon Musk will most likely go down in history as one of the greatest disruptive innovators of all time. His genius is not so much true invention as it is taking an existing invention, seeing it as being successful in a certain business environment and supplying the infrastructure needed to make the product successful. Hence the Tesla electric automobile and the Supercharger network of charging stations. According to James Chen, Tesla's Vice President of Regulatory Affairs, Chen (2014) electric vehicles and Superchargers are about alleviating the world's addiction to oil. Tesla plans to have a network built by the end of 2015 that will cover 98 percent of the U.S. population, and that will ultimately mean that Tesla drivers will never be more than 100 miles from a Supercharger (Chen, 2014). Musk started his empire as co-founder of PayPal (CrunchBase, 2014). PayPal was acquired by eBay in 2002 for 1.5 billon dollars of which Musk received approximately 165 million dollars for his 11.7% share of PayPal (2014). He used that money to start other businesses. When a manufacturing workforce is open to the positive potential of disruptive innovation, with a focus on quality and efficiency, Lean Six Sigma becomes easier to implement.

How to Implement Lean Six Sigma in a Manufacturing Production Company

Lean Six Sigma enables an organization to not only recognize areas for improvement, it also enables an organization to develop innovative solutions. According to Lokesh (2010) organizations must have a compelling reason to implement Lean Six Sigma. If a company is falling behind its competitors and losing market share, no matter the product or service, there is a need to improve. If a company's quality is slipping and there are repeated recalls or rework, there is a need to improve. If a company's stakeholders are demanding better performance metrics, there is a need to improve. Lokesh suggests that organizations create a burning platform mentality. Without a burning platform, there is seldom a motivation to implement a continuous improvement initiative. Company leadership should become familiar with the burning platform, and understand how Lean Six Sigma can address the problems in the platform statement (Lokesh, 2010).

Companies that have experienced the benefits of the implementation of Lean Six Sigma recognize that a high level of commitment is crucial to the success of the program. Lean Six Sigma provides the toolbox for improving quality and profitability. Unfortunately these tools come with a high rate of failure instead of a lifetime guarantee. To use these tools effectively requires commitment. Some would suggest that success requires "a religious type conversion that results in a personal commitment to a new way of thinking" (Carreira & Trudell, 2006). These process improvement initiatives are often treated as projects where people are trained, short-term accomplishments are celebrated, and then old habits begin to regain control (Voehl, 2014). Thorough training for employees in every area of the business is a necessity to create a culture of continuous improvement.

Once leadership commits to the concept, the training must begin throughout the company. This may take two to three years and corporate level results may take five or more years to show (Taghizadegan, 2006). In the following paragraphs are examples of how some companies implemented Lean Six Sigma.

Jack Welch began his Six Sigma journey with General Electric in 1995 with 200 projects and a focus on intensive training programs. He then implemented 9,000 more projects in 1996 and 1997 while still making a large investment towards training each year. This required a great belief in the quality initiative and an impressive financial commitment to the training process (Byrne, 1998).

Lockheed Martin has shown total commitment through the quality program they call Lockheed Martin in the 21st Century (LM21). In their continual pursuit of "Operating Excellence," they have not only invested heavily in the training of employees on every level and in every department, but they are also concerned with the training of suppliers (Schechter, 2004).

Xerox Corporation began to adopt Lean Six Sigma practices in 2003. In 2011 the company reported to have more than 70 percent of Senior Executives Green Belt trained as well as 1,300 Black Belts trained or certified, 9,000 Green Belts trained or certified, and 45,000 Yellow Belts (Corporation, 2011).

It is evident by the large scale of financial commitment, and manpower dedication that companies are placing a great value on the training in the pursuit of improved quality and processes. W. Edwards Deming said "Lack of knowledge... that is the problem." In his 14 Points on Quality Management, the number thirteen point on the list was to "Institute a vigorous program of education and self-improvement for everyone" and he urged that it was necessary to allocate resources in research and education (Deming, 2000). In the book TPS – Lean Six Sigma: Linking Human Capital to Lean Six Sigma: A New Blueprint for Creating High Performance Companies, the authors suggest that the human element is the most important aspect of continued success with Lean Six Sigma. Lean Six Sigma provides the tools, but it is the "Lean Thinking" that is necessary to continue to use the tools and use them appropriately for any length of time. The continued success of the program depends upon "Lean Thinking" to the point of a cultural transformation where every person in the organization is consciously aware of the potential for waste and improvement as they go about their daily jobs (Rampersad, 2007).

With so many large companies such as General Electric, Lockheed Martin and Xerox, proving their dedication to Lean Six Sigma, it stands to reason that jobseekers with a working knowledge of the principles would show favorably in an increasingly competitive market (see Table 1).

Table 1. Results of eight companies that implemented Lean Six Sigma

Company	Goal	Impact of Six Sigma
Allied Signal (now Honeywell)	Maximize growth and productivity by reducing defects and waste	In 5 years of using Six Sigma - Realized results in $600 million annual savings (Green, 2000).
Caterpillar Inc.	Increase revenue growth	By 2005, after 4 years - Increased revenues by 80 percent (Blitz, 2008).
Dr. Pepper Snapple Group	Increase competitiveness through process improvement	April 2010 through July 2012, Dr. Pepper realized a $104 million financial impact and 13% reduction in customer complaints from their Lean Six Sigma project implementation ("Success Stories- Dr. Pepper Snapple Group," 2014).
DuPont	Increase competitiveness through process improvement	In 4 years of using Six Sigma - Realized more than $1.6 billion in cost savings as well as a reduction in environmental impact and an increased safety record (Brue, 2006).
Ford Motor Company	Focus on quality to lower costs and increase market share	2000 - Six Sigma credited with a $52 million increase to the bottom line. 2001 - Estimated $300 million contribution from closed projects and a two-point increase in customer satisfaction (Paton, September 1, 2001).
General Electric	Increase competitiveness through process improvement	Using Six Sigma, increased bottom line by more than $2 billion in 1999 and $2.4 billion in 2000 (Brue, 2006).
Lockheed Martin	Increase efficiency and improve financial and operating performance	By 2007 – 1,154 Lean Six Sigma events yielding over $95 million in savings (Digest, 2008).
Motorola	Increase competitiveness through process improvement	Increased net income from $2.3 billion in 1978 to $8.3 billion in 1988 through the implementation of Six Sigma (Taghizadegan, 2006).

Seven Steps of Implementation

The following is a summary of 7 steps of Lean Six Sigma implementation:

1. Recognize a Need

Management must first acknowledge that there is a need to improve. Then, if management determines that Lean Six Sigma is the appropriate tool to facilitate the improvements, the process of continuous improvement begins.

2. Select, Train, and Develop Implementation Leaders

Next, select the right people to train and lead the initiatives. According to Lakesh (2010) it is important that whoever is selected must be able to work together as a team, and be empowered to carry out initiatives.

3. Teach the Methodology and Develop a Culture

It would be unthinkable to expect a workforce to learn Lean Six Sigma, know how to implement it, and measure the results without significant and continuous education.

4. Develop an Activity List

Develop a workforce culture of listening to the customer and using customer feedback in alignment with company goals to determine the order of activities.

5. Give Team Ownership

Genuine ownership includes employee trust and empowerment.

6. Quantify Results

If an improvement has been made then the results should be quantifiable within a reasonable amount of time.

7. Recognize Contributions and Share the Rewards

When goals are met or exceeded, pause to give recognition and celebrate. Then share the profits with those who helped generate them.

Time and Cost to Train and Implement Lean Six Sigma

As for the time to implement Lean Six Sigma into your organization, aggressive implementation will take 12 to 18 months minimum (Silverstein, 2010). To truly get your organization to the point where we're seeing a real change in the culture toward one that has a greater appreciation of quality, approaches problems in a more structured manner, and is more data driven in its approach to decision making, expect that to take 18 months for a small company or business unit and 3-5 years for a large organization (2010).

The financial cost to train personnel and implement Lean Six Sigma in a manufacturing production company depends on the size and goals of the organization.

Joe De Feo, President and Executive Coach at Juran Institute, offers his views on deploying Six Sigma in large and small companies alike,

All companies can save money by reducing the causes of defects in products, deficiencies in services and processes, and by improving sales through greater customer satisfaction. However, a small company (less than 100 employees) will have fewer resources available than a larger company (1,000 employees) to complete projects. The magnitude of improvement will be different between large and small companies. (De Feo, 2010)

Lean Six Sigma in Small Business

In making the more difficult case for employing Six Sigma in small business Thomas Pyzdek (2010) found that many Six Sigma experts have expressed doubt that Six Sigma can be used effectively in small, or even in some medium-sized, organizations. However, while the approach to deployment must be modified, it is possible for small businesses to successfully implement Six Sigma. Here is how.

At the outset, several givens must be in place:

- The owner of the business supports Six Sigma completely and actively, and is willing to personally spend time on it.
- The company has a routine core of work that will benefit from the process rigor of Six Sigma.
- The organization's culture is open to change.

CONCLUSION

By increasing productivity, Lean Six Sigma can play a pivotal role in reversing loss of U.S manufacturing jobs. Strengthening industry, academia and government partnerships in manufacturing, the backbone of most developed nations, means industry personnel in the classroom and academic students in the industrial workplace with some federal, state and local government inclusion.

As for fostering relationships between industry, academia and government, the Chegg study sheds a lot of light on the disconnect between college graduates' perception of workforce readiness and skills that prospective employers are looking for. For example, the Chegg study says,

Our studies revealed a gap between the skills hiring managers reported needing in recent graduates and the needed skills students perceive themselves as having mastered…. Students put more importance on the name of the institution listed on their diploma, versus an employer's view of the importance of school prestige. A full 45% of students, from schools across the nation, believe a degree from a prestigious school is very or extremely important to make them more attractive to employers. By contrast, only 28% of hiring managers found this important. This 17-point gap creates a false sense of disadvantage in students from less-prestigious schools and misleads prestigious schools' students about how far school status alone will take them. (Chegg, 2013)

Other misconceptions about graduate readiness versus employee needs as revealed by the Chegg (2013) study were:

Students have an even more inflated sense of the traction personal connections will give them. More than three-quarters of surveyed college students, 77%, believed professional or personal connections in their *field of interest was important for securing a job. Thankfully, employment opportunities aren't based exclusively on "who you know" – only 52% of hiring managers agreed that those connections are very or extremely important for a graduate to land a job in their field of study. Maybe the threat of schoolyard antics making their way onto students' "permanent records" created the false impression that one's performance in school would really matter to employers in the long-term. But when it comes to grade point averages, employers are much more forgiving than students expect. Sixty-eight percent of students think a high GPA is very or extremely important for landing a job. 48% of hiring managers think it is very or extremely important. (Chegg, 2013)*

The following attributes are the ones that hiring companies are looking for in work-ready college graduates:

- There are a number of collegiate experiences that hiring managers deemed at least somewhat important in their hiring decisions about recent graduates:
- 93% of hiring managers want to see that the graduates they hire have demonstrated the initiative to lead.
- 91% of hiring managers hope to see that applicants they hire have participated in extracurricular activities related to their field of study.
- 82% think the recent graduates they hire should have completed a formal internship before graduating from college (Chegg, 2013).

According to Chegg (2013):

The President or the United States himself has signaled a future in which a school's eligibility for federal funding will be tied to the data documenting its students' post-collegiate successes – and struggles – in the workplace. Among student populations, there is a grave concern about paying for college and being unable to find work after graduation.

Certainly collaboration between industry, academia and government could create employment matches like the ones mentioned above. Skills like Lean Six Sigma could benefit all parties concerned and provide manufacturing production company CEO's a strategy to compete globally.

REFERENCES

Antony, J. (2008). What is the role of academic institutions for the future development of Six Sigma? *International Journal of Productivity and Performance Management, 57*(1). Retrieved from http://www.emeraldinsight.com/journals.htm?articleid=1641825

Block, M. (2007). *National Public Radio: Gatorade Inventor Robert Cade Dies*. Retrieved from http://www.npr.org/templates/story/story.php?storyId=16665667

BLS Handbook of Methods. (2014). *Productivity Measures: Business Sector and Major Subsectors*. Bureau of Labor Statistics.

Brue, G., & Howes, R. (2006). *Six Sigma -The McGraw-Hill 36-hour course*. New York: McGraw-Hill.

Byrne, G., Lubowe, D., & Blitz, A. (2007). *Driving operational innovation using Lean Six Sigma*. IBM Global Business Services. Retrieved from http://www-935.ibm.com/services/us/gbs/bus/pdf/g510-6331-01-leansixsigma.pdf

Byrne, J. (1998, June). How Jack Welch Runs GE. *BUSINESSWEEK*. Retrieved from: http://www.businessweek.com/1998/23/b3581001.htm

Carreira, B., & Trudell, B. (2006). *Lean Six Sigma That Works: A Powerful Action Plan for Dramatically Improving Quality, Increasing Speed, and Reducing Waste*. New York: American Management Association. EBSCOhost (accessed May 6, 2014).

Chavern, D. (2013). *Greater Elkhart (IN) Chamber of Commerce: Manufacturing: Driving Growth at Home and Competition Abroad*. Retrieved from https://www.uschamber.com/speech/%E2%80%9Cmanufacturing-driving-growth-home-and-competition-abroad%E2%80%9D-remarks-david-chavern-chief

Chegg. (2013). *Bridge That Gap: Analyzing the Student Skill Index*. Retrieved from http://www.insidehighered.com/sites/default/server_files/files/Bridge%20That%20Gap-v8.pdf

Christensen, C. (2014). *Disruptive Innovation*. Retrieved from http://www.claytonchristensen.com/key-concepts/

Crate, S. (2006). *i Six Sigma: Historical Perspective of Lean*. Retrieved from http://www.isixsigma.com/new-to-six-sigma/history/historical-perspective-lean/

CrunchBase. (2014). *Elon Musk: Person Overview*. Retrieved from http://www.crunchbase.com/person/elon-musk

De Feo, J. (2010). *i Six Sigma: Ask the Expert: The Topic – Large and Small Deployments*. Retrieved from http://www.isixsigma.com/implementation/deployment-structure/ask-expert-large-small-deployments/

Deming, W. E. (2000). *Out of the Crisis*. Cambridge, MA: MIT Press.

Dr. Pepper Success Stories. (2014). *TexasLeanSixSigma*. Retrieved from http://www.texasleansixsigma.com/success-stories/dr_pepper

Economic Snapshot. (2000). *The link between productivity growth and living standards*. Retrieved from http://www.epi.org/publication/webfeatures_snapshots_archive_03222000/

Galdabini, G. (2013, February 12). *Re: FreeEnterprise.com, U.S. Manufacturing: The World's Third Largest Economy*. Retrieved from http://www.freeenterprise.com/economy-taxes/us-manufacturing-worlds-third-largest-economy

Green, R. (2000). *Reshaping Six Sigma at Honeywell - Dedicated teams successfully merge two divergent quality systems.* Quality Digest. Retrieved from: http://www.qualitydigest.com/dec00/html/honeywell.html

Harry, M., Mann, P., Hodgins, O., Hulbert, R., & Lacke, C. (2010). *Practioner's Guide to Statistics and Lean Six Sigma for Process Improvements*. Hoboken, NJ: John Wiley & Sons.

Hayes, J., & Phillips-Hahn, A. (2003). Explore: Research at the University of Miami. In *Gatorade: The Idea that Launched an Industry*. Retrieved from http://research.ufl.edu/publications/explore/v08n1/gatorade.html

Industrial Revolution. (2014). In *Encyclopaedia Britannica*. Retrieved from http://www.britannica.com/EBchecked/topic/287086/Industrial-Revolution

Jobs, S. (2005). *You've got to find what you love, Jobs says*. Retrieved from http://news.stanford.edu/news/2005/june15/jobs-061505.html

Joyce, M., & Schechter, B. (2004). *The Lean Enterprise-A Management Philosophy at Lockheed Martin.* Retrieved from: http://handle.dtic.mil/100.2/ADA435279

Lean Six Sigma Maturity at Lockheed Martin. (2007, November 6). *Quality Digest*. Retrieved from http://www.qualitydigest.com/inside/six-sigma-news/lean-six-sigma-maturity-lockheed-martin

Lokesh, R. (2010). *Eight Steps to a Successful Lean Six Sigma Implementation*. Retrieved from http://www.isixsigma.com/implementation/success-factors/8-steps-successful-lean-six-sigma-implementation/

Lubowe, D., & Blitz, A. (2008, September). Driving Operational Innovation Using Lean Six Sigma. *Business Finance - Best Practices for Finance Executives*. Retrieved from http://businessfinancemag.com/business-performance-management/driving-operational-innovation-using-lean-six-sigma

Manyika, J., Chui, M., Bughin, J., Dobbs, R., Blisson, P., & Marrs, A. (2013). *Disruptive technologies: Advances that will transform life, business and the global economy*. McKinsey & Company: Insights and Publications. Retrieved from http://www.mckinsey.com/insights/business_technology/disruptive_technologies

Martinez, P. (2009). *Campus Using Six Sigma to Improve Business Operations*. The University of Arizona UA News. Retrieved from http://uanews.org/story/campus-using-six-sigma-improve-business-operations

Mortenson, T. G. (2012). *State Funding: A Race to the Bottom and Presidency*. Retrieved from: http://0 ehis.ebscohost.com.sheba.ncat.edu/ehost/pdfviewer/pdfviewer?sid=655cfa93-26d5-4d43-b684-82d0af468cd0%40sessionmgr104&vid=4&hid=102

Obama, B. (2014). Think and Do. *NC State University Manufacturing Innovation*. Retrieved from http://www.ncsu.edu/power/

Paton, S. (2000, September 1). No Small Change: Making Quality Job 1 Again. *Quality Digest*. Retrieved from http://www.qualitydigest.com/sept01/html/ford.html

Perry, M. (2012). *Manufacturing's Declining Share of GDP is a Global Phenomenon, and It's Something to Celebrate*. U. S. Chamber of Commerce Foundation. Retrieved from http://www.uschamberfoundation.org/blog/2012/03/manufacturing%E2%80%99s-declining-share-gdp

Perry, M. J. (2013, February 9). *Re: If top 500 US manufacturing firms were a separate country, they would have been the third largest economy last year* [Web log comment]. Retrieved from http://www.aei-ideas.org/2013/02/if-top-500-us-manufacturing-firms-were-a-separate-country-they-would-have-been-the-third-largest-country-last-year/

Peter D. Hart Research Associates, Inc. (2006). *How Should Colleges Prepare Students to Succeed in Today's Global Economy?* Retrieved from http://www.americanprogress.org/wp-content/uploads/issues/2012/06/pdf/workforce_training.pdf

Pyzdek, T. (2010). *A Roadmap for Deploying Six Sigma in Small Businesses*. Retrieved from http://www.isixsigma.com/implementation/basics/roadmap-deploying-six-sigma-small-businesses/

Rampersad, H., & Anwar, E. (2007). *TPS-Lean Six Sigma linking human capital to Lean Six Sigma: a new blueprint for creating high performance companies*. Retrieved from: http://www.books24x7.com/marc.asp?bookid=27102

SA8000. (1997). *SA 8000 Standard: 2008*. Retrieved from http://www.sa-intl.org/index.cfm?fuseaction=Page.ViewPage&PageID=937

Shorr, B. A., & Wong, A. (2013). Two Faces of Economic Development: The Ethical Controversy Surrounding U.S.-Related Sweatshops in Developing Asian Countries. In Ethical Challenges in Trans-Pacific Relations: Selected Essays. Academic Press.

Silverstein, D. (2010). *The Topic – Deploying and Implementing Six Sigma*. Retrieved from http://www.isixsigma.com/implementation/deployment-structure/ask-expert-deploying-implementing-six-sigma/

Social Accountability International. (1997). *SA8000 Standard: 2008*. Retrieved from http://www.sa-intl.org/index.cfm?&viewpage&pageid=473

Stephen, S., & Soares, L. (2012). *Let's Get Serious About Our Nation's Human Capital-A Plan to Reform the U.S. Workforce Training System*. Retrieved from http://www.americanprogress.org/wp-content/uploads/issues/2012/06/pdf/workforce_training.pdf

Strupe, M. (2009). *Lean vs Six Sigma: What's the Difference*? The Ultimus BPM Blog. Retrieved from http://www.ultimus.com/Blog/bid/33875/Lean-vs-Six-Sigma-What-s-the-Difference

Taghizadegan, S. (2006). *Essentials of lean six sigma* (Science Direct Reader version). Retrieved from: http://www.sciencedirect.com/science/article/pii/B9780123705020500047

The Association of American Colleges And Universities. (2014). *It Takes More than a Major: Employer Priorities for College Learning and Student Success.* Retrieved from http://www.aacu.org/leap/documents/2013_EmployerSurvey.pdf

The Economist. (2012). *Manufacturing: The Third Industrial Revolution*. Retrieved from http://www.economist.com/node/21553017

The Economist. (2013). *When giants slow down: Emerging economies*. Retrieved from http://www.economist.com/news/briefing/21582257-most-dramatic-and-disruptive-period-emerging-market-growth-world-has-ever-seen#sthash.03wd8L5K.dpbs

The Skills and Qualities Employers Value Most in Their New Hires. (2014). Retrieved from http://www.naceweb.org/press-releases.aspx

The Tesla Motors Team. (2014, April 24). *Re: 100 Supercharger Stations* [Web log comment]. Retrieved from http://www.teslamotors.com/blog/100-supercharger-stations

U.S. Department of Defense, Department of the Army. (2014). *2014 Annual Report on Business Transformation - Providing Readiness at Best Value* (Ref ID: 6-2837C37). Retrieved from http://www.army.mil/article/118302/2014_Army_Business_Transformation_Report__Providing_readiness_at_best_value/

Voehl, F. (2014). *The lean six sigma black belt handbook tools and methods for process acceleration.* Retrieved from http://site.ebrary.com/lib/nyulibrary/Doc?id=10722362

Xerox Corp. (2011). *Lean Six Sigma - Delivering measureable results our customers value.* Retrieved from http://www.xerox.com/assets/pdf/2012_GRC_LeanSixSigma_Brochure.pdf

Yashchin, A. (2014). *The Blog: Redefining Education to Close the Workforce Skills Gap*. Retrieved from http://www.huffingtonpost.com/avi-yashchin/redefining-education-to-c_b_4676818.html

ADDITIONAL READING

Misrahi, T. (2012). *World Economic Forum* [Blog]; The future of the manufacturing industry. Retrieved from http://forumblog.org/2012/02/manufacturing-for-growth/Practioner'sGuidetoStatisticsandLeanSixSigmaforProcessImprovements

Thornton, P., & Ross, L. (2010). *Chartered Institute of Management Accountants*: The global manufacturing sector: current issues: Retrieved from http://www.cimaglobal.com/Documents/Thought_leadership_docs/Global_manufacturing_report.pdf

KEY TERMS AND DEFINITIONS

Abatement: The reducing or ending of something.

Ethics: A set of guiding principles that govern humans' right and wrong actions.

Global: Anywhere in the world versus "international" meaning with only certain nations.

Innovation: A new process, method or invention.

Productivity: Labor measurement where output (measured in units of whatever is produced) is divided by input, measured in man hours required to make the product.

Quality: The feeling that one gets when performance exceeds expectation.

Standard of Living: Economic conditions; financial ability to purchase goods and services in a certain geographical area.

Chapter 8
Data Fusion Aiding Tool (DAFAT) Design for Emergency Command and Control Using Lean Principles

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ABSTRACT

Disaster events, such as September 11, 2001, Hurricane Katrina, and the Southeast Asian Tsunami, have taught America and the world the importance of preparing for emergency response to a disaster that may arise from natural disasters or man-made disasters. Decisions regarding emergency response often rely on incomplete information and imprecise data, whereas responsive measures to disasters must be efficient in time and effective in accuracy to minimize possible loss of lives and properties. The domain of emergency response requires the interaction and collaboration of multiple stakeholders with different standard operating procedures. Excluding lean principles in the design of the emergency management information system can be as devastating as the disaster itself. This chapter analyzes the impacts of lean principles in the understanding of command and control, its nature, and the characteristics of an emergency domain, providing better insight into the problems associated with information processing during emergency response planning.

DOI: 10.4018/978-1-4666-7320-5.ch008

INTRODUCTION

As a result of the events of September 11, 2001, America realized it is imperative to prepare for emergency responses that may result from natural disasters such as hurricanes or man-made disasters such as acts of terrorism. A disaster is defined as an emergency event that overwhelms local resources and requires assistance from neighboring cities, counties, states and/or the federal government. These organizations have standard policies and shared command and control (C2) structures to deal with these incidents. C2 provides the basic leadership and management structure to deal with disasters at the strategic, operational and tactical levels (Ntuen, Balogun, Boyle, & Turner, 2006). For example, at the strategic level, the Federal Emergency Management Administration (FEMA) in the United States is responsible for determining the severity of disasters and the policies to be implemented for each disastrous incident. At the operational level, the state and municipality agencies have their FEMA approved rules, which are responsible for providing the emergency response modalities and resource allocations. At the tactical level, the individual city where an incident occurs is involved in the delegation of emergency response personnel (first responders, paramedics, etc.) to the area of interest.

A disaster (condition or event that requires emergency response) in any form often occurs without any prediction. Associated with a disaster are various levels of information uncertainties. As a result of these uncertainties, decisions' regarding emergency response often relies on incomplete information and imprecise data; whereas responsive measures to disasters must be efficient in time and effective in accuracy, to minimize possible loss of lives and properties. In addition to information uncertainty, the domain of emergency response C2 requires interaction and collaboration of multiple stakeholders with different standard operating procedures (SOP). A failure in information management of these multifaceted stakeholders can be as equally devastating as the disaster itself. Moreover, lean principles in the conception and design of any system to minimize failures in information management of these multifaceted stakeholders can also be devastating. The numerous stories on the 2005 Hurricane Katrina that occurred in New Orleans, Louisiana, USA, provided some insight. Examples of disaster incidents and the flaws associated with their C2 information management are presented in the next section.

SAMPLE EMERGENCY SCENARIOS

Hurricane Katrina

Hurricane Katrina, a category 4 hurricane, surged the gulf state region on August 29, 2005. Thousands of people lost their lives and many properties were destroyed. According to Jefford (2005), over 90,000 square miles of the gulf coast area were declared as disaster areas; New Orleans, one of the cities affected, had 80% of its area covered by floods, which resulted from the broken levees. According to the congressional testimony of Security Secretary of the Department of Homeland Security Michael Chertoff,, Hurricane Katrina caused about 1.5 million people to evacuate the gulf coast area, destroyed about 250,000 homes, resulted in 1200 lives lost and caused an estimate of 600,000 people to require shelter (Chertoff, 2005). More notably, Hurricane Katrina posed many problems for the C2 decision makers, including:

- Lack of accurate, timely and reliable information about the condition of the incident;
- Lack of coordination between levels of government;
- Destruction of the communication infrastructure;
- Inadequate logistics planning;
- Overwhelming demand for local and state resources; and
- Lack of robust and flexible C2.

Hurricane Katrina was massive, and its effects were beyond the planning and resource capabilities of the local, state, and federal governments.

Southeast Asian Tsunami

The Southeast Asian Tsunami occurred on December 26, 2004. It spanned 13 countries, and as many as 300,000 lives were lost, many buildings and infrastructures were destroyed. Since the massive destruction of the tsunami was unprecedented, many countries responded to assist the affected Asian countries with humanitarian aid. The lack of early warning signals was attributed to the huge number of casualties of the tsunami. Cities and villages could not be accessed quickly because of the destruction of the transportation infrastructure. Nevertheless, emergency response was massive, but the affected countries' resources were overwhelmed by the magnitude of the tsunami's destruction. Some of the problems with the emergency response of the Asian Tsunami can be summarized as follows:

- Destruction of the transportation infrastructure;
- Lack of emergency response planning;
- Overwhelming of local resources;
- Unprepared and lack of leadership in managing the coalition of responders; and
- No formal C2 structure.

Earthquake in Pakistan

On October 8, 2005, a 7.6 Richter scale earthquake caused severe damages in the Muzaffarabad area of Pakistan. As many as 18,000 lives were reported lost and 44,000 people were injured. Response efforts were hampered as access roads were blocked due to landslides. The emergency response was also massive and the magnitude of the earthquake's destruction overwhelmed the country's resources. The response problems of the earthquake in Pakistan can be summarized as follows:

- Destruction of the transportation infrastructure;
- Lack of emergency response planning;
- Overwhelming of the resources; and
- No formal C2 structure

These examples demonstrate that C2 is vital to emergency incidents involving mass casualties and to the emergency response domain in general. Gaining an understanding of C2, its nature and the characteristics of an emergency domain, provide better insight to the challenges associated with information processing during an emergency response planning. In addition, the previously mentioned natural disasters exhibit the following problems with C2 in the emergency domains:

- Lack of accurate, timely and reliable information about the condition of incidents;
- Lack of coordination between levels of stakeholders (e.g., government and responding agencies);
- Management of complex information from interacting heterogeneous entities;
- Problems with scheduling resources;
- Management of problems - loss of lives and properties; and
- Poor communication due to lack of shared information.

Understanding Command and Control in Emergency Situations

Command and control (C2) defines the art and science of leadership and management. Leaders are the people who must give directives and set goals for a defined organizational mission. Similarly, managers who are tasked with coordinating resources are required to carry out the mission. While the leader reasons at the highest level of the task abstraction, the manager operates at the middle to atomic level of the system hierarchy, which is usually translated into actions. In essence, the manager is responsible for control activities, and they are controlled from above by the commander. At either level, some sort of performance is used to guide the operation of the system.

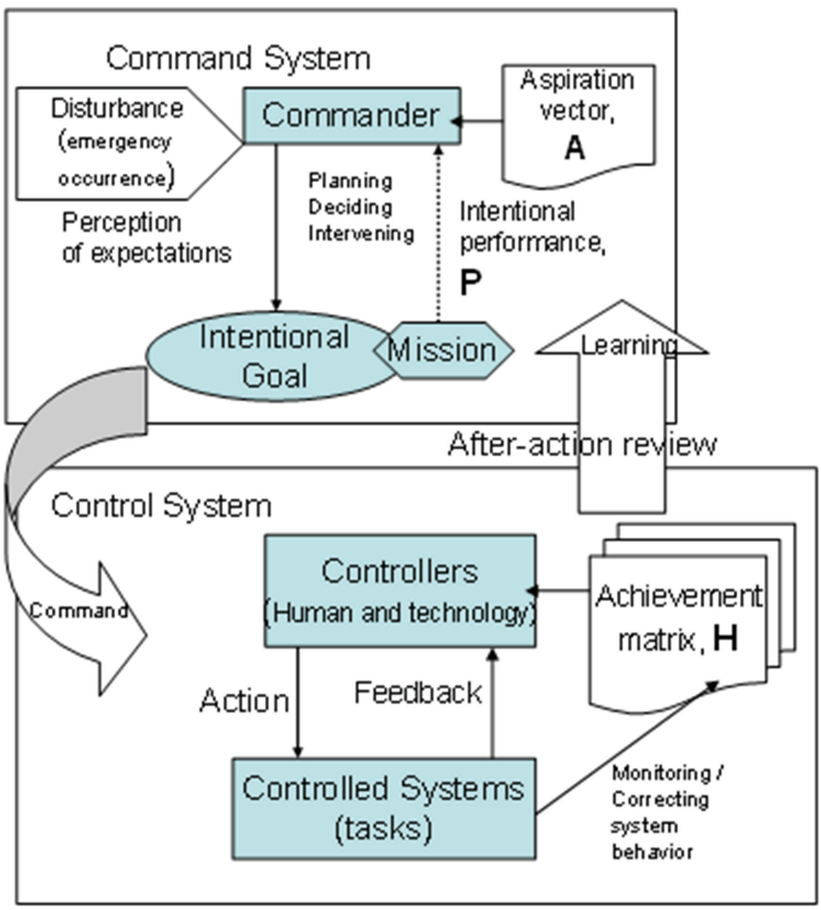
Bushman, Mitchell, Jones and Rubin (1993) noted in C2 systems, "Human operators are faced with monitoring and controlling large, complex systems that rely heavily on the use of automation" (p. 111). Considering the great difficulty associated with collecting and processing data or information from complicated emergency management tasks, computer-based decision models provide a means for information management at different levels of the organization. Several investigators have pursued decision-support development for emergency management. Wohl, Entin, Kleinman and Pattipati (1989) have developed modeling approaches to understanding human decision processes in the C2 domain. They reviewed mathematical models of team performance and provided qualitative frameworks for integrating the different modeling perspectives. Particularly relevant to the emergency C2 in this research are the notions of dynamic planning and execution of tasks using multivariate information from multiple human expert planners. Durkin (1994) addressed these issues from organizational control models using artificial intelligence. Durkin noted, control knowledge is a problem solving strategy, specifically suitable for the functional representation of a human operator's knowledge. At least five functional knowledge were identified: common sense knowledge used by experts; temporal knowledge that holds time and place of events; domain knowledge that specifies the situation and nature of emergency; explanatory knowledge for reasoning about causation and effect of incidents; and maintenance knowledge for capturing lessons learned. These knowledge components are often used in performance analysis of information flow in C2 systems (Biswas, Kapadia, & Yu, 1997; Raghunathan, 1997).

In the ERM C2 domain, planning, monitoring and learning are more important. These are what Smith and Downs (1975) referred to as trainability factors since they enhance the human cognitive and perceptual skills (Campbell, 1997). Figure 1 is used to illustrate the generic components of C2 tasks as developed by Ntuen et al. (2006). As shown in Figure 1, the commander is responsible for planning and setting goals through a goal aspiration defined by the vector A.

The control system is responsible for tracking behaviors of the system states and is denoted by matrix H; conditioned on such subtasks as monitoring and correcting errors. During training, sample tasks that are representative of the generic C2 functions are defined and represented by a computer decision-support system. The US Marine Corps Command and Control (1996) describes command as the mechanism that "recognizes what needs to be done" and control as assuring "that appropriate actions are taken" (p. 37).

Pigeau and McCann (2002) defined command as the human desire necessary to achieve the mission and control as the supporting structures provided by command to accomplish it and to deal with risk. In this definition, control

Figure 1. Sample generic C2 architecture



supports command and command must be able to develop innovative and/or novel solutions to achieve the mission. From these definitions, situation awareness, risk management, decision making, and sense making are essential to command. As cited in Albinsson (2004), Shattuck and Woods (2000) defined command and control in context of a distributed supervisory control system as a remote supervisor who uses their influence through communications to provide plans and procedures to local actors in order to adapt to their changing environments. From this definition, the remote supervisor, who may be a single commander or the group of commanders as in joint command and control structure, must exhibit some qualities. Pigeau and McCann (2002) referred to these qualities as dimensions of command. These dimensions are competency, authority, and responsibility (CAR).

EMERGENCY RESPONSE DOMAIN

Information Management in the Emergency Response Domain

Emergency Response Management (ERM) is a collaborative effort requiring the coordination of experts and specialists with a variety of skills in planning, logistics, and operations. ERM C2 staffs needs quick access to information in order to support collaborative work between the field responders. These needs have led to the development of emergency response decision tools. One of the requirements of such tools is to support information management with a particular focus on the integration of disparate information. In context of the task, the emergency response teams are required to process vast amounts of information in real-time.

Communication in emergency incidents is described as the "life blood" of the emergency response. The communication may be in several forms and among and between various members of the agencies participating in the emergency response situation. Agencies interact with each other producing various underling patterns, which may evolve into a global effect. Interaction in an emergency domain can be viewed as a collaborative effort of many federal, state, and local agencies. The importance of communication was exemplified by Perrow (2003) when he observed:

A substantial literature on disasters over the last 35 years has shown that for natural, industrial and most recently the deliberate disaster of September 11, planning and rehearsal by authorities at the local level *(fire, police and medical facilities) makes a large difference in the effectiveness of the response. Even 'table top' exercises, where people sit in a room and pretend to summon resources and intervene, disclose incompatible communication devices and argot, incompatible routines, and warring cultures. (p. 23)*

Emergency Domain as a Complex Adaptive System

Complex adaptive systems are systems that exhibit coherence under change through conditional actions and anticipations without a central direction (Holland, 1994). A complex adaptive system has four properties and three mechanisms. The four properties are aggregation, non-linearity, flows, and diversity. The three mechanisms are tagging, internal models, and building blocks. Aggregation is simply the clustering of agents, whereas agents are the core elements of CAS (Dooley, 1996). Agents interact randomly with each other and develop a pattern of behavior that influences the behaviors of other agents and the system as a whole. This emergent behavior is characterized by non-additivity as the sum of the parts of CAS does not equal the whole (Czerwinski, 2003). In the ERM domain several agents interact. Some examples include the police, firefighters, military, and civilian medical personnel. These agents interact with each other to produce a response pattern through information sharing, dialogs and negotiations, and conflict resolutions that allow the "best" operating policies to be translated into actionable knowledge. The complex interaction of the agents can lead to the emergence of non-linearity properties.

The third property, flows, represents the information and resources that go through the system. Multiplier effects and recycling effects are two properties of flows. These properties are hidden within the interactions of agents and are evidence that support the non-linearity of the CAS. In the emergency domain, many pieces of information come from many sources, some of which are credible and some are not. This information must be processed and used to improve situation awareness required to support decision making. Finally, diversity property represents the characteristics of the stakeholders from different agencies with different backgrounds. In the emergency domain, this is true because many responders come from different agencies with different operating procedures and cultures.

In summary, an emergency domain can be viewed as a collaborative enterprise where agents randomly interact with each other in a chaotic and unpredictable environment. As a result the unpredictive nature of information characteristics in the emergency domains, the agents responsible for planning, decision making, and execution should receive some form of analytical support. Such support tools should help to collect and manage information during an emergency response planning cycle.

Emergency Domain as an Uncertain Environment

An uncertain environment represents situations or events that occur with little or no predictable information. Two types of uncertainties can be used to describe situations that require emergency response tasks (Helton, 1997): aleatory and epistemic. Aleatory uncertainties can be characterized as due to randomness. They are inherent, irreducible, and unpredictable in nature. Epistemic uncertainties are subjective and arise from limited or imperfect knowledge. Epistemic uncertainty can be attributed to C2 decision makers who try to gather and analyze information when events happen, e.g., asking eye witnesses to describe what they saw.

Emergency Domain as an Unstructured Planning System

Emergency domain represents an unstructured planning domain. Unstructured planning can be defined as a planning process where the methodologies for conventional planning are not applicable. In an unstructured planning domain, no previously made plans can exactly fit the planning needed for the domain (Ntuen & Park, 1995). Planning for any emergency situation cannot totally fit any standard recipe because the conditions and characteristics of the emergency tasks are not known until after the situation has occurred. Therefore, planning for emergency situations fits well into the complex and chaos quadrants of the Cynefin problem typology developed by Kurtz and Snowden (2003).

A typical C2 structure developed for information management in an emergency response domain with the characteristics of complexity and chaos should have the following capabilities:

Adaptive: be able to adapt to new problem characteristics with minimal cost of making changes to the C2 structure. It should also be self-organized and evolutive;

- **Flexible:** Be amenable for application to different problem contexts with spatio-temporal features. That is, it should not be stove piped to known and atypical problems only;
- **Opportunistic:** Be able to recognize new opportunities with "satisficing" gains; redo plans to fit new and novel scenarios (Hayes-Roth, 1979); and

- **Improvise:** Be able to manage existing resources as well as being able to create or suggest new ways that can overcome deadlock constraints.

Emergency Domain as a Complex Collaborative Information Processing System

Collaboration is a process in the cognitive domain that involves two or more agents to work together toward a common purpose (Alberts, Garstka, Hayes, & Signori, 2001). Information in an emergency domain is gathered from various agencies and requires the collaboration of several C2 resources to analyze the information required to translate decision-making into action. Information-centric collaboration will be effective with the following features:

- **Team Situation Awareness (TSA):** Endsley (1988) defines situation awareness (SA) as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (p. 97). Salas, Dickinson, Converse, and Tannenbaum (1992) define a team as "a distinguishable set of two or more people who interact dynamically, interdependently, and adaptively toward a common and valued goal/object/mission, who have each been assigned specific roles or functions to perform, and who have a limited life span of membership" (pp. 126-127). Thus, TSA involves the team's assessment (i.e., perception, comprehension, and projection) of the current situation, which can include the surrounding environment (including any equipment or systems), the task and the team itself. Specifically, a TSA requires a common display of the problem concept map, which depicts the average mental model of the team members.
- **Plan Synchronization:** Information distributed across all echelons of an emergency response C2 (ERC2) structure must be synchronized through robust planning models, time and space interactions, and interactive role coordination that support useful redundancy designed to minimize information entropy and communication vulnerability.
- **Conflict Management:** Communication and information sharing among and between teams and C2 structure should dissipate minimum mass-energy exchange. Through transparent dialogs and use of common lexicons, emergency responders can reduce plan conflicts and reach a consensus in such time that rescue efforts result in no loss of life.

Some Selected Decision Support Systems for Emergency Management

Mendonca, Beroggi, and Wallace (2001) developed a conceptual decision support model for emergency planning. They proposed a decision support concept for improvisation in emergency management. The concept is based on the paradigm of operational risk management and is motivated by the observation that emergency response organizations must be prepared to improvise during response activities. They discussed the process of emergency response in light of this paradigm and identified the opportunities for supporting the process.

In another decision support system (DSS), Buzolic, Mladineo, and Knezic (2002) developed an experimental software system known as DPPI (Disaster Preparation and Prevention Initiative), project for telecommunications and information support during emergency situations. The objective of the DSS is to support decision processes in the phases of preparation, prevention and planning of a protection system from natural and other catastrophes, in phases throughout interventions during an emergency situation in the telecommunications segment. The basic module of the DSS is the GIS (Geographical Information System) of the area covered by the project with all necessary data about the region. Using a combination of GIS and multicriteria decision models, according to dominant natural catastrophes such as earthquakes, floods, weather, wildfires, and others, data about the vulnerability of the telecommunications system are generated.

CAMEO was developed in 1988 by the EPA's Chemical Emergency Preparedness and Prevention Office (CEPPO) and the National Oceanic and Atmospheric Administration (NOAA) Office of Response and Restoration, in an effort to assist the first responder with accessing information about chemical spill and explosion, both timely and accurately. It has since become a suite of three separate and integrated application software: CAMEO, MARLOT (Mapping Applications for Response, Planning and Local Operational Tasks) and ALOHA (Area Locations of Hazardous Atmospheres). MARLOT provides a mapping capability to CAMEO and ALOHA provides the atmospheric dispersion model to evaluate dangerous chemical vapors released to the atmosphere. Tools provided by CAMEO include a database of chemicals and their effects in the atmosphere or during explosion, a search engine to quickly locate a particular chemical and the dispersion model to evaluate released chemicals. HAZUS-MH, a knowledge based software, was created by Federal Emergency Management Agency (FEMA) to provide risk assessment analysis of potential losses due to floods, hurricanes, and earthquakes before or after the disasters occur. Its latest version, HAZUS-MH MR1, is upgraded with a Building Inventory Tool (BIT), Inventory Collection Survey Tool (InCAST) and Flood Information Tool (FIT). Also, it provides Geographic Information System (GIS) capabilities. Tools provided by HAZUS include earthquake model, hurricane model, flood model, and GIS.

WebEOC is a web-based emergency management communications system developed by Emergency Service Integrators (ESI) to provide secure real time emergency information management to emergency operation centers. WebEOC provides access to state and national weather trends, satellite images, and mapping information. WebEOC aggregates this information and displays them on the monitor or projector for the decision maker. Given the cooperation from the CAD vendor, it can interface with 911 CAD systems to provide status information on 911 calls and dispatch responses. Tools provided by WebEOC include web access to national and state weather, satellite images, and mapping information.

CoBRA 4.0 developed by Defense Group Incorporated (DGI), is decision support software designed for large scale and all-hazard incidents. It provides first responders with interactive tools, guides, Standard Operating Procedures (SOP), NIMS/ICS forms, checklists, and incident reporting capabilities. Tools provided by CoBRA 4.0 include databases on chemical, biological, radiological and explosive threats; SOPs and checklists that provide threat response, evidence collection and investigative procedures; guides such as the NIOSH pocket guide and Jane's Chem-Bio Handbook; electronic form capabilities to NIMS/ICS forms; incident reporting capabilities that provide logs of users' actions with time and date stamps, and administrator tools that support collaborative planning and provide different departments with the capability to input their own plans, checklists, maps, and local data. In addition, the Emergency Preparedness Incident Command Simulation (EPICS) was developed by the U.S. Army Training and Doctoring Command Analysis Center (TRAC) at White Sands Missile Range, New Mexico. It is computer-based, scenario-driven simulation software that provides the user to create a desired crisis situation through its Janus suite of tools. EPICS is a training tool for command and control personnel and crisis managers. It provides the capability to evaluate operation plans and response plans at various levels of the emergency situation and analysis system effectiveness.

Responder Assets Management Systems (RAMS) was developed by Oak Ridge National Laboratory in 2001 to assist first responders to respond to daily emergencies as well as mass casualty incidents. RAMS include tools for timekeeping, scheduling, dispatch analysis, personnel training, equipment tracking, and street management. The decision support tool in RAMS is the

Response Options Generator (ROG). ROG provides location and status of resources such as hospitals, satellite clinics, and medical equipment. It generates schedules for first responders and identifies resource shortages. The European Generic Emergency Response Information System (EGERIS) was developed in 2003 by a group of European countries. EGERIS capabilities include real time information about an emergency incident to emergency services. EGERIS provides communications tools such as PDAs, GSM mobile phones and GPS to responders, satellite command and control centers and the main command and control center. The GPS tool provides real time location of the responders. First responders are able to send field data to the command center for analysis and recovery planning.

Emergency Response Synchronization Matrix (ERSM), developed by Argonne National Laboratory is an emergency response planning software system that allows response planning from multiple jurisdictions to be developed, maintained, and integrated into a unified response plan. ERSM provides planning and exercise design and control tools. The Consequence Assessment Tool Set (CATS), developed by the Science Applications International Corporation, provides real time disaster analysis and data integration from various sources. CATS provides databases, computer models of emergency situations, GIS, contingency, and logistic planning and consequence management capabilities. CATS uses the ArcView GIS and ArcView Spatial Analyst to provide demographic and infrastructure information by accessing many databases on the internet.

Need for Information Fusion

Information management in the emergency domain offers varied challenges to the emergency response team (ERT). Complex and interrelated plans from different C2 agents must be developed and executed in real-time. Limited resources must be carefully managed and coordinated and time-critical, high stake decisions must be made. To support the ERT personnel, information resources and data must be quickly and efficiently processed, analyzed, and presented to fully support critical decisions. Computers perform these tasks better.

Generating a requirement for fusing information with uncertain, incomplete, and sometimes conflicting data from disparate sources, in real time to produce actionable knowledge can be challenging. There are two general views of information fusion. First, information fusion is a multilevel, multifaceted process dealing with the detection, association, classification, correlation, estimation, and combination of data and information from multiple sources to form a vector of decision variables required to help the decision maker. Examples of this level of information fusion are multiple sensor data fusion in a robot environment or geographic information management using statistical methods such as the Kalman filter (Tian, Li, & Jin, 2003; Wu, Siegel, & Ablay, 2003) and in military C2 systems based on artificial intelligence and qualitative knowledge based methods (Niculescu, 2001). Secondly, information fusion is a synergistic process, in that it attempts to overcome uncertainty associated with individual data/information sources by combining them using a common metric. Here, the major goals of information fusion are to minimize uncertainty in information and increase decision reliability.

A Need for a System Based on Lean Principal

Lean is a management philosophy focusing on reduction of the seven wastes (over-production, waiting time, transportation, processing, inventory, motion, and scrap) in manufactured products (Nave, 2002). By eliminating waste, quality is improved, and production time and cost are reduced. Lean process improvements by following five key steps; first studying the process by directly observing the work activities and their flow. Second, study the process to systematically eliminate wasteful activities and their flow. Third, come to agreement among those affected by the process in terms of what the process needs to accomplish and how to do this. Next, attack and solve problems using a systematic method, and finally, integrate the above approach throughout the organization. After applying these steps, the selection of the right lean tool is essential.

The lean tools include Kaizen, Value Stream Process mapping, 5 S, Kanban, Error Proofing, Prevention and predictive maintenance, Set-up time reduction, Reduce lot sizes, Line-balancing, Schedule leveling, standardized work, and visual management (Nave, 2002). Kaizen seeks to standardize work processes while eliminating waste using combine, simplify and eliminate as guiding words. Value Streams are actions required to create a product or service from raw material until it reaches the customer. Also, they seek to capture the activities taking place while people undergo their work. Five S creates a work environment that is clean, well-organized and efficient (Bateman & David, 2002).

Kanban is a pull inventory management that improves process management by focusing on visual control of the process. Error Proofing seeks to enhance a worker's job performance by improving the functional tasks. In Preventive and predictive maintenance, the preventive stage maintains the equipment in good condition so unexpected downtimes do not occur. Predictive maintenance schedules routine maintenances so everyone knows and can plan for a machine or a piece of equipment being unavailable (Mika, 2005). Set-up time is the period between the productions of the last good part in one series of parts to the first good part in the next series of parts. Efforts need to be done to find ways to eliminate waste in setups, thus speeding up the process of setup. Reduced batch sizes allow each piece as it is created to flow from one operation to the next with no delays, storages, or work-in-process inventories. Line Balancing occurs when work is performed by each operator evenly over time with no peaks or valleys. Each worker or machine has the same amount of time, so no one person or machine is waiting for something to do or having to hurry up to maintain workflow. Schedule Leveling establishes a schedule which allows the same amount to be produced daily with minimal fluctuations in demand. Standardized work comes up with a standardized operating procedure so that a job is done in the same way. Finally, Visual Management enables someone to look at a job or work space, and knows in a glance that something has been misplaced or mismanaged. With these Lean tools and techniques, a company will be able to run more efficiently getting rid of their waste (Harris and Donatelli, 2005).

On one hand, Six Sigma is a statistical concept that represents the amount of variation present relative to customer requirements or specifications. Six Sigma methodologies were created by Bill Smith, a former engineer of Motorola. He developed this principle because of the increasing complexity of systems and products used by consumers created higher than desired system failure rates. The benefits of adopting Six Sigma will enhance ability to provide value to the customer, enhance understanding of key business processes, and it will reduce waste and improve profit performance. The goal of Six Sigma is to reach 3.4 defects per million opportunities over the long term, all the while seeking to reduce the variability present in the process. Six Sigma principles were developed successfully by Motorola in 1987 in a form of business strategy concepts and management philosophy that sets high standard of discipline in meeting extremely high objectives, collecting data and analyzing results to an almost zero-degree of tolerance as a way of reducing waste, defects and irregularities in both products and services (Mader, 2010).

Lean Six Sigma is a combination of two quality improvement methodologies both aimed at "improving business processes (Sigma, 2012). Both techniques emphasize "business processes and process metrics," to increase "customer satisfaction" by "providing quality and on-time products and services" (Sake & Hahn, 2013). Both methodologies are complimentary. "Lean cannot bring a process under statistical control, and Six Sigma alone cannot dramatically improve process speed or reduce invested capital" (Oguz, Hutchinson, & Han, 2012) (Vivekananthamoorthy & Sankar, 2011). Six Sigma will remove defects, but it will not provide solutions to process flow optimization, whereas lean principles, do not employ the statistical tools required to attain the lean process capabilities (Hesami, Nikookar, & Harsej). Six Sigma is a statistical program employing a "data-based and analytical approach by using tools" to remove process variation "and deliver error-free products and services such as voice of the customer, measurement systems analysis (MSA), and statistical hypothesis testing, design of experiments, and failure modes and effects analysis" (Sake & Hahn, 2013; Hesami, Nikookar, & Harsej, n.d.; Vivekananthamoorthy & Sankar, 2011; Sigma, 2012). Six Sigma enhances the "process capability" to reach business excellence (Hesami, Nikookar, & Harsej, n.d.; Sigma, 2012). Lean aims to produce "simplified, efficient value-adding processes while sharing information," to reduce "inventory cost," produce "higher productivity and flexibility," and respond faster to customers and their needs (Dumitrescu & Dumitrache, 2011). Lean uses these tools, namely; "value stream mapping, workflow balancing, and kanban pull signaling systems to produce work, simplify and improve process efficiency, and increase delivery speed" (Sake & Hahn, 2013), and is "performance-based" (Dumitrescu & Dumitrache, 2011).

Lean in Software Design/Development

Lean can be applied to software development (termed as lean software development), as in manufacturing (Normalm, 2011). In lean philosophy, elimination of waste is paramount (Normalm, 2011). This waste elimination concept is applied to software development and resulted in seven types of wastes (Normalm, 2011). The seven wastes of software development are, as follows: "partially done work, extra processes, extra features, task switching, waiting, motion, and defects" (Normalm, 2011). The emphasis of lean development in software development is to reduce wastes, as follows: "reducing overproduction, processing steps, information collection time, unnecessary test plans, decision time, re transportation time, paper work, development time as work on one feature at a time, and having requirements bucket" (Jailia, Sujata, Jailia, & Agarwal, 2011). An example of a company that applied the lean philosophy to its software development would be IMVU (Widman, Hua, & Ross, 2010). IMVU successfully applied lean principles "at the technical level in the software development process" (Widman, Hua, & Ross, 2010). IMVU encountered several challenges in software development, as follows: "choosing the right product feature, long development cycle, endless testing, and debugging" (Widman, Hua, & Ross, 2010). IMVU found common wastes in software development as cited above (Jailia, Sujata, Jailia, & Agarwal, 2011; Widman, Hua, & Ross, 2010).

In general, the strengths of lean manufacturing would be value creation whereby a "robust, adaptive, flexible, and responsive enterprise" is built (Value creation covers "value identification, value proposition, and value delivery"), and team concept (Nayak). Its weakness is "not an analytical process" but a "collection of principles and practices," if applied, would decrease wastes in time (Nayak). The future of lean in software design/development would be during recession, as a survival tool, by maintaining sustainability through "fast delivery, easy management, managing high risks in the software industry, better human resource management, and maintaining financial strength" (Jailia, Sujata, Jailia, & Agarwal, 2011).

DAFAT INFORMATION FUSION MODEL

DAFAT information fusion model was based on the novel hybrid Dempter-Shafer/Fuzzy Cognitive Map (Balogun, 2009). DST has been used to fuse information from multiple independent sources where there are uncertainties and incomplete information. DST has been shown to be a better information fusion methodology in the areas where epistemic uncertainties exist, such as in the emergency domain. FCM has been used widely in many applications as a tool to provide sensitivity analysis on concept relations of cause-effect systems. The attractiveness of FCM include:

- The ability of the FCM to incorporate the experts knowledge,
- The ability to combine knowledge obtained from various sources,
- The ability to synchronously update the concepts and causal influences, and
- The ability to serve as sensitivity analysis tools to validate domain experts during planning or preplanning phases.

The hybrid DST/FCM model provided a framework where the information fusion capability of DST could be used to set the initial system state variables for FCM analysis. FCM suffers from the lack of a systematic way to define the initial systems state of a context, which has always been arbitrarily chosen by the domain experts. This novel model provided the domain experts the tool to fuse information in real time and immediately see the impact of their decision making through the output provided by the FCM. For detail workings of DST and FCM, the reader should consult books on these concepts. Figure 2 shows the hybrid model. Figure 3 shows the flowchart of the hybrid model.

Data Fusion Aiding Tool (DAFAT)

The information fusion model is implemented with DAFAT, a Data Fusion Aiding Tool developed for this research. DAFAT provides three decision aiding tools consisting of Fuzzy Cognitive Map (FCM), Dempster-Shafer (DS) and Hybrid DS/FCM. These tools are located in the simulation menu.

Using the Hybrid DS/FCM Tool

To use the hybrid DS/FCM tool, the user:

- Selects the hybrid DS/FCM item from the simulation menu. The hybrid DS/FCM tool allows the user to automatically set the initial state vector. The procedure for setting up the concepts, creating the connection matrix, defining the frame of discernments, and specifying beliefs are similar to those described previously.

Figure 2. A hybrid model of DST and FCM

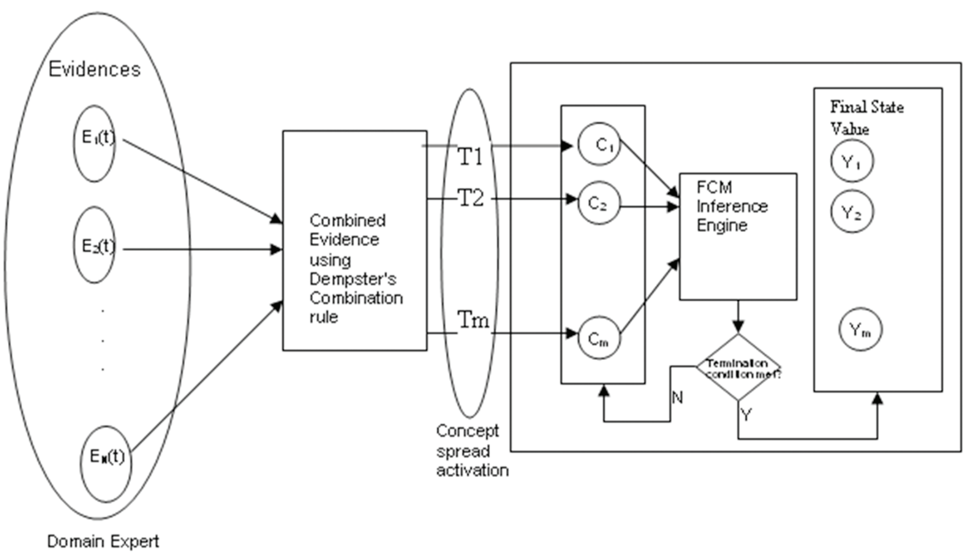
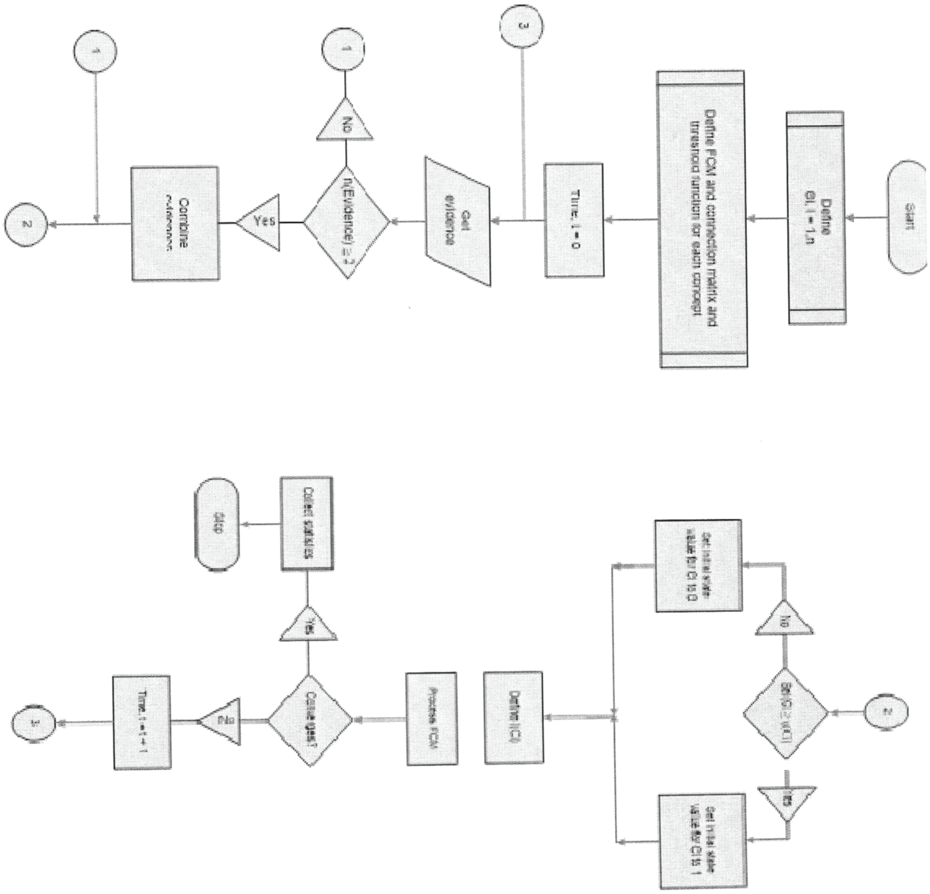


Figure 3. Flowchart of the hybrid DST-FCM



- Once these parameters are set, the user combines the beliefs by clicking on Combine belief button. This is completed concept by concept (Figure 4). Belief combination and threshold selection screens are displayed as in other procedures.
- Once the threshold has been defined, the user clicks the “Done” button. Another concept’s frame of discernment can then be chosen by highlighting it in the select the frame of discernment list box and clicking “Select” button. The user repeats the steps to combine the belief and define the threshold for that concept.
- After this is completed for the concepts of interest, the user clicks on the Simulate button and the result screen is displayed (see Figure 5).

Figure 4. An hybrid DS/FCM tool screen

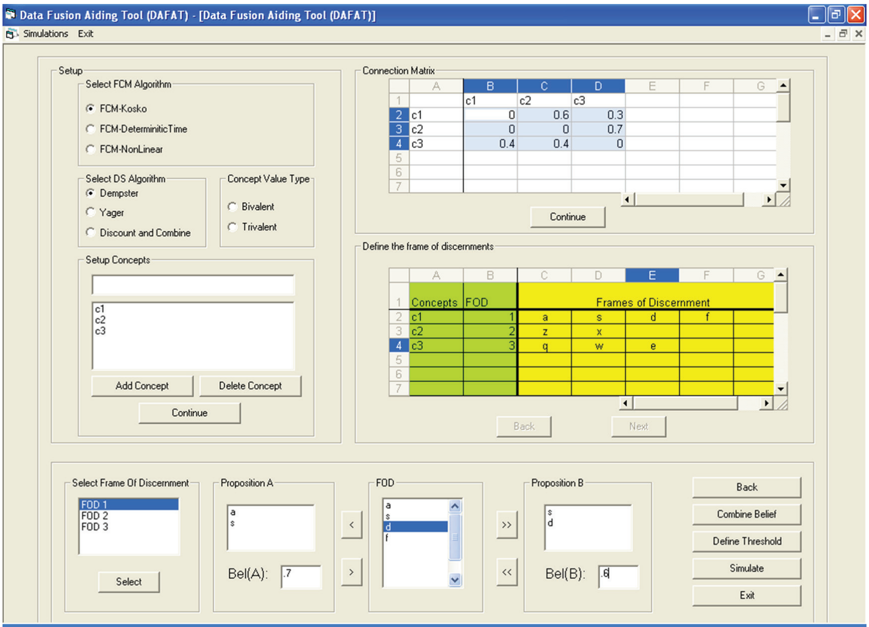
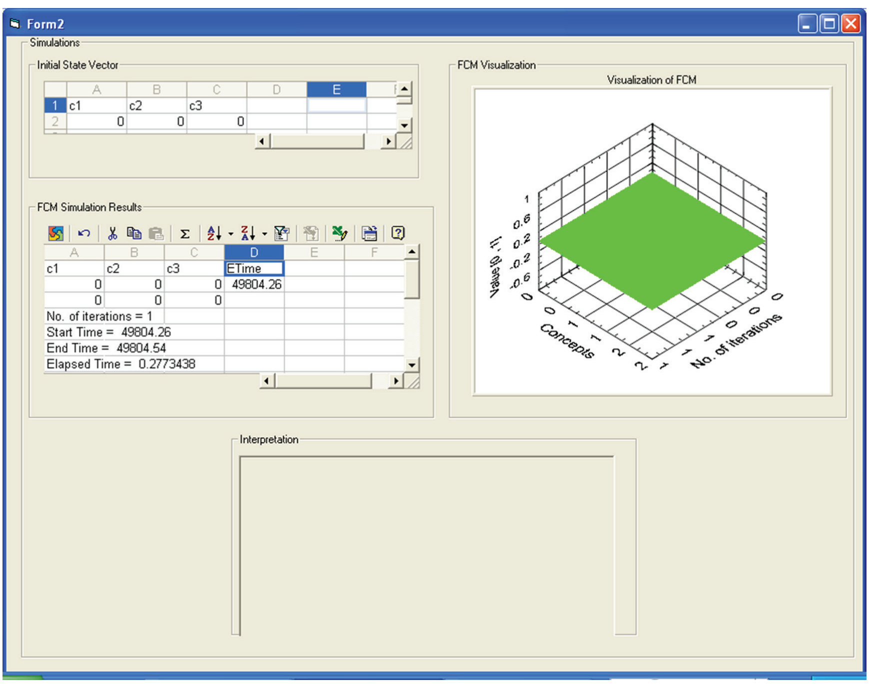


Figure 5. Simulation result screen



HYBRID DS/FCM

This section presents the application of the hybrid Dempster-Shafer/Fuzzy Cognitive Map using the following scenario.

Scenario: Flooding in High Rock

Consider a situation that requires an emergency response. It was 12:00 noon on October 17, 2013, when the weather forecast called for a severe thunderstorm in the High Rock Lake area of Rowan County. This area is moderately populated and consists of both residential and business areas including the lake and subdivisions. In addition, High Rock Lake has a levee, which is not a flood control structure. Within 45 minutes of the forecast, the clouds began to darken and rain has begun to fall. According to the forecast, the thunderstorm was expected to expire by 11:00 pm. The FEMA predicted the possibilities of flood, displacement of citizens, and a likely curfew to curtail looting. Three concepts, flood, displacement, and curfew are defined as C_1, C_2 $C_{3,}$ respectively. The connection matrix for this scenario is presented in Table 1.

The belief combination methods used in this hybrid model consists of Dempster's rule of combination (DS) and the Discount and Combine rule of combination (DC) were used. The hybrid DS/FCM combinations simulated consist of DS/FCM-Kosko, DS/FCM-NL, DC/FCM-Kosko and DC/FCM-NL.

Experiment with Hybrid DS/Kosko's FCM

The simulation of the hybrid DS/FCM-Kosko for this scenario used the eight initial state values and the result is presented in Table 2. In the simulation, the initial state vectors, I_0 = [0 0 0] represented that no activity was present in the three concepts. The final state vector also reflected no activity in the three concepts, with I_1 = [0 0 0]. The Hybrid DS/Kosko's FCM reached the

Table 1. Connection matrix

	Flood	Displacement	Curfew
Flood	0	0.6	0.3
Displacement	0	0	0.7
Curfew	0.4	0.4	0

Table 2. Flood case simulation results

Simulation No.	Initial State Vector	Final State	No. of Iterations	Completion Time (sec.)
1	0 0 0	0 0 0	1	0.1786
2	0 0 1	0 0 1	1	0.1753
3	0 1 0	0 1 1	2	0.2572
4	0 1 1	0 1 1	1	0.1788
5	1 0 0	1 1 1	3	0.3309
6	1 0 1	1 1 1	2	0.2668
7	1 1 0	1 1 1	2	0.2962
8	1 1 1	1 1 1	1	0.1802

equilibrium state in a single iteration and the completion time was 0.1786 seconds. Likewise, simulation #8 has the initial state vector, $I_0 = [1\ 1\ 1]$. This represents that all three concepts are active. Also, the equilibrium state was reached in a single iteration, and the completion time was 0.1802 seconds.

For the simulation #5, the initial state vector, $I_0 = [1\ 0\ 0]$ was used. The Hybrid DS/Kosko's FCM reached an equilibrium state in three iterations with, $I_3 = [1\ 1\ 1]$. Also, simulations #6 and #7 with $I_0 = [1\ 0\ 1]$ and $I_0 = [1\ 1\ 0]$, respectively, reached the equilibrium states in two iterations with, $I_2 = [1\ 1\ 1]$. The completion times for simulations 5, 6, and 7 are 0.3309, 0.2668, and 0.2962 seconds, respectively. The results show when a flood occurs, residents in the affected area are likely to be displaced and a curfew may be imposed to prevent loss of lives and looting.

In simulations #3 and #4 with $I_0 = [0\ 1\ 0]$ and $I_0 = [0\ 1\ 1]$ the system reached an equilibrium state with $I_{n\,=}$ $[0\ 1\ 1]$ taking two and one iterations, respectively. The completion times for simulations #3 and #4 are 0.2572 and 0.1788 seconds, respectively. The result shows whenever residents of an affected area are displaced, a curfew may be imposed. Simulation #2 with $I_0 = [0\ 0\ 1]$ reached an equilibrium state in one iteration with, $I_1 = [0\ 0\ 1]$, and the completion time was 0.1836 seconds. This means that a curfew may be imposed for reasons other than flood. To further illustrate the time-based behaviors of the simulation, Table 2 shows the state vector values for each iterations for simulation #3 starting with $I_0 = [1\ 0\ 0]$.

CONCLUSION

This paper has implemented, analyzed, and demonstrated DAFAT, a novel hybrid Fuzzy Cognitive Map (FCM) and Dempster-Shaffer (DS) as information fusion system in the domain of emergency command and control problems. The proposed hybrid model was analyzed with sample emergency response information fusion problems. To support the emergency response management teams, information must be quickly and efficiently processed, analyzed and presented in a manner that will fully support critical decisions. This hybrid information fusion technique provides the real time analytical tools for this purpose. The method allows for real time integration of opinions from many experts involved in the emergency response planning process.

There are several advantages from the hybrid methods adopted in this paper. Sources of information were assigned different weights to signify their credibility. In addition, experts were assigned weights to signify their level of experience and proficiency. The initial system states provided by the threshold function can be used to approximate the current state of an emergency situation. As time progresses in the emergency situation, new information may be received. DAFAT provides for real time prediction of the system states using the hybrid algorithms and has been successfully tested with fifty concept variables.

REFERENCES

Alberts, D. S., Garstka, J. J., Hayes, R. E., & Signori, D. T. (2001). *Understanding Information Age Warfare*. Washington, DC: CCRP Press, CCRP Publication Series.

Albinsson, P. (2004). *Interacting with command and control systems: Tools for operators and designers.* Linköpings Studies in Science and Technology, Thesis No. 1132, ISSN 0280-7971.

Balogun, O. (2009). *Supporting Information Fusion Tasks in Emergency Command and Control Domains Using a Hybrid Fuzzy Cognitive Map and Dempster-Shafer Algorithms*. North Carolina Agricultural and Technical State University.

Bateman, N., & David, A. (2002). Process improvement programmes: A model for assessing sustainability. *International Journal of Operations & Production Management*, *22*(5), 515–526. doi:10.1108/01443570210425156

Biswas, G., Kapadia, R., & Yu, X. W. (1997). Combined qualitative-quantitative steady-state diagnosis of continous-valued systems. *IEEE Transactions on Systems, Man, and Cybernetics*, *SMC-27*(2), 167–185. doi:10.1109/3468.554680

Bushman, J. B., Mitchell, C. M., Jones, P. M., & Rubin, K. S. (1993). ALLY: An operator's associate for cooperative supervisory control systems. *IEEE Transactions on Systems, Man, and Cybernetics*, *SMC-23*(1), 111–128. doi:10.1109/21.214771

Buzolic, J., Mladineo, N., & Knezic, S. (2002). Decision support system for disaster communications in Dalatia. *International Journal of Emergency Management*, *21*, 34–41.

Capitol Hill Press Releases. (2005, October 6). *Jefford's statement on Hurricane Katrina response*. Federal Document Clearing House.

CATS. (n.d.). Retrieved from http://www.esri.com/news/arcnews/fall99articles/07-catsemer.html

Chertoff, M. (2005). Response to Hurricane Katrina, congressional testimony. *Federal Document Clearing House*. CoBRA 4.0. Retrieved from http://www.defencegroupinc.com/cobra/sw_cobra.htm

Command and Control. (1976). Computer-Aided Management of Emergency Operations (CAMEO). *US Marine Corps MCDP*, *6*, 33–60.

Czerwinski, T. J. (2003). *Coping with bounds: Speculations on non-linearity in military affairs*. Washington, DC: CCRP Publisher.

Dooley, K. (1996). A nominal definition of complex adaptive systems. *The Chaos Network*, *8*(1), 2–3.

Dumitrescu, C., & Dumitrache, M. (2011). The impact of lean six sigma on the overall results of companies. Economia. *Seria Management*, 535-544.

Durkin, J. (1994). *Expert Systems: Design and Development*. New York: Macmillan. Retrieved from http://www.hoise.com/vmw/04/articles/vmw/LV-VM-06-04-20.htm

ERSM. (n.d.). Retrieved from http://www.anl.gov/techtransfer/pdf/profile%20ERSM%209-16-04.pdf

Harris, G., & Donatelli, A. (2005). *Value-stream mapping as a lean management tool*. Huntsville, AL: University of Alabama.

Hayes Roth, B., & Hayes Roth, F. (1979). A Cognitive Model of Planning. *Cognitive Science*, *3*(4), 275–310. doi:10.1207/s15516709cog0304_1

HAZUS-MH. (n.d.). Retrieved from http://www.fema.gov/hazus

Helton, J. C. (1997). Uncertainty and sensitivity analysis in the presence of stochastic and subjective uncertainty. *Journal of Statistical Computation and Simulation*, *57*(1-4), 3–57. doi:10.1080/00949659708811803

Hesami, S., Nikookar, I., & Harsej, F. (n.d.). *Integrated model of six sigma and lean on organization productivity*. Retrieved June 10, 2014, from Asia Pacific Industrial Engineering and Management System: http://apiems.net/conf2013/1083.pdf

Holland, J. H. (1994). Echoing emergence: Objectives, rough definitions, and speculations for ECHO-class models. In G. Cowan, D. Pines, & D. Melzner (Eds.), *Complexity: Metaphors, Models, and Reality*. Adisson-Wesley.

Jailia, E., Sujata, M., Jailia, M., & Agarwal, M. (2011). Lean software development ("as a survival tool in recession"). *International Journal of Software Engineering and its Applications*, 63-70.

Kurtz, C. F., & Snowden, D. J. (2003). The new dynamics of strategy: Sensemaking in a complex and complicated world. *IBM Systems Journal*, *42*(3), 462–483. doi:10.1147/sj.423.0462

Mader, D. P. (2009). 3.4 per million. *The Right Decision*, 50-51.

MCDP6. (1996). *Command and Control*. US Marine Corps MCDP 6.

Mendonça, D., Berroggi, G. E. G., & Wallace, W. A. (2001). Decision support for improvision during emergency response. *International Journal of Emergency Management*, *1*(1), 30–41. doi:10.1504/IJEM.2001.000507

Mika, G. (2005). *Kaizen event implementation manual*. Society of Manufacturing Engineers.

Nave, D. (2002, March). How To Compare Six Sigma, Lean and the Theory of Constraints. *Quality Progress*, 73-78.

Nayak, B. (n.d.). *Lean manufacturing and value management convergence of divergent tools*. Retrieved June 10, 2014, from Save International: http://www.value-eng.org/knowledge_bank/attachments/200629.pdf

Niculescu, M. (2001). *Sensor fusion algorithms for unmanned air vehicle: Aerosonde Robotic Aircraft Notting Hill*. Victoria.

Normalm, T. (2011). *Achieving lean software development: Implementation of agile and lean practices in a manufacturing-oriented organization*. (Student thesis). Uppsala University, Uppsala, Sweden.

Ntuen, C.A., Balogun, O., Boyle, E., & Turner, A. (2006). Supporting command and control in emergency management domain using cognitive systems engineering. *Journal of Ergonomics, 49*(12), 12–13, 1415–1436.

Ntuen, C. A., & Park, E. H. (1995). An experiment in scheduling and planning of non-structured jobs: Lessons learned from artificial intelligence and operational research toolbox. *European Journal of Operational Research, 84*(1), 96–115. doi:10.1016/0377-2217(94)00320-C

Oguz, C., Hutchinson, K. J., & Han, S. (2012). Implementing lean six sigma: a case study in concrete panel production. In *Proceedings for the 20th Annual Conference of the International Group for Lean Construction*. San Diego, CA: Montezume Publishing.

Perrow, C. (2003). *Disaster prevention and mitigation*. Unpublished manuscript. Yale University.

Pigeau, R., & McCann, C. (2002, Spring). Re-conceptualizing command and control. *Canadian Military Journal,* 53–64.

Raghunathan, S. (1997). Qualitative reasoning in quantitative modeling. *IEEE Transactions on Systems, Man, and Cybernetics*, *SMC-27*, 683–690. doi:10.1109/3468.618267

RAMS. (n.d.). Retrieved from http://www.ornl.gov/info/ornlreview/v33_3_00/software.htm

Sake, H., & Hahn, B. (2013, April 18). *Applying lean, six sigma, BPM, and SOA to drive business results.* Retrieved June 10, 2014, from IBM RedBooks: http://www.redbooks.ibm.com/redbooks.nsf/RedbookAbstracts/redp4447.html?Open

Salas, E., Dickinson, T. L., Converse, S. A., & Tannebaum, S. I. (1992). Toward an understanding of team performance and training. In R. J. Sweezey & E. Salas (Eds.), *Teams: Their training and performance* (pp. 3–29). Norwood, NJ: Ablex Publication.

Shattuck, L. G., & Woods, D. D. (2000). Communication of intent in military command and control systems. In C. McCann & R. Pigeau (Eds.), *The Human in Command: Exploring the Modern Military Experience, (pp. 279–91)*. New York: Plenum. doi:10.1007/978-1-4615-4229-2_19

Sigma, G. L. (2012). *The basics of lean six sigma*. Retrieved June 10, 2014, from Go Lean Six Sigma: http://www.goleansixsigma.com/the-basics-of-lean-six-sigma/

Smith, M., & Downs, S. (1975). Trainable assessments for apprentice selection in shipbuilding. *Journal of Occupational Psychology*, *48*(1), 39–42. doi:10.1111/j.2044-8325.1975.tb00295.x

Tian, W., Li, Q., & Jin, Z. (2003). Sensor fusion in remote sensing satellites using a modified Kalman filter. *Measurement Science & Technology*, *14*(3), 356–357. doi:10.1088/0957-0233/14/3/315

Vivekananthamoorthy, H., & Sankar, S. (2011). Lean six Sigma. In A. Coskun, T. C. Inal, & M. E. Serteser (Eds.), *Six Sigma Projects and Personal Experiences* (pp. 1-23). Rijeka, Croatia: Intech. Retrieved from http://www.esi911.com

What is EPICS? (n.d.). Retrieved from http://www.epics.astcorp.com

Widman, J., Hua, S. Y., & Ross, S. C. (2010). Applying lean principles in software development process–a case study. *Issues in Information Systems*, 635–639.

Wohl, J. G., Entin, E. E., Kleinman, D. L., & Pattipati, K. (1989). Human decision processes in military command and control. In W. B. Rouse (Ed.), Advances in Man-Machine Systems, (vol. 1, pp. 261–307). Academic Press.

Wu, H., Siegel, M., & Ablay, S. (2003). Sensor fusion using Dempster-Shafer theory II: Static weighting and Kalman filter-like dynamic weighting. In *Proceedings of Instrument and Measurement Technology Conference*. Vail, CO: Academic Press.

Wu, H., Siegel, M., Stiefelhagen, R., & Yang, J. (2002). Sensor fusion using Dempster-Shafer theory. In *Proceedings of IEEE Instrumentation and Measurement Technology Conference*, (pp. 21–23). IEEE.

ADDITIONAL READING

Hobbs, B. F., Ludsin, S. A., Knight, R. L., Ryan, P. A., Biberhofer, J., & Ciborowski, J. J. H. (2002). Fuzzy cognitive map as a tool to define management objectives for complex ecosystems. *Ecological Applications*, *12*(5), 1548–1565. doi:10.1890/1051-0761(2002)012[1548:FCMAAT]2.0.CO;2

Kardaras, D., & Karakostas, B. (1999). The use of fuzzy cognitive maps to simulate information systems strategic planning process. *Information and Software Technology*, *4*(15), 197–210. doi:10.1016/S0950-5849(98)00125-6

Kardaras, D., & Mentzas, G. (2002). Using fuzzy cognitive map to model and analyze business performance assessment. Advanced in Industrial Engineering Applications and Practice II (Chen J.,l Mital A eds), 63–68.

Kosko, B. (1986). Fuzzy cognitive maps. *International Journal of Man-Machine Studies*, *24*(1), 65–75. doi:10.1016/S0020-7373(86)80040-2

Kosko, B. (1987). Adaptive bidirectional associative memories. *Applied Optics*, *26*(923), 4947–4960. doi:10.1364/AO.26.004947 PMID:20523473

Kosko, B. (1992). *Neural networks and fuzzy systems: A dynamical systems approach to machine learning*. Englewood Cliffs, NJ: Prentice Hall.

Lalmas, M. (1997). Dempster-Shafer theory of evidence applied to structured documents: Modeling uncertainty. *Annual ACM Conference on Research and Development in Information Retrieval archive.* Proceedings of the 20th annual international ACM SIGIR Conference on Research and development in information retrieval Philadelphia, Pennsylvania, 110–118. doi:10.1145/258525.258546

Ndousse, T. D., & Okuda, T. (1996). Computational intelligence for distributed fault management in networks using fuzzy cognitive maps. *IEEE International Conference ICC Conference Record, Converging Technologies for Tomorrow's Applications*, June 23–27, 3, 1558–1562. doi:10.1109/ICC.1996.533672

KEY TERMS AND DEFINITIONS

Command and Control (C2): The art and science of leadership and management. Military Commanders use the term to state what needs to be done and ensure that they are done appropriately.

Data: Unorganized numbers, letters, or graphics which have not be processed.

Data Fusion: The method of incorporating various data representing the same real-world object into a reliable, correct, and suitable representation.

Disaster: A condition or event that requires emergency response which may cause great damage or loss of life.

Information: The result of processed data which is presented in a usable form.

Six Sigma: A statistical concept that represents the amount of variation present relative to customer requirements or specifications.

Chapter 9
Lean Six Sigma in Healthcare:
A Review of Theory and Practice

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ABSTRACT

The chapter clarifies emerging aspects and trends of Lean Six Sigma (LSS) in healthcare through the systematic examination of 162 peer-reviewed articles in business, management, and healthcare disciplines that have been published over a ten-year period from 2004 to January 2014. Every article is analyzed using a scheme of six distinct dimensions including year of publication, journal, applications areas, tools and techniques, benefits and improvements, and research type. The chapter provides significant insights into the state of the art of LSS in healthcare research and clarifies confusion in the literature as to what constitutes LSS role in improving healthcare context.

INTRODUCTION

Implementing Lean Six Sigma (LSS) in non-manufacturing sector like healthcare is interesting and challenging topic. Healthcare service contains many complex systems and processes with various stakeholders that should operate under pressures of high clinical and administrative quality levels. LSS

DOI: 10.4018/978-1-4666-7320-5.ch009

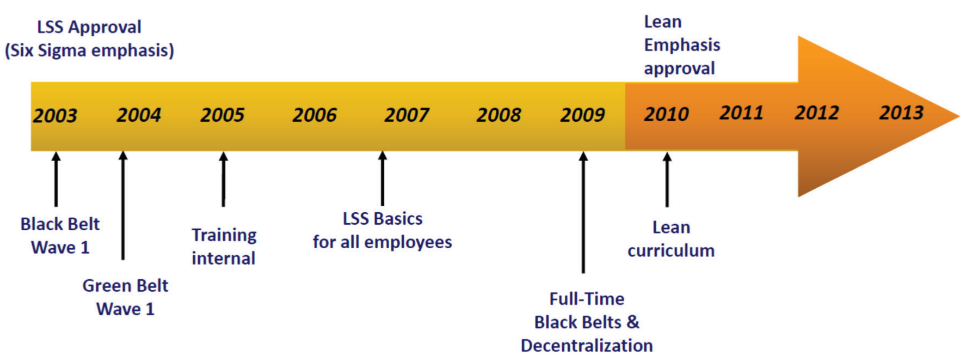
methodology has been gradually adopted in healthcare since early 2000s in order to reducing medical errors and improving quality of patient care and safety levels for patients and healthcare workers (Taner et al, 2007).

The pressures on healthcare services have increased dramatically in the last decade due to increasing financial pressures, ageing population, managerial sophistications, and operational and technological inefficiency (de Koning et al, 2006). Accordingly, many researchers and practitioners consider LSS as the magic cure of healthcare problems as it supports and sustains capacity, speed and accuracy of various healthcare processes such as improving MRI exam scheduling and increasing capacity in X-ray rooms (Taner et al, 2007), improving waiting time for the medical service (Ahmed et al., 2013; Roth et al (2010), reducing clinical and administrative errors (Gowen III et al., 2012), eliminating waste Elimination (Cima et al., 2011; de Bucourt et al., 2011), increasing satisfaction of patients and health employees (Bucci and Musitano, 2011; Chiarini, 2013), and reducing length of stay (Gayed et al., 2013; Mandahawi, 2011).

While there is an agreement on the historical development of Six Sigma methodology as presented in the Figure 1, it appears that there is a little consensus on the definition of the term. Six Sigma has been developed by Motorola in the 1980s as a result of linking finest elements of scientific management and continuous quality improvement initiatives. From a statistical perspective, Six Sigma can be considered as a metric of process measurement symbolized by the Greek letter σ that represents the amount of variation with a normal data distribution that targets quality level of 3.4 defects per million opportunities (DPMO) (Aboelmaged, 2011).

The focus of Six Sigma is not on counting the defects in processes, but rather the number of chances or opportunities in a process that could produce

Figure 1. Timeline of LSS (adapted from Heckert, 2013)



defects therefore causes of quality problems can be eliminated before they are transformed into defects (Antony, 2006). From a managerial perspective, Six Sigma can be considered as an improvement program for reducing variation (Andersson et al., 2006). From a strategic perspective, Six Sigma could be described as a business strategy to improve business profitability, effectiveness and efficiency of all operations to increase customer satisfaction (Kwak and Anbari, 2006).

The labeled concept Lean Six Sigma (LSS) is a combination of two complementary philosophies; Lean and Six Sigma. LSS is a business improvement methodology aiming at maximizing shareholders' value by enhancing costs, speed, quality, speed, and customer satisfaction. Although LSS has its origins in manufacturing organizations, it has been widely adopted by service organizations. What makes Lean Six Sigma different from previous quality methodologies is the adoption of structured quality roles and tools across organizational hierarchy instead of transferring quality issues to first administrative line or to specific quality department (Snee, 2004). According to George (2002), the key focus of LSS is on activities that cause the customer's critical-to-quality issues and create the longest time delays in any process. Working on these activities offer the greatest opportunity for improvement in cost, quality, capital, and lead time. Although the guiding theories of Lean and Six Sigma methodologies are different, they are complementary in nature since both seek to improve the process. Lean philosophy establishes the standards of eliminating waste and reducing cycle time in processes with little impact on process variation, while Six Sigma shows how these standards can be achieved with minimum variation through applying a problem-solving approach using statistical tools and techniques (Aboelmaged, 2010). In addition, lean standards covers the entire organization value chain, while Six Sigma concentrates more attentively on certain projects or processes within an organization. Such integration between Lean and Six Sigma as an improvement methodology brings many benefits to the organization including maximizing shareholder value and improve their satisfaction and cost, quality and speed of processes (Byrne et al., 2007).

Typically, LSS research efforts have been conducted in a wide range of manufacturing and service settings with scant literature on how LSS research is structured within specific setting or domain. Therefore, the purpose of this chapter is to investigate LSS research in healthcare context and present a comprehensive review of these studies. The review covers 162 journal articles published over 10 years between 2004 and January 2014. The paper is divided into four remaining sections. First, the research methodology used in the study is described. This is followed by the classification framework in the second section. Third, LSS in healthcare articles are analyzed and the classification results are reported. Finally, conclusions are presented and the implications for future research are presented.

RESEARCH METHODOLOGY

The structured review in this chapter focuses on papers that are published in peer-reviewed journals where academics and practitioners use to acquire and disseminate high quality research findings. Therefore, editorials, news reports, book reviews, viewpoints, conference papers, master and doctoral dissertations, textbooks, and unpublished working papers were excluded. The survey focused only on papers with 'Lean Six Sigma' and 'Healthcare', 'Hospital' or 'Medical' as a part of their titles or abstracts. Finally, to avoid never ending revision of the article, the January 2014 was selected as the cut-off date. These criteria should allow a quality and comprehensive set of papers on LSS in healthcare by different fields. This effort has been carried out over 22 months through extensive internet search, database search, reference checking, etc. However, it is possible that there exist an article which is not surveyed in this paper.

Considering the diverse nature of LSS research, it would be difficult to classify the literature under any specific themes. As a result, different online databases were selected and searched to provide a comprehensive bibliography on LSS in healthcare. The literature contributions were primarily of articles from research databases including PubMed, Wiley Interscience, Science Direct, (Elsevier), EBSCO, Ingenta, Emerald, ProQuest, Inderscience, ASQ, Springer and IEEE-Xplore.

LSS IN HEALTHCARE: A CLASSIFICATION FRAMEWORK

The search yielded 162 articles on LSS in healthcare from 108 journals (for a full list of these articles see Appendix). Each article was carefully reviewed and classified from several perspectives. Although this research is not exhaustive, it serves as a comprehensive base for gaining robust insights into LSS in healthcare. The classification framework was based on the nature of LSS literature and the work of Glasgow et al. (2010) and De Koning et al. (2006). The articles were reviewed, analyzed and classified based on the following categories:

1. Year of publication
2. Publication journal
3. Major application areas
4. Key tools and methods
5. Improvements and benefits to healthcare context
6. Dominating research method

This framework provided guidelines for pursuing rigorous research on LSS in healthcare and clarify the confusion in the literature regarding what constitutes LSS theory and how does it integrate with improvement strategies in that context.

RESULTS AND ANALYSIS OF THE CLASSIFICATIONS

1. Distribution of LSS in Healthcare by Year of Publication

Figure 2 shows the distribution of 162 articles on LSS in healthcare published over the period from 2004 to January 2014. There appears to be scant research outputs before 2004. The publication trend has been improved in recent years and the number of articles has increased significantly in 2013 which indicates an increasing interest in LSS applications in healthcare.

2. Distribution of Articles by Journal

There were a total of 108 different journals from healthcare and business disciplines that published articles on LSS in healthcare (Figure 3).

Figure 2. Distribution of articles on LSS in healthcare by year (2004 - January 2014)

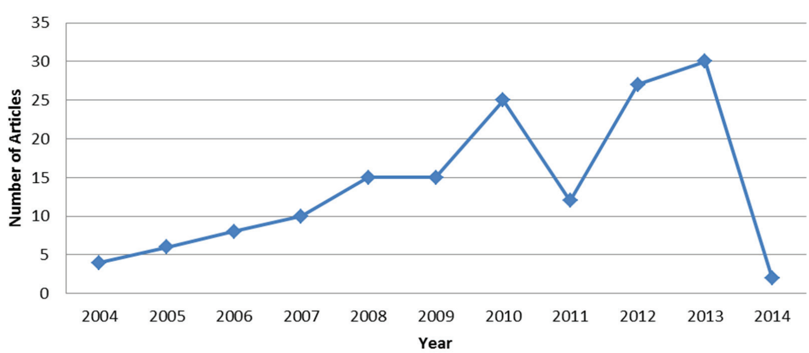
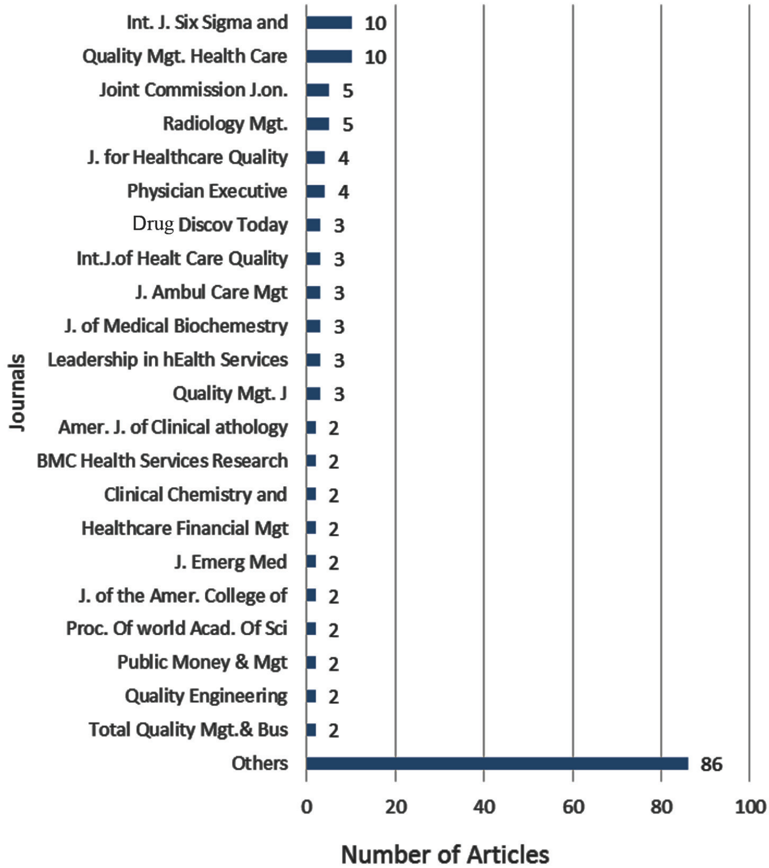


Figure 3. Distribution of articles on LSS in healthcare by journal

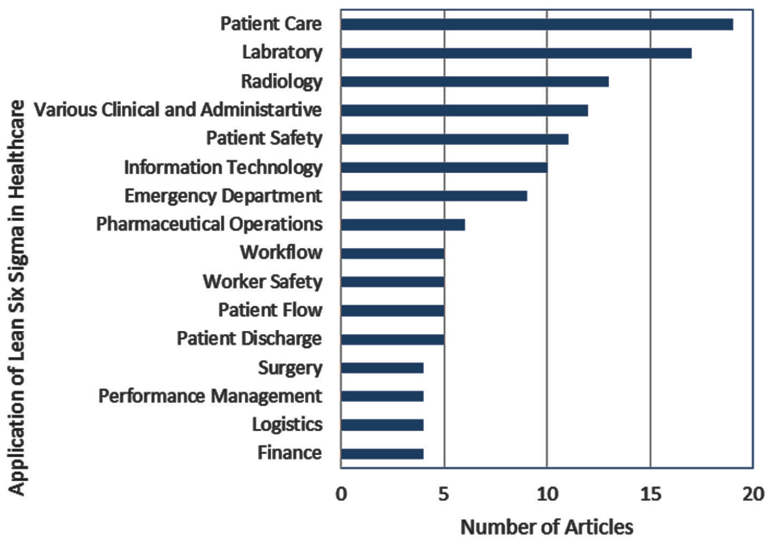


3. Distribution of Articles by Area of Application

Figure 4 illustrate top areas of LSS application in healthcare. It is unavoidable to have an article that is relevant to more than one theme, so listing an article under more than one theme was allowed. For example, an article may address radiology department as an application and safety as a key process for improvement. In such a case, a more weighted process is chosen to classify the article according to the author's judgment.

Twenty 20 areas of application were identified in the articles. The most heavily investigated area of application is *patient care* (19 articles) where quality of healthcare delivery in general is the key focus. The second largest area of LSS application in healthcare is *Laboratory* department (17 articles) where reliability of results, testing process, standards, reporting, waste

Figure 4. Distribution of articles by area of LSS application in healthcare



elimination, turnaround time (TAT), and automation were of high LSS concern. Moreover, *Radiology* department (13 articles) was among the top three areas of LSS applications in healthcare. The main concern was improving imaging quality and processes, workflow, patient flow, procurement, examination time, satisfaction, waste elimination. Table 1 provides a list of author contributions within each area of LSS application in healthcare.

4. Distribution of Articles by LSS Tools and Methods

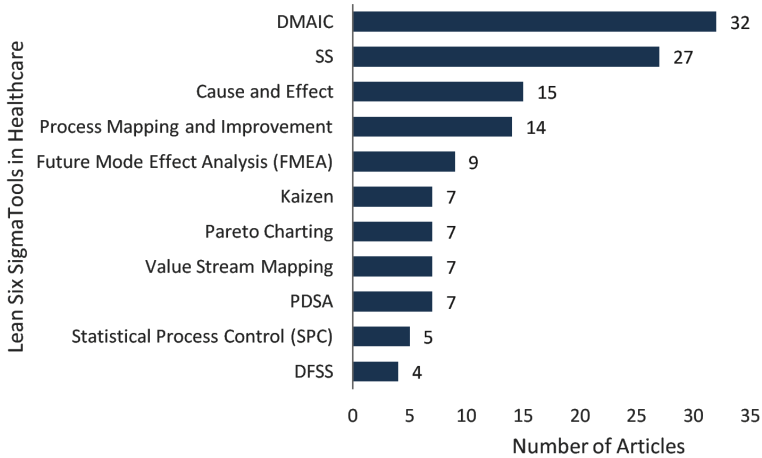
A great deal of literature on LSS in healthcare has focused on tools and techniques that can be employed by LSS teams to manage quality problems in healthcare. Examples of these tools and techniques include *DMAIC*, *DFSS*, *5S*, *Pareto analysis*, *root cause analysis*, *process mapping* or *process flow chart*, *Gantt chart*, *affinity diagrams*, *run charts*, *histograms*, *quality function deployment* (QFD), *suppliers-input-process-output-customer* (SIPOC), *Kano model*, *brainstorming*, *process capability analysis*, *benchmarking*, etc. Moreover, a LSS technique may utilize various tools. For example, *statistical process control* (*SPC*) is a technique that may utilize various tools including *control charts*, *histograms*, *root cause analysis*, etc.

Figure 5 shows that the largest part of LSS in healthcare literature deals with the theorization and application of *DMAIC* methodology (32 articles).

Table 1. Author contribution to areas of LSS application in healthcare

Area of LSS Application in Healthcare	Authors
Patient Care	Aldarrab (2006); Black (2009); Dahl (2009); Fairbanks (2007); Farzianpour et al. (2012); Fillingham (2007); Garfield (2009); Glasgow et al. (2010); Hina-Syeda et al. (2013); Kim et al (2006); Lin et al (2013); Martin (2007); Mathieson (2006); Neufeld et al. (2013); Parks et al (2008); Veluswamy et al. (2010); Viau and Southern (2007); Young et al. (2004); Dahl (2009)
Laboratory	Blick (2013); Carlson et al. (2012); Cloete and Bester (2012); Das, B. (2011); Gijo et al (2013); Hassell et al. (2010); Llopis et al. (2011); Mayer et al (2011); Plebani and Lippi (2011); Stankovic (2004; 2008); Stankovic and DeLauro (2010); Stoiljković et al (2011); Sunyog (2004); Villa (2010); Pantanowitz et al (2008); Costello and Molloy (2009)
Radiology	Aakre et al (2010); Bashir et al (2012); Bucci and Musitano (2011); Coffin (2013); de Bucourt et al (2011); García-porres et al. (2013); McDonald and Kirk (2013); Waldron (2011); Yamamoto et al (2010); Bahensky et al (2005); Viau and Southern (2007); Chan et al. (2005); Roth et al (2010)
Various Clinical and Administrative Processes	Black (2009); Bullas et al. (2007); de Koning et al. (2006); Gamm et al (2007); Gremyr et al (2012); Gowen III et al. (2012); Jimmerson et al (2005); McJoynt et al. (2009); Taner et al. (2007); Schweikhart and Dembe (2009); Yusof et al. (2012); Van Den Heuvel et al. (2005)
Patient Safety	Buell (2010); Farzianpour et al. (2012); Gowen III et al. (2012); Karsten (2011); Martin (2007); McFadden et al. (2014); Niemeijer et al (2011); Schriefer and Leonard (2012); Shabot et al (2013); Stankovic (2004); Veluswamy et al. (2010)
Information Technology	Aleem (2013); Bhaskar et al. (2012); Holden and Hackbart (2012); Johnson et al. (2009); Stoiljković et al (2011); Pantanowitz et al (2008); Pate (2012); Villa (2010); Yusof et al. (2012); Zandi (2013)
Emergency Department	Aldarrab (2006); Dickson et al. (2009); Christianson et al (2005); Crane et al (2014); Eite et al. (2010); Mandahawiet al (2010); Mazzocato et al. (2012); Van den Heuvel et al. (2006); Zilm et al (2010)
Pharmaceutical operations	Al-Araidah et al (2010); Bi et al. (2013); Junker et al (2011); Noguera et al (2013); Sewing et al. (2008); Ullman and Boutellier (2008)
Patient Discharge	Allen et al. (2010); El-Banna (2012); Frings and Grant (2005); Niemeijer et al. (2010; 2012)
Patient Flow	Aakre et al (2010); Chan et al. (2005); Fairbanks (2007); Jimmerson et al (2005); Mathieson (2006)
Worker Safety	Baddour and Saleh, (2013); Carboneau et al (2010); Chassin (2013); Kaplan et al. (2009); Miles (2006)
Workflow	Bahensky et al (2005); Hassell et al. (2010); Holden and Hackbart (2012); Roth et al (2010); Sunyog (2004)
Surgery	Cima et al. (2011; 2013); Dickson (2013); Nicolay et al.(2012)
Performance Mgt.	Christianson et al (2005); Niemeijer et al (2011); Rajan et al. (2012); Robbins et al (2012)
Logistics	Al-Qatawneh et al. (2013); de Bucourt et al (2011); Jin, M. et al. (2008); Van Lent et al. (2012)
Finance	Caldwell (2006); Gitlow and Gitlow (2013); Mugdh and Pilla (2012); Tyson (2010)

Figure 5. Distribution of articles by LSS tools and methods in healthcare



DMAIC is used to improve already existing processes and can be divided into five phases; define, measure, analyze, improve and control. Several studies have shown successful cases of *DMAIC* application in healthcare (see Table 2 for author contributions). The second largest LSS tools applied in healthcare is *5S principles* (27 articles). *5S principles* refer to five Japanese words that are used to organize and manage the workspace and workflow with intent of eliminating waste and reducing process inefficiencies. The *5S principles* are:

- **(Seiri) Sort:** Ensuring only important items are stored in the workspace and eliminating any other items that are not used in the process.
- **(Seiton) Straighten:** Focusing on "straightening" the work path for materials, tools and the work process through physically organizing the work area with the best locations for the needed items "every item is in its place." Straighten involves removal of clutter and use of ergonomic principles to arrange required items in an efficient manner.
- **(Seiso) Sweep:** Keeping the workplace clean and neat. Cleanliness is a regular part of the daily work effort, not an extra effort initiated when the workplace gets too messy at the end of every shift or operation.
- **(Seiketsu) Standardize:** Applying consistent and standardized ways of working through which everyone knows their role and responsibility so that actions are taken the same right way every time.
- **(Shitsuke) Sustain:** Ensuring that the previous stated principles will be continually applied as a part of the culture of the institution and everyone's responsibility.

Table 2. Author contributions to LSS tools and methods in healthcare

LSS Tools	Authors
DMAIC	Al-Araidah et al (2010); Allen et al. (2010); Al-Qatawneh et al. (2013); Baddour and Saleh, (2013); Carboneau et al (2010); Chand (2011); Cheng and Chang (2012); Chiarini (2012); Cloete and Bester (2012); DuPree et al (2009); Elik (2013); Feng and Antony (2010); Feng and Manuel (2008); Gijo et al (2013); Gowen III et al. (2012); Hilton et al. (2008); Mandahawi (2011); Mandahawiet al (2010); Martinez et al. (2011); Mazzocato et al. (2012); McJoynt et al. (2009); Miles (2006); Mozammel and Mapa (2012); Niemeijer et al (2011); Niemeijer et al. (2010); Niemeijer et al. (2012); Paccagnella et al (2012); Pan et al. (2008); Robbins et al (2012); Taner (2013); Taner et al. (2007); Toledo et al (2013)
5S	Al-Araidah et al (2010); Bahensky et al (2005); Caldwell (2006); Chand (2011); Cheng and Chang (2012); Cima et al. (2011); de Bucourt et al (2011); Gayed et al (2013); Gowen III et al. (2012); Grove et al. (2010); Jin. et al. (2008); Junker et al (2011); Laureani et al (2013); Mathieson (2006); Niemeijer et al (2012); Niemeijer et al. (2010); Rajan et al. (2012); Roth et al (2010); Schattenkirk (2012); Stankovic (2008); Stankovic and DeLauro (2010); Taner (2013); Tyson (2010); Van den Heuvel et al. (2006); Viau and Southern (2007); Villa (2010); Yusof et al. (2012)
Cause and Effect	Allen et al. (2010); Chiarini (2012); El-Banna (2012); Gowen III et al. (2012); Gijo et al (2013); Hina-Syeda et al. (2013); Laureani et al (2013); Miles (2006); Schriefer and Leonard (2012); Seidl and Newhouse (2012); Taner (2013); Taner et al. (2007); Van den Heuvel et al. (2006); Viau and Southern (2007); Yu et al. (2008)
Process Mapping and Improvement	Allen et al. (2010); Christianson et al (2005); Deckard et al (2010); Feng and Antony (2010); Frings and Grant (2005); Gowen III et al. (2012); Lin et al (2013); Mazzocato et al. (2012); Schattenkirk (2012); Stankovic (2008); Stoiljković et al (2011); Taner (2013); Taner et al. (2007); Villa (2010)
Failure Mode Effect Analysis (FMEA)	Chiarini (2012); Cloete and Bester (2012); Hina-Syeda et al. (2013); Karsten (2011); Niu et al. (2010); Schriefer and Leonard (2012); Seidl and Newhouse (2012); Taner et al. (2007); Van den Heuvel et al. (2006)
PDSA	Feng and Antony (2010); Fischman (2010); Gowen III et al. (2012); Morrow (2012); Nicolay et al.(2012); Schriefer and Leonard (2012); Varkey and Kollengode (2011);
Value Stream Mapping	Chiarini (2012); Cima et al. (2011); Gowen III et al. (2012); Grove et al. (2010); McJoynt et al. (2009); Stankovic (2008); Yusof et al. (2012)
Pareto Charting	Allen et al. (2010); Chiarini (2012); Cloete and Bester (2012); Hina-Syeda et al. (2013); Mandahawi (2011); Taner et al. (2007); Van den Heuvel et al. (2006)
Kaizen	Bahensky et al (2005); Cloete and Bester (2012); Gowen III et al. (2012); Schattenkirk (2012); Stankovic (2008); Stoiljković et al (2011); van Leeuwen and Does (2010)
Statistical Process Control (SPC)	Allen et al. (2010); Gowen III et al. (2012); Nicolay et al.(2012); Taner et al. (2007); Van den Heuvel et al. (2006)
DFSS	Gremyr et al (2012); Junker et al (2011); Kaplan et al. (2009); Mandahawiet al (2010)
Ishikawa Diagram	Cloete and Bester (2012); Van den Heuvel et al. (2006)
Design of Experiment (DOE)	El-Banna (2012); Van den Heuvel et al. (2006)

Table 2 illustrates a list of author contributions to each of LSS tools and methods in healthcare.

5. Distribution of Articles by Improvements and Benefits to Healthcare Context

When LSS is implemented successfully in healthcare context, it will offer a disciplined approach for improving effectiveness and efficiency in a broad range of operations. The most cited benefit of LSS in healthcare is reducing *patient waiting time* (34 articles). Table 3 represents author contributions to LSS benefits in healthcare, while Figure 6 shows the rank of these benefits as their citation in the literature.

Table 3. Author contributions to LSS benefits and improvement in healthcare

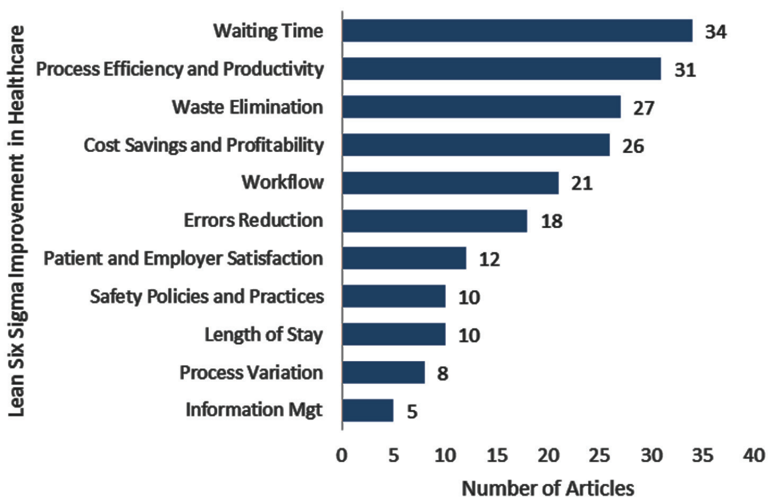
Improvement	Authors
Waiting Time	Aakre et al (2010); Ahmed et al (2013); Al-Araidah et al (2010); Aleem (2013); Allen et al. (2010); Blick (2013); Chan et al. (2005); Christianson et al (2005); Cima et al. (2011); Costello and Molloy (2009); Das (2011); de Koning et al. (2006); Deckard et al (2010); Eite et al. (2010); El-Banna (2012); Fairbanks (2007); Fischman (2010); Gijo et al (2013); Hassell et al. (2010); Jimmerson et al (2005); Johnson et al. (2009); Lin et al (2013); Mandahawiet al (2010); Mathieson (2006); Mayer et al (2011); Mazzocato et al. (2012); Niemeijer et al. (2010); Paccagnella et al (2012); Roth et al (2010); Sunyog (2004); Van den Heuvel et al. (2006); Young et al. (2004); Yu et al. (2008); Zilm et al. (2010);
Process Efficiency and Productivity	Aakre et al (2010); Cheng and Chang (2012); Craven et al. (2006); Dahl (2009); Deckard et al (2010); Feng and Manuel (2008); Frings and Grant (2005); Garfield (2009); Gowen III et al. (2012); Gremyr et al (2012); Grove et al. (2010); Holden and Hackbart (2012); Junker et al (2011); Kovach et al. (2008); Langabeer et al (2009); Mandahawi (2011); Mazzocato et al. (2012); McJoynt et al. (2009); Mugdh and Pilla (2012); Niemeijer et al. (2012); Schriefer and Leonard (2012); Schweikhart and Dembe (2009); Sewing et al. (2008); Stankovic (2008); Stankovic and DeLauro (2010); Taner (2013); Tyson (2010); Ullman and Boutellier (2008); Yu et al. (2008); Yusof et al. (2012); Zilm et al. (2010)
Waste Elimination	Al-Araidah et al (2010); Bahensky et al (2005); Caldwell (2006); Chand (2011); Cheng and Chang (2012); Cima et al. (2011); de Bucourt et al (2011); Gayed et al (2013); Gowen III et al. (2012); Grove et al. (2010); Jin. et al. (2008); Junker et al (2011); Laureani et al (2013); Mathieson (2006); Niemeijer et al (2012); Niemeijer et al. (2010); Rajan et al. (2012); Roth et al (2010); Schattenkirk (2012); Stankovic (2008); Stankovic and DeLauro (2010); Taner (2013); Tyson (2010); Van den Heuvel et al. (2006); Viau and Southern (2007); Villa (2010); Yusof et al. (2012)
Cost Saving and Profitability	Bahensky et al (2005); Bucci and Musitano (2011); Caldwell (2006); Carboneau et al (2010); Carlson et al. (2012); Chiarini (2012); Christianson et al (2005); Cima et al. (2011); Dahl (2009); de Koning et al. (2006); El-Banna (2012); Feng and Antony (2010); Gayed et al (2013); Gitlow and Gitlow (2013); Gowen III et al. (2012); Impellizzeri et al (2009); Jimmerson et al (2005); Jin, M. et al. (2008); Kaplan et al. (2009); Kovach et al. (2008); Niemeijer et al (2012); Schweikhart and Dembe (2009); Sewing et al. (2008); Stankovic (2008); Sunyog (2004); Taner (2013)

continued on following page

Table 3. Continued

Improvement	Authors
Workflow	Bi et al. (2013); Crane et al (2014); Fairbanks (2007); Fischman (2010); García-porres et al. (2013); Holden and Hackbart (2012); Jin, M. et al. (2008); Johnson et al. (2009); Junker et al (2011); 9Kuo et al (2011); Mazzocato et al. (2012); McJoynt et al. (2009); Morrow (2012); Neufeld et al. (2013); Pantanowitz et al (2008); Parks et al (2008); Schriefer and Leonard (2012); Taner (2013); Taner et al. (2007); Toledo et al (2013); Villa (2010)
Clinical and Administrative Errors	Ahmed et al (2013); Chassin (2013); Cloete and Bester (2012); Costello and Molloy (2009); Das (2011); Elik (2013); Garfield (2009); Gowen III et al. (2012); Jimmerson et al (2005); Langabeer et al (2009); McJoynt et al. (2009); Noguera et al (2013); Paccagnella et al (2012); Pantanowitz et al (2008); Plebani and Lippi (2011); Stankovic (2004); Stankovic and DeLauro (2010); Van Den Heuvel et al. (2005);
Satisfaction of Patients and Employees	Bucci and Musitano (2011); Chiarini (2013); DuPree et al (2009); Eite et al. (2010); El-Banna (2012); Impellizzeri et al (2009); Kaplan et al. (2009); McDonald and Kirk (2013); McFadden et al. (2014); Mozammel and Mapa (2012); Stankovic (2008); Taner (2013)
Length of Stay	Ahmed et al (2013); Blick (2013); Gayed et al (2013); Mandahawi (2011); Mandahawiet al (2010); Niemeijer et al. (2010); Niemeijer et al. (2012); Toledo et al (2013); Van Den Heuvel et al. (2005); van Leeuwen and Does (2010)
Safety Policies and Practices	Baddour and Saleh, (2013); Carboneau et al (2010); Chassin (2013); Chiarini (2012); Christianson et al (2005); Deckard et al (2010); Farzianpour et al. (2012); Karsten (2011); Morrow (2012); Veluswamy et al. (2010)
Process Variation	Chand (2011); Cima et al. (2011); Gitlow and Gitlow (2013); Pan et al. (2008); Stankovic (2004); Stankovic (2008); Stuenkel and Faulkner (2009); Woodard (2005)
Information Management	Blick (2013); Costello and Molloy (2009); Mozammel and Mapa (2012); Yusof et al. (2012); Zandi (2013);

Figure 6. Distribution of articles by LSS benefits and improvement in healthcare



The literature has emphasized the key role of LSS in reducing *patient waiting time* in several healthcare departments such as pathology department (Gijo et al., 2013), emergency department (Mandahawi et al., 2010) and hospital registration (Yu and Yang, 2008). The second cited benefit of LSS in healthcare was *improving process efficiency and* productivity (31 articles). Examples of include improve the efficiency of resident rounding process (Chand, 2011), operating room (Cima et al., 2011), internal medicine residency clinic (Fischman, 2010), laboratory department (Villa, 2010) and physician productivity in a clinical department (Feng and Antony, 2010). *Waste elimination* was among the top three benefits of LSS application in healthcare (27 articles). For example, Bahensky et al. (2005) reported that LSS has a positive impact on identification and elimination of non-value added activities in Radiology CT scanning.

Mozammel and Mapa (2012) applied LSS in nursing shift directors process improvement to create a baseline metric of the existing process, eliminate the non-value added tasks from the daily workload, and provide control methodologies for sustainability. They indicated that the greatest achievement has been the reduction in overall documentation from 39% to 26%. Jin et al. (2008) revealed that LSS applications in healthcare logistics center design and operation has resulted in better storage management, better use of space, an improved and cleaner workspace, more timely and efficient delivery of the right items with the right amount to the right patients and tracking and reducing waste. Other key benefits of LSS applications in healthcare include *cost saving, workflow*, *reduction of clinical and administrative errors, satisfaction of patients and employees, improving length of stay, enhancing safety policies and practices, process variation, and better management of healthcare information.*

6. Distribution of Articles by Research Method

The distribution of articles by research method is shown in Figure 7. About sixty-five percent of the articles (105 articles) were classified as empirical articles using either surveys or case studies, while about 35% of the articles (57 articles) were theoretical articles which usually employ extensive literature review to focus on the development of concepts, propositions, models, or theory building of LSS in healthcare. Also, it is clear that *case study* is the most dominant research method in LSS in healthcare articles (95 articles, 59%). Figure 8 shows the growing gap over the years between case study method and other research methods, particularly survey research. Case study method is used to document and analyze LSS application in a wide variety of

Figure 7. Distribution of articles by empirical and theoretical LSS research in healthcare

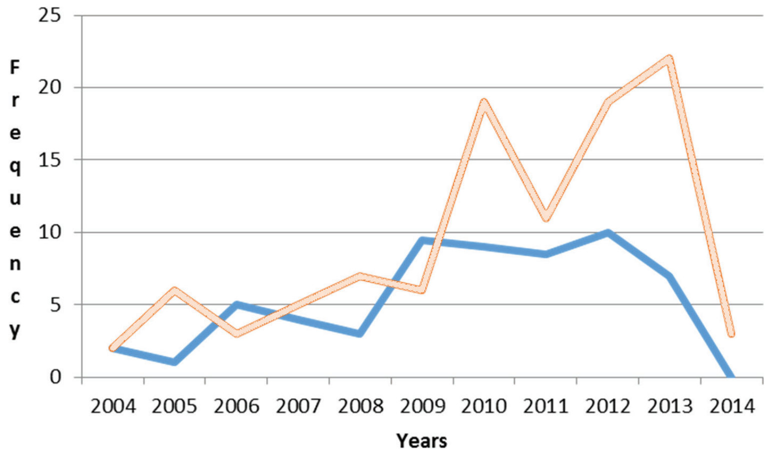
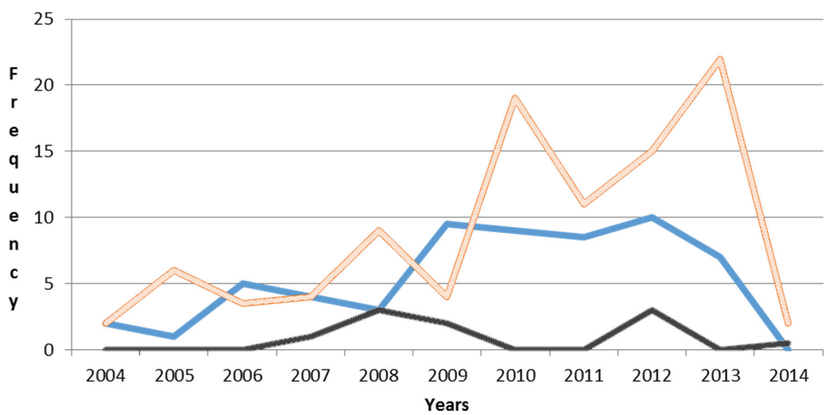


Figure 8. Distribution of LSS in healthcare articles by case, survey and review methods



hospitals, clinics, departments and processes such as emergency department (Dickson et al., 2009), healthcare logistics (Jin et al., 2008), cancer center (McJoynt et al., 2009), liver and knee MRI examinations (Ruth et al., 2010), patient care in a mammography center (Viau, 2007). On the contrary, survey research represents the least dominant research method in LSS in healthcare (10 articles, 6.2%) where typical wide perspective or superficial generalization are employed to a large number of respondents or cases.

Examples of LSS in healthcare survey research involve Farzianpour et al. (2012) who surveyed patient safety in inpatient wards in a university hospital. They suggested that the quality level of physical environment and safety training were medium while safety of patients' beds, health and management of incidents were at desirable quality level. Also, Gowen et al. (2012) surveyed six Sigma and lean management in US hospitals. They indicated that process improvement (PI) initiatives mediate the effect of medical error sources to enhance three hospital outcomes involving patient safety, operational effectiveness, and competitiveness.

Hilton et al. (2008) applied survey research to examine factors critical to the success of LSS quality program in an Australian hospital. They indicated that there are gaps between what the respondents expect as being a necessary part of a quality program and the actual results in the hospital.

CONCLUSION AND IMPLICATIONS FOR FUTURE RESEARCH

Our conclusions are based on the analysis of 162 LSS in healthcare articles that were published in 108 journals over a ten-year period from 2004 to January 2014. Overall, we have observed that LSS research has attracted the attention of both practitioners and academics within the healthcare context reflecting an increasing trend over years. Clearly, LSS research is difficult to confine to specific healthcare discipline as it is scattered across various journals from different disciplines. However, the leading journals contributing to LSS in healthcare research represent multidisciplinary perspectives integrating quality, management and healthcare in general with less focus from clinical or medical journals on LSS. While processes related to *patient care* and *laboratory* quality dominate LSS application areas in healthcare, less emphasis has been given to issues related to processes involving healthcare safety, workflow, surgery and logistics. The review has observed that LSS in healthcare research is empirical in nature which fortifies the use of primary data. Case study was the dominant research method in LSS in healthcare and this is may be due to the nature of quality problems in general that need to be documented and examined over a period of time (Aboelmaged, 2010). In addition, the lack of LSS implementation across wide range of healthcare services and processes makes the use of survey methods impractical. In addition, empirical nature of LSS in healthcare research allow for implementing various LSS tools and methods including DMAIC and 5S as expected. Nevertheless, little attention has been given to other tools such as *Kaizen, Ishikawa Diagram* and *Design of Experiment* (DOE). It is noteworthy that reducing *patient waiting time, improving process efficiency* and *waste elimination* are the greatest benefits of LSS application in healthcare. In contrast, reducing process variation and enhancing information management are barely perceived as among the key benefits of LSS applications in healthcare.

Although this review does not claim to be exhaustive, it does provide reasonable insights into the state of the art of LSS in healthcare research. There is very little room for clarifying the confusion in the literature as to what constitutes LSS theory and how does it integrate with improvement strategies in different contexts. We would argue that theoretical development is critical to enhance forthcoming LSS studies. Based on the literature review presented in this chapter, we identify below a number of research implications and directions for future research as follows:

- Mapping LSS research efforts in healthcare would encourage researchers and practitioners to propose standards for successful LSS projects in healthcare as well as designing LSS curriculum within healthcare context.
- Life cycle of LSS projects in healthcare is not well established. Therefore, documenting common phases in LSS life cycle within healthcare context and role of organizational factors that accelerate or hold up these phases.
- Distinguishing between clinical and administrative processes while examining LSS application in healthcare is also important.
- There is no doubt that LSS will grow rapidly in future covering various disciplines and domains. Hence, there is a need to structure LSS application within each domain. Particularly, when there is a dominance of specific organizational culture model.
- There is a need for rigors research constructing LSS barriers based on user experience in such context.
- The link between LSS and other approaches such as reengineering and governance require further research efforts to underline the degree of integration and evolving tools and techniques that can be used.
- Researchers can benefit from integrating analytical and empirical research methods to provide deep insights into LSS research through applying triangulation approach and using multiple data sources.
- Researchers are also encouraged to compare findings of peer-reviewed articles with books and conference proceedings on LSS to inform managers and practitioners the current trends and challenges of LSS implementation.

Research on LSS is a never-ending process, however this chapter attempts to insinuate significant insights into the state of the art of LSS in healthcare research and clarify confusion in the literature as to what constitutes LSS role in improving healthcare context.

REFERENCES

Aboelmaged, M. G. (2010). Six Sigma quality: A structured review and implications for future research. *International Journal of Quality & Reliability Management*, *27*(3), 269–318. doi:10.1108/02656711011023294

Aboelmaged, M. G. (2011). Reconstructing Six Sigma barriers in manufacturing and service organizations: The effects of organizational parameters. *International Journal of Quality & Reliability Management*, *28*(5), 519–541. doi:10.1108/02656711111132562

Andersson, R., Eriksson, H., & Torstensson, H. (2006). Similarities and differences between TQM, six sigma and lean. *The TQM Magazine*, *18*(3), 282–296. doi:10.1108/09544780610660004

Antony, J. (2006). Six Sigma for service processes. *Business Process Management Journal*, *12*(2), 234–248. doi:10.1108/14637150610657558

Byrne, G., Lubowe, D., & Blitz, A. (2007). Using a lean Six Sigma approach to drive innovation. *Strategy and Leadership*, *35*(2), 5–10. doi:10.1108/10878570710734480

De Koning, H., & Verver, J. P. S. (2006). Lean six sigma in healthcare. *Journal for Healthcare Quality*, *28*(2), 4–11. doi:10.1111/j.1945-1474.2006.tb00596.x PMID:16749293

George, M. L. (2002). *Lean Six Sigma: Combining Six Sigma Quality with Lean Speed*. New York: McGraw-Hill.

Glasgow, J. M., Scott-Caziewell, J. R., & Kaboli, P. J. (2010). Guiding inpatient quality improvement: A systematic review of Lean and Six Sigma. *Joint Commission Journal of Quality Qual Patient Saf*, *36*(12), 533–540. PMID:21222355

Heckert, L. (2013). *Lean Six Sigma at Alliant Energy*. Available at: http://www.alliantenergy.com/wcm/groups/wcm_internet/@int/@ae/documents/document/mdaw/mdmy/~edisp/032825.pdf

Kwak, Y. H., & Anbari, F. T. (2006). Benefits, obstacles, and future of Six Sigma approach. *Technovation*, *26*(5-6), 708–715. doi:10.1016/j.technovation.2004.10.003

ADDITIONAL READING

Assarlind, M., Gremyr, I., & Bäckman, K. (2013). Multi-faceted views on a Lean Six Sigma application. *International Journal of Quality & Reliability Management*, *30*(4), 387–402. doi:10.1108/02656711311308385

Christenson, R. H., Snyder, S. R., Shaw, C. S., Derzon, J. H., Black, R. S., & Mass, D. et al. (2011). Laboratory medicine best practices: Systematic evidence review and evaluation methods for quality improvement. *Clinical Chemistry*, *57*(6), 816–825. doi:10.1373/clinchem.2010.157131 PMID:21515742

Psychogios, A., Atanasovski, J., & Tsironis, L. (2012). Lean Six Sigma in a service context. *International Journal of Quality & Reliability Management*, *29*(1), 122–139. doi:10.1108/02656711211190909

Ransom, S., Joshi, M., & Nash, D. (2004). *The Healthcare Quality Book: Vision, Strategy, and Tools*. Chicago: Health Administration Press.

Yamazaki, T., Ikeda, M., & Umemoto, K. (2011). Enhancement of healthcare quality using clinical-pathways activities. *Vine*, *41*(1), 63–75. doi:10.1108/03055721111115557

KEY TERMS AND DEFINITIONS

5S Principles: An approach that is used to organize and manage the workspace and workflow aiming at eliminating waste and reducing process inefficiencies. The approach uses 5 Japanese words including (Seiri) Sort, (Seiton) Straighten, (Seiso) Sweep, (Seiketsu) Standardize and (Shitsuke) Sustain.

DMAIC: Is a step-by-step six sigma approach focusing on defining, measuring, analyzing, improving and controlling quality initiatives.

Lean Six Sigma: An approach focused on improving quality, reducing variation and eliminating waste in an organization.

Quality: A measure of excellence or a state of being free from defects, deficiencies, and significant variations.

Six Sigma: A metric of process measurement symbolized by the Greek letter σ that represents the amount of variation with a normal data distribution that targets quality level of 3.4 defects per million opportunities (DPMO).

APPENDIX

A Full List of Analyzed LSS in Healthcare Articles

160. Aakre, K.T., Valley T. B., & O'Connor, M. K. (2010). Quality initiatives: improving patient flow for a bone densitometry practice: results from a Mayo Clinic radiology quality initiative. *Radiographics*, 30(2), 309-315.
161. Ahmed, S., Manaf, N. H., & Islam, R. (2013). Effects of Lean Six Sigma application in healthcare services: a literature review. *Rev Environ Health*, 28(4), 189-194.
162. Al-Araidah, O., Momani, A., Khasawneh, M., & Momani, M. (2010). Lead-time reduction utilizing lean tools applied to healthcare: the inpatient pharmacy at a local hospital. *Journal for Healthcare Quality*, 32(1), 59–66.
163. Aldarrab, A. (2006). Application of lean six sigma for patients presenting with st-elevation myocardial infarction: the Hamilton health sciences experience. *Healthcare Quality*, 9(1), 56-61.
164. Aleem S. (2013). Translating 10 lessons from lean six sigma project in paper-based training site to electronic health record-based primary care practice: challenges and opportunities. *Qual Manag Health Care*, 22(3), 224-35.
165. Allen, T. T., Shih-Hsien, T., Swanson, K., & McClay, M. A. (2010). Improving the Hospital Discharge Process with Six Sigma Methods. *Quality Engineering* 22(1), 13-14.
166. Al-Qatawneh, L., Abdallah, A., & Zalloum, S. (2013). Reducing Stock-out Incidents at a Hospital Using Six Sigma. *Proceedings of World Academy of Science, Engineering and Technology* 77, 463-470.
167. Baddour, A. A., Saleh, & Hager A. (2013). Use Six Sigma Approach to Improve Healthcare Workers Safety, *International Journal of Pure and Applied Sciences and Technology*, 18(1), 54-71.
168. Bahensky, J. A., Roe, J., & Bolton, R. (2005), Lean sigma--will it work for healthcare? *J Healthc Inf Manag*. Winter, 19(1), 39-44.
169. Bashir, M. R., Dale, B. M., Gupta, R. T., Horvath, J. J., Boll, D. T., & Merkle, E. M. (2012). Gradient shimming during magnetic resonance imaging of the liver: comparison of a standard protocol versus a novel reduced protocol. *Invest Radiol*, 47(9), 524-539.

170. Bhaskar, R., Kapoor, A., & Vo, A. (2012). Pioneering the health care quality improvement in india using six sigma: a case study of a northern India hospital. *Journal of Cases on Information Technology*, 14(4), 41-55.
171. Bi, F. C., Frost, H. N., Ling, X., Perry, D. A., & Sakata, S. K. (2013). Driving external chemistry optimization via operations management principles. *Drug Discov Today*, pii: S1359-6446(13).
172. Black, J. (2009). Transforming the patient care environment with Lean Six Sigma and realistic evaluation. *J Healthc Qual*. 3, 29-35.
173. Blick, K. (2013). Providing critical laboratory results on time, every time to help reduce emergency department length of stay: how our laboratory achieved a six sigma level of performance. *American Journal of Clinical Pathology*. *140*(2), 193-202.
174. Bonilla, C., Pawlicki, T., Perry, L., & Wesselink, B. (2008). Radiation oncology Lean Six Sigma project selection based on patient and staff input into a modified quality function deployment. *International Journal of Six Sigma and Competitive Advantage*, 4(3)196-208.
175. Bucci, R. V., & Musitano, A. (2011). A Lean Six Sigma journey in radiology. *Radiol Manage*. 33(3), 27-33.
176. Buell, J. M. (2010). Lean Six Sigma and patient safety: a recipe for success. *Healthc Exec*. 25(2), 26-38.
177. Bullas, S., & Bryant, J. (2007). Successful Systems Sustaining Change. *Studies in Health Technology and Informatics,* 129, 1199-1203.
178. Caldwell, C. (2006). Lean-Six Sigma: tools for rapid cycle cost reduction. *Healthc Financ Manage*. 60(10), 96-108.
179. Carboneau, C., Benge, E., Jaco, M., & Robinson, M. (2010). A Lean Six Sigma Team Increases Hand Hygiene Compliance and Reduces Hospital-Acquired MRSA Infections by 51%. *Journal for Healthcare Quality*, 32(4)61–70.
180. Carlson, R. O., Amirahmadi, F., & Hernandez, J. S. (2012). A primer on the cost of quality for improvement of laboratory and pathology specimen processes. *Am J Clin Pathol*, 138(3), 347-54.
181. Chan, W. P., Wen-Ta, C., Wan-Ming, C., Min-Fang, L., & Chu, B. (2005). Applying Six Sigma methodology to maximise magnetic resonance imaging capacity in a hospital. *International Journal of Healthcare Technology & Management*, 6 (3), 321-330.
182. Chand, D. (2011), Observational Study Using the Tools of Lean Six Sigma to Improve the Efficiency of the Resident Rounding Process. *Journal of Graduate Medical Education*, 3(2), 144-150.

183. Chassin, Mark (2013). Improving The Quality Of Health Care: What's Taking So Long?. *Health Affairs*. 32(10), 1761-1765.
184. Chen-Yang, C., & Pu-Yuan, C. (2012). Implementation of the Lean Six Sigma framework in non-profit organisations: A case study. *Total Quality Management & Business Excellence* 23(3/4), 431-441.
185. Chiarini, A. (2012). Risk management and cost reduction of cancer drugs using Lean Six Sigma tools. *Leadership in Health Services*, 25(4), 318 – 330.
186. Chiarini, A. (2013). Building a Six Sigma model for the Italian public healthcare sector using grounded theory. *International Journal of Services and Operations Management,* 14(4), 491-508.
187. Chiarini, A., & Bracci, E. (2013). Implementing Lean Six Sigma in healthcare: issues from Italy *Public Money & Management*, 33(5), 361-368.
188. Christianson, J., Warrick, L., Howard, R., & Vollum, J. (2005). Deploying Six Sigma in a Health Care System as a Work in Progress. *Joint Commission Journal on Quality and Patient Safety*, 31(11), 603-613.
189. Cima, R., Dankbar, E., & Lovely, J. (2013). Colorectal Surgery Surgical Site Infection Reduction Program: A National Surgical Quality Improvement Program–Driven Multidisciplinary Single-Institution Experience. *Journal of the American College of Surgeons*, 216(1), 23-33.
190. Cima, R., Brown, M., & Hebl, J. (2011). Use of Lean and Six Sigma Methodology to Improve Operating Room Efficiency in a High-Volume Tertiary-Care Academic Medical Center. *Journal of the American College of Surgeons*, 213(1), 83–92.
191. Cloete, B. C., & Bester, A. (2012) A Lean Six Sigma approach to the improvement of the selenium analysis method. *Onderstepoort J Vet Res*, 79(1), E1-E13.
192. Coffin, C. T. (2013). The continuous improvement process and ergonomics in ultrasound department. Radiol Manage, 35(1), 22-35.
193. Costello, C., Molloy, & O. (2009). A process model to support automated measurement and detection of out-of-bounds events in a hospital laboratory process. *Journal of Theoretical and Applied Electronic Commerce Research*, 4(2), 31-54.
194. Crane, P. W., Zhou, Y., Sun, Y., Lin, L., & Schneider, S. M. (2014). Entropy: A Conceptual Approach to Measuring Situation-level Workload Within Emergency Care and its Relationship to Emergency Department Crowding. *J Emerg Me*d., pii: S0736-4679(13)01106-2.

195. Craven, E., Clark, J., & Cramer, M. (2006). NewYork-Presbyterian Hospital uses Six Sigma to build a culture of quality and innovation. *Journal of Organizational Excellence*, 25(4), 11–19.
196. Dahl, O. J. (2009). Cost and efficiency lead to increased value for the patient and bottom line for the practice. *J Med Pract Manage.,* 25(2), 87-99.
197. Das, B. (2011). Validation Protocol: First Step of a Lean-Total Quality, Management Principle in a New Laboratory Set-up in a Tertiary Care Hospital in India. *Ind J Clin Biochem*, 26(3), 235–243.
198. De-Bucourt, M., Busse, R., & Guttler, F. (2011). Lean manufacturing and Toyota Production System terminology applied to the procurement of vascular stents in interventional radiology. *Insights Imaging*, 22, 415–423.
199. De-Koning, H., Verver, J., van den Heuvel, J., Bisgaard, S., & Does, R. (2006). Lean Six Sigma in Healthcare. *Journal for Healthcare Quality*, 28(2), 4–11.
200. Deckard, G. J., Borkowski, N., Diaz, D., Sanchez, C., & Boisette S. A. (2010). Improving timeliness and efficiency in the referral process for safety net providers: application of the Lean Six Sigma methodology. *J Ambul Care Manage.* 33(2), 124-130.
201. Delisle, D. (2013). Care transitions programs: a review of hospital-based programs targeted to reduce readmissions. *Professional Case Management* 18(6), 273-283.
202. DelliFraine, J., & Langabeer, J. (2009).An institutional perspective on quality initiatives: evidence beyond manufacturing. *International Journal of Information Systems and Change Management*, 4(1), 3-14.
203. DelliFraine, J. L, Langabeer, J. R., & Nembhard, I. M. (2010). Assessing the evidence of Six Sigma and Lean in the health care industry. *Qual Manag Health Care*. 19(3), 211-25.
204. Dickson, A. (2013). Utilizing a Lean Six Sigma Approach to Reduce Total Joint Arthroplasty Surgical Site Infections in a Community Hospital. *American Journal of Infection Control*, 41(6), S131-S132.
205. Dickson, E., Anguelov, Z., Vetterick, D., Eller, A., & Singh, S. (2009). Use of Lean in the Emergency Department: A Case Series of 4 Hospitals. *Annals of Emergency Medicine*, 54(4), 504-510.
206. DuPree, E., Martin, L., & Anderson, R. (2009). Improving Patient Satisfaction with Pain Management Using Six Sigma Tools. *Joint Commission Journal on Quality and Patient Safety*, 35(7), 343-350.

207. Eitel, D. R., Rudkin, S. E., Malvehy, M. A., Killeen, J. P., & Pines, J. M. (2010). Improving service quality by understanding emergency department flow: a White Paper and position statement prepared for the American Academy of Emergency Medicine. *J Emerg Med.*, 38(1), 70-9.
208. El-Banna., & Mahmoud, A. (2012). Improving Patients Discharge Process in Hospitals by using Six Sigma Approach, Improving Patients Discharge Process in Hospitals by using Six Sigma Approach. *Proceedings of World Academy of Science, Engineering and Technology,* 68, 112-121.
209. Elik, L. L. (2013). Learning and applying new quality improvement methods to the school health setting. NASN Sch Nurse., 28(6), 306-11.
210. Everett, L. Q., & Sitterding, M. C. (2013). Building a culture of innovation by maximizing the role of the RN. *Nurs Adm Q.*, 37(3), 194-202.
211. Fairbanks, C. B. (2007). Using Six Sigma and Lean methodologies to improve OR throughput. *AORN J*. 86(1), 73-82.
212. Farzianpour, F., Fouroshani, A., Dargaha, K., & Hosseini, H. (2012). Patient safety in inpatient wards: sample of a university hospital. *American Journal of Applied Sciences*, 9(12), 2004-2011.
213. Feng, M. & Manuel, C. (2008). Under the knife: a national survey of six sigma programs in US healthcare organizations. *International Journal of Health Care Quality Assurance*, 21(6), 535 – 547.
214. Feng, Q., & Antony, J. (2010). Integrating DEA into Six Sigma methodology for measuring health service efficiency. *The Journal of the Operational Research Society*, 61(7), 1112-1121.
56. Fillingham, D. (2007). Can lean save lives?. *Journal of Leadership in Health Services*, 20(4), 231-241.
58. Fischman, D. (2010). Applying Lean Six Sigma methodologies to improve efficiency, timeliness of care, and quality of care in an internal medicine residency clinic. *Qual Manag Health Care*, 19(3), 201-10.
215. Frings, G. W., & Grant, L. (2005). Who Moved My Sigma Effective Implementation of the Six Sigma Methodology to Hospitals. *Quality and Reliability Engineering International*, 21(3), 311-328.
216. Gamm, L., Kash, B., & Bolin, J. (2007). Organizational technologies for transforming care: measures and strategies for pursuit of IOM quality aims. *J Ambul Care Manage*, 30(4), 291-301.
217. García-porres, J., & Ortiz-posadas, M. R. (2013). Sigma Level Performance of the Innovated Process in the Imaging Department at a Mexican Health Institute. *Journal of Digital Imaging*, 26(2), 353-60.

218. Garfield, S., Barber, N., Walley, P., Willson, A., & Eliasson, L. (2009). Quality of medication use in primary care - mapping the problem, working to a solution: a systematic review of the literature. *BMC Medicine*, 7(50), 1-12.
219. Gayed, B., Black, S., Daggy, J., & Munshi, I. A. (2013). Redesigning a joint replacement program using Lean Six Sigma in a Veterans Affairs hospital. *JAMA Surg*., 148(11), 1050-6.
220. Gijo, E., Antony, J., & Hernandez, J. (2013). Reducing patient waiting time in a pathology department using the Six Sigma methodology. *Leadership in Health Services*, 26(4), 253 – 267.
221. Gitlow, H. S., & Gitlow, A. L. (2013). Deming-Based Lean Six Sigma Management as an Answer to Escalating Hospital Costs. *The Quality Management Journal*, 20(3), 6-9.
222. Glasgow, J. M., Scott-Caziewell, J. R., & Kaboli, P. J. (2010). Guiding Inpatient Quality Improvement: A Systematic Review of Lean and Six Sigma. *Joint Commission Journal on Quality and Patient Safety*, 36(12), 533-540.
223. Gowen, C., Stock, G., & Mcfadden, C. (2008). Simultaneous implementation of Six Sigma and knowledge management in hospitals. *International Journal of Production Research,* 46(23), 6781-679.
224. Gowen, C. R., McFadden, K. L., & Settaluri, S. (2012). Contrasting continuous quality improvement, Six Sigma, and lean management for enhanced outcomes in US hospitals. *American Journal of Business*, 27(2), 133-153.
225. Gremyr, I., Gustavsson, S., & Gideberg, A. (2012). The medication process - a design for Six Sigma project. *International Journal of Six Sigma and Competitive Advantage* (7)1, 1-11.
226. Grove, A L., & Meredith, M. J. O. (2010). Lean implementation in primary care health visiting services in National Health Service UK. *Qual Saf Health Care*, 19(5), 9 – 13.
227. Hassell, L., Glass, C., Yip, C., & Eneff, P. (2010). The combined positive impact of Lean methodology and Ventana Symphony autostainer on histology lab workflow. *BMC Clinical Pathology*, 10(2), 1-9.
228. Hilton, R., Balla, M., & Sohal, A. S. (2008). Factors critical to the success of a Six-Sigma quality program in an Australian hospital. *Total Quality Management & Business Excellence*, 19(9) 887-896.
229. Hina-Syeda, H., Kimbrough, C., Murdoch, W., & Markova, T. (2013). Improving Immunization Rates Using Lean Six Sigma Processes: Alliance of Independent Academic Medical Centers National Initiative III Project. *The Ochsner Journal*, 13, 310–318.

230. Holden, R., & Hackbart, G. (2012). From group work to teamwork: A case study of "Lean" rapid process improvement in the ThedaCare Information Technology Department. *IIE Transactions on Healthcare Systems Engineering*, 2(3), 190-201.
231. Hurley, B. T., Taylor, J., Levett, C., & Huber, E. H (2008), Implementation of six sigma and lean methodology into the anticoagulation management process. *Journal of Thrombosis and Thrombolysis*, 25, 106-109.
232. Impellizzeri, F., Bizzini, M., Leunig, M. Maffiuletti, N., & Mannion, A. (2009). Money matters: exploiting the data from outcomes research for quality improvement. *Eur Spine J.,* 18, 348–359.
233. Jimmerson, C., Weber, D., & Sobek, II, D. (2005). Reducing Waste and Errors: Piloting Lean Principles at IHC. *Joint Commission Journal on Quality and Patient Safety*, 31(5), 249-257.
234. Jin, M., Switzer, M., & Agirbas, G. (2008). Six Sigma and Lean in healthcare logistics centre design and operation: a case at North Mississippi Health Services. *International Journal of Six Sigma and Competitive Advantage,* 4(3), 270-288.
235. Johnson, C. W., Chatterjee, M., & Kubala S. (2009). Efficient and effective compound management to support lead optimization. *J Biomol Screen*. 14(5), 523-30.
236. Junker, B., Maheshwari, G., & Ranheim, T. (2011). Design-for-Six-Sigma To Develop a Bioprocess Knowledge Management Framework. *PDA J Pharm Sci Technol*., 65(2), 140-65.
237. Kaplan, S., Bisgaard, S., Truesdell, D., & Zetterholm, S. (2009). Design for Six Sigma In Healthcare: Developing an Employee Influenza Vaccination Process. *Journal for Healthcare Quality*, 31(3), 36–43.
238. Karsten, M (2011). Patient Safety: Commitment versus Compliance. *Nurse Leader*, 9(4), 47-49.
239. Kim, C., Spahlinger, D., Kin, J., & Billi J. (2006). Lean health care: What can hospitals learn from a world-class automaker?. *Journal of Hospital Medicine*, 1(3), 191–199.
240. Kollberg, B., Dahlgaard, J.. & Brehmer, P. O. (2007). Measuring lean initiatives in health care services: issues and findings. *International Journal of Productivity and Performance Management*, 56, 7 – 24.
241. Kovach, J., De La Torre, L., & Walker, D. (2008). Continuous improvement efforts in healthcare: a case study exploring the motivation, involvement and support necessary for success. *International Journal of Six Sigma and Competitive Advantage,* 4(3), 254-269.

242. Kuo, A. M. H., Borycki, A., & Kushniruk, A. (2011). A healthcare Lean Six Sigma system for postanesthesia care unit workflow improvement. *Qual Manage Health Care*. 20(1), 4-14.
243. Langabeer, J. R., DelliFraine, J. L., Heineke, J., & Abbass, I. (2009). Implementation of Lean and Six Sigma quality initiatives in hospitals: a goal theoretic perspective. *Operations Management Research*. 2, 13-27.
244. Laureani, A., Malcolm, B., & Jiju, A. (2013). Applications of Lean Six Sigma in an Irish hospital. *Leadership in Health Services*, 26 (4), 322 – 337.
245. Lin, S. Y., Gavney, D., Ishman, S. L., & Cady-Reh, J. (2013). Use of lean sigma principles in a tertiary care otolaryngology clinic to improve efficiency. *Laryngoscope*. 123(11), 2643-8.
246. Llopis, M., Trujillo, G., Llovet, M., & Tarres, E. (2011). Quality indicators and specifications for key analytical-extranalytical processes in the clinical laboratory. Five years' experience using the Six Sigma concept. *Clinical Chemistry and Laboratory Medicine*. 49(3), 463-470.
247. Mandahawi, N., Al-Shihabi, S., Abdallah, A., & Alfarah, Y. (2010). Reducing waiting time at an emergency department using design for Six Sigma and discrete event simulation. *International Journal of Six Sigma and Competitive Advantage*, 6(1-2), 91-104.
248. Mandahawi, N., Al-Araidah, O., Boran, A., & Khasawneh, M. (2011). Application of Lean Six Sigma tools to minimise length of stay for ophthalmology day case surgery. *International Journal of Six Sigma and Competitive Advantage*, 6(3), 156-172.
249. Mannon, M. (2014). Lean Healthcare and Quality Management: The Experience of ThedaCare. *Quality Management Journal*, 21(1), 4-7.
250. Martin, W. F. (2007). Quality Models: Selecting the Best Model to Deliver Results. *Physician Executive*. 33(3), 24-31.
251. Martinez, E., Chavez-Valdez, P., & Holt, N. (2011). Successful Implementation of a Perioperative Glycemic Control Protocol in Cardiac Surgery: Barrier Analysis and Intervention Using Lean Six Sigma. *Anesthesiology Research and Practice*, Article ID 565069.
252. Mathieson, S. (2006). Lean healthcare. Weight watchers. *Health Service Journal*, 116, 4-5.
253. Mayer, H., Brummer, J., & Brinkmann, T. (2011). Precise turnaround time measurement of laboratory processes using radiofrequency identification technology. *Clin Lab.*, 57(1-2), 75-81.

254. Mazzocato, P., Holden, R., & Brommels, M. (2012). How does lean work in emergency care? A case study of a lean-inspired intervention at the Astrid Lindgren Children's hospital, Stockholm, Sweden. *BMC Health Services Research*, 12(28), 1-13.
255. McDonald, A. P., & Kirk, R. (2013). Using lean Six Sigma to improve hospital based outpatient imaging satisfaction. *Radiol Manage*., 35(1), 38-45.
256. McFadden, K., Lee, J., Gowen, C., & Sharp, B. (2014) Linking Quality Improvement Practices to Knowledge Management Capabilities. *Quality Management Journal*, 21(1), 34-55.
257. McJoynt, T., Hirzallah, M., & Satele, D. (2009). Building a Protocol Expressway: The Case of Mayo Clinic Cancer Center, *Journal of Clinical Oncology*, 27, 3855-3860.
258. Miles, E. N. (2006). Improvement in the incident reporting and investigation procedures using process excellence (DMAI2C) methodology, *Journal of Hazardous Materials*, 130(1-2), 169-181.
259. Morrow, R. (2012). Perioperative Quality and Improvement. *Anesthesiology Clinics*, 30(3), 555-563.
260. Mozammel, A., & Mapa, L. (2012). Application of Lean Six Sigma in Healthcare - Nursing Shift Directors Process Improvement. *Journal of Management & Engineering Integration*, 4(2), 58-65.
261. Mugdh, M., & Pilla, S. 2012. Revenue cycle optimization in health care institutions. A conceptual framework for change management. *Health Care Manag*, 31(1), 75-80.
262. Murphree, P., Vath, R. R., & Daigle, L. (2011). Sustaining Lean Six Sigma projects in health care. *Physician Exec*., 37(1), 44-58.
263. Neufeld, N. J., Hoyer, E. H., Cabahug, P., González-Fernández, M., Mehta, M., Walker, N. C., Powers, R. L., & Mayer, R. S. (2013). A Lean Six Sigma quality improvement project to increase discharge paperwork completeness for admission to a comprehensive integrated inpatient rehabilitation program. *Am J Med Qual*., 28(4), 301-317.
264. Nicolay, C. R., Purkayastha, S., Greenhalgh, A., Benn, J., Chaturvedi, S., Phillips, N., & Darzi, A. (2012). Systematic review of the application of quality improvement methodologies from the manufacturing industry to surgical healthcare. *British Journal of Surgery*, 99(3), 324–335.
265. Niemeijer, G. C., Flikweert, E., Trip, A., Does, R. J., Ahaus, K. T., Boot, A. F., & Wendt, K. W. (2012). The usefulness of lean six sigma to the development of a clinical pathway for hip fractures, Journal of Evaluation in Clinical Practice, 19(5), 909–914.

266. Niemeijer, G. C., Trip, A., de Jong, L, J., Wendt, K. W., & Does, R. J. (2012). Impact of 5 years of lean six sigma in a University Medical Center. Qual Manag Health Care, 21(4), 262-278.
267. Niemeijer, G., Does, R.. de Mast, J., Trip, A., & Huevel, J. V. D. (2011). Generic Project Definitions for Improvement of Health Care Delivery: A Case-Based Approach, *Quality Management Health Care*, 20 (2), 152–164.
268. Niemeijer, G., Trip, A., Ahaus, K., Does, R. J., & Wendt, K. W. (2010). Quality in Trauma Care: Improving the Discharge Procedure of Patients by Means of Lean Six Sigma, *The Journal of TRAUMA® Injury, Infection, and Critical Care*, 69(3), 614-619.
269. Niu, G., Lau, D., & Pecht, M. (2010). Computer Manufacturing Management Integrating Lean Six Sigma and Prognostic Health Management, *International Journal of Performability Engineering*, 6(5), 453-466.
270. Noguera, F., Megía, F., Riquelme, F., Balasch, I., Parisi, S., Solsona, M. D., & Poveda, A. J. L. (2013). Improving inpatient pharmacoterapeutic process by Lean Six Sigma methodology, *Rev Calid Asist*., 28(6), 370-80.
112. Paccagnella, A., Mauri, A., & Spinella, N. (2012). Quality improvement for integrated management of patients with type 2 diabetes. *Qual Manag Health Care*, 21(3), 146-59.
114. Feng-Chuan, P., Mei, Y. S., & Shen, J. C. (2008). Reducing unplanned endotracheal extubation in hospital ICU through Six Sigma and HQIC. *International Journal of Six Sigma and Competitive Advantage*, 4(4), 382-394.
271. Pantanowitz, L., Hornish, M., & Goulart, R. A. (2008). Informatics applied to cytology. *Cytojournal*, 29(5), 16-24.
272. Parks, J. K., Klein, J., Frankel, H. L., Friese, R. S., & Shafi, S. (2008). Dissecting delays in trauma care using corporate lean six sigma methodology. *J Trauma*, 65(5), 1098-104.
273. Pate, C. (2012). Focusing Quality Improvement Efforts through Lean Six Methods in Health Information Technology. *International Journal of Reliable and Quality E-Healthcare*, 1(1), 21-23.
274. Plebani, M., & Lippi G. (2011). Closing the brain-to-brain loop in laboratory testing. *Clin Chem Lab Med*., 49(7), 1131-3.
275. Pocha, C. (2010). Lean Six Sigma in health care and the challenge of implementation of Six Sigma methodologies at a Veterans Affairs Medical Center. *Qual Manag Health Care*, 19(4), 312-8.

276. Polk, J. D. (2011) Lean Six Sigma, innovation, and the change acceleration process can work together. *Physician Exec*., 37(1), 38-42.
277. Proudlove, N., Moxham, C., & Boaden, R. (2008). Lessons for Lean in Healthcare from Using Six Sigma in the NHS. *Public Money & Management*, 28, 27-34.
278. Rajan, A., Sullivan, R., Bakker, S., & van Harten, W. H. (2012). Critical appraisal of translational research models for suitability in performance assessment of cancer centers. Oncologist, 17(12), e48-57.
279. Reijula, J., & Tommelein, I. (2012). Lean hospitals: a new challenge for facility designers, *Intelligent Buildings International*, 4(2), 126-143.
280. Robbins, J., Garman, A. N., Song, P. H., & McAlearney, A. S. (2012). How high-performance work systems drive health care value: an examination of leading process improvement strategies. *Qual Manag Health Care*., 21(3), 188-202.
281. Roth, C., Boll, D., Wall, L., & Merkle, E. (2010). Evaluation Of MRI Acquisition Workflow With Lean Six Sigma Method: Case Study Of Liver And Knee Examinations, *American Journal of Roentgenology*, 195(2), 150-156.
282. Schattenkirk, D. (2012). Building sustainable internal capacity for quality within a healthcare environment, *TQM Journal*, 24(4), 374-382.
283. Schriefer, J., & Leonard, M. S. (2012). Patient safety and quality improvement: an overview of QI. *Pediatr Rev*. 33(8), 353-359.
284. Schweikhart, S., & Dembe, A. (2009). The Applicability of Lean and Six Sigma Techniques to Clinical and Translational Research, *J Investig Med*., 57(7), 748–755.
285. Seidl, K. L., & Newhouse, R. P. (2012). The intersection of evidence-based practice with 5 quality improvement methodologies. *J Nurs Adm*. 42(6), 299-304.
286. Sewing, A., Winchester, T., Carnell, P., Hampton, D., & Keighley, W. (2008). Helping science to succeed: improving processes in R&D. *Drug Discov Today*. 13(5-6), 227-33.
287. Shabot, M. M., Monroe, D., Inurria, J., Garbade, D., & France, A. C. (2013). Memorial Hermann: high reliability from board to bedside. *Jt Comm J Qual Patient Saf.,* 39(6), 253-7.
288. Stankovic, A. K., & DeLauro, E. (2010). Quality improvements in the preanalytical phase: focus on urine specimen workflow. *MLO Med Lab Obs*., 42(3), 20, 22, 24-7.
289. Stankovic, A. K. (2004). The laboratory is a key partner in assuring patient safety. *Clin Lab Med*., 24(4), 1023-35.

290. Stankovic, A. (2008). Developing a Lean Consciousness for the Clinical Laboratory. Journal of Medical Biochemistry, 27(3), 354-361.
291. Stoiljkovic, V., Trajkovic, J., & Stoiljkovic, B. (2011). Lean Six Sigma Sample Analysis Process in a Microbiology Laboratory. *Journal of Medical Biochemistry*. 30(4), 346–353.
292. Stuenkel, K., & Faulkner, T., (2009). A community hospital's journey into Lean Six Sigma. Fr*ont Health Serv Manage.*, 26(1), 5-13.
293. Sunyog, M. (2004). Lean Management and Six-Sigma yield big gains in hospital's immediate response laboratory. Quality improvement techniques save more than $400,000. *Clin Leadersh Manag Rev*., 18(5), 255-8.
294. Taner, M. (2013). Application of Six Sigma methodology to a cataract surgery unit. International Journal of Health Care Quality Assurance, 26(8), 768 – 785.
295. Taner, M., Sezen, B., & Antony, J. (2007). An overview of six sigma applications in healthcare industry," *International Journal of Health Care Quality Assurance*, 20(4), 329 – 340.
296. Toledo, A. H., Carroll, T., Arnold, E., Tulu, Z., Caffey, T., Kearns, L. E., & Gerber, D. A. (2013). Reducing liver transplant length of stay: a Lean Six Sigma approach. *Prog Transplant*, 23(4), 350-64.
297. Tyson, P. (2010). Preparing for the new landscape of payment reform. *Healthc Financ Manage*. 64(12), 42-8.
298. Ullman, F., & Boutellier R. (2008). A case study of lean drug discovery: from project driven research to innovation studios and process factories. *Drug Discov Today*, 13(11-12), 543-50.
299. Heuvel, V. D., Does, R. & de Koning, H. (2006). Lean Six Sigma in a hospital, *Int. J. Six Sigma and Competitive Advantage*, 2(4), 377-381.
300. Heuvel, V. D., Does, J., Ronald, J. M. M., & Verver, J, P, S. (2005). Six Sigma in healthcare: lessons learned from a hospital. *International Journal of Six Sigma and Competitive Advantage*. 1(4), 380-388.
301. van Leeuwen, K., & Does, R. (2010). Quality Quandaries: Lean Nursing. *Quality Engineering*, 23(1), 94-99.
302. Van Lent, W., Sanders, E., & Van Harten, W. (2012). Exploring improvements in patient logistics in Dutch hospitals with a survey, *BMC Health Services Research*, 12, 1-9.
303. Varkey, P., & Kollengode, A. (2011). A framework for healthcare quality improvement in India: the time is here and now!. *J Postgrad Med*. 57(3), 237-41.
304. Varkey, P., Reller, M., & Resar, R. (2007). Basics of Quality Improvement in Health Care. *Mayo Clinic Proceedings*, 82(6), 735–739.

305. Veluswamy, R., & Price, R. (2010). I've Fallen and I Can't Get Up: Reducing the Risk of Patient Falls. *Physician Executive*. 36(3), 50-3.
306. Vest, J., & Gamm, L. (2009). A critical review of the research literature on Six Sigma, Lean and StuderGroup's Hardwiring Excellence in the United States: the need to demonstrate and communicate the effectiveness of transformation strategies in healthcare. *Implementation Science*, 4(35), 1-9.
307. Viau, M., & Southern, B. (2007). Six Sigma and Lean concepts, a case study: patient centered care model for a mammography center. *Radiol Manage*,29(5), 19-28.
308. Villa, D. (2010). Automation, Lean, Six Sigma: Synergies for Improving Laboratory Efficiency. *Journal of Medical Biochemistry Journal of Medical Biochemistry*, 29(4), 339–348.
309. Waldron, D. (2011). Visit, revamp, and revitalize your business plan: Part 2. *Radiol Manage*., 33(3), 16-20.
310. Waring, J., & Bishop, S. (2010). Lean healthcare: Rhetoric, ritual and resistance. *Social Science & Medicine*, 71(7), 1332–1340.
311. Woodard., & Tanisha, D. (2005). Addressing Variation in Hospital Quality: Is Six Sigma the Answer?. *Journal of Healthcare Management*. 50(4), 226-36.
312. Yamamoto, J. J., Malatestinic, B. L., & Angela, J. R. (2010). Facilitating process changes in meal delivery and radiological testing to improve inpatient insulin timing using Six Sigma method. *Qual Manage Health Care*, 19(3), 189-200.
313. Young, T., Brailsford, S., Connell, C., Davies, R., Harper, P., & Klein, J. H. (2004). Using industrial processes to improve patient care. *BMJ*, 17, 162–164.
314. Yu, Q., & Yang, Kai (2008). Hospital registration waiting time reduction through process redesign. *International Journal of Six Sigma and Competitive Advantage*, 4(3), 240-253.
315. Yusof, M., Khodambashi, S., & Mokhtar, A. (2012). Evaluation of the clinical process in a critical care information system using the Lean method: a case study. *BMC Medical Informatics and Decision Making*, 12, 1-14.
316. Zandi, F. (2013). Identification of e-Health reference architecture using a bi-objective medical informatics decision support framework: the optimal lean and six sigma alignment. *Journal of Decision Systems*, 22(3), 202-223.
317. Zilm F., Crane, J., Roche., & K. T. (2010). New directions in emergency service operations and planning. *J Ambul Care Manage*, 33(4), 296-306.

Chapter 10

An Assessment of Leadership Traits and the Success of Six Sigma Projects

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ABSTRACT

In this chapter, more effective green belt leaders rated themselves higher than less effective green belt leaders on the following traits: articulate, perceptive, self-confident, self-assured, and determined. In addition, the more effective green belt leaders reported stronger upper management support than did less effective green belt leaders. In this chapter, more effective black belt leaders rated themselves higher than less effective black belt leaders on the following traits: articulate, perceptive, self-confident, self-assured, determined, dependable, and friendly. The more effective black belt leaders also reported stronger upper management support and project experience than did less effective black belt leaders. Clearly, in times of economic uncertainty and increasing global competiveness, managers need to be able to recognize the individuals who possess the needed traits to make their companies profitable.

DOI: 10.4018/978-1-4666-7320-5.ch010

INTRODUCTION

Fuqua and Newman (2005) argue that systems theory is the most appropriate approach in the twenty-first century for achieving effective leadership in an organization. Systems theory defines leadership more broadly than the traditional bureaucratic models of leadership; it focuses on all members as leaders, rather than just one leader and a great many followers. The benefits of implementing systems theory are flexibility in leadership roles; increase sense of continuity within an organization over time; power and authority as relates to function and responsibility (those with specific expertise in a given area and who bear responsibility for outcomes in that area would be vested with power and authority over that arena of organizational functioning). Chemers (2000) defined effective leadership as “a process of social influence in which one person is able to enlist the aid and support of others in the accomplishment of a common task.” First he argued that the leader must be perceived as competent and trustworthy by her/his followers. Next, leaders must coach, guide, and support their followers in a way that allows followers to contribute to group goal attainment while satisfying their own personal needs and goals. Finally, effective leaders must use the skills and abilities possessed by themselves and their followers to accomplish the group’s mission. Hedricks and Weinstein (1999), in their analysis of a personality profile of a corporate leader, found effective leadership to interrelate with the following four competency areas: Influencing and Directing; Building Relationships; Problem Solving and Decision Making; and Personal Organization and Time Management. With respect to Influencing and Directing, leaders possessed the motivation to assertively and persuasively present their ideas, to successfully complete projects. In the competency area of Building Relationships, leaders placed less emphasis on developing interpersonal relationships for the purpose of socializing, and leaders did not have a high need to be liked. Leaders excelled in the area of Problem Solving and Decision Making because of their above average risk-taking and sense of urgency. Finally, with respect to Personal Organization and Time Management, leaders appear to be focused on implementing their highly innovative ideas in such a way as to ensure their timely completion of projects.

Kilburg (2007) focused on reverence and temperance as the foundation of effective leadership. Ancient Chinese and Greek models of effective leadership were based on the assumption that individuals in these positions must first seek and practice virtuous behavior. Only when they were thought to have reasonably demonstrated that they understood and could consistently enact behavior that was reverent, temperate, courageous, just, and wise would such individuals be proposed for senior positions in state government.

Duff (2007) delivered a speech to graduates of the Professional Executive Leadership School in which he defined an effective leader. Captain Duff serves with the Lynchburg, Virginia, Police Department. According to Captain Duff, characteristics of effective leaders include the following:

- **Optimism:** Thinking positively all the time;
- **True North Vision:** Must establish a vision thinking towards the future;
- **Relentless Preparation:** Must always be prepared by constantly analyzing strengths, weaknesses, opportunities, and threats;
- **Teamwork:** Must think in terms of "we" instead of "I";
- **Communication:** Must have good verbal and written communication skills; and
- **Courage:** Must not be afraid to make the right decision.

As demonstrated above, effective leadership can be defined from many different perspectives. Effective leadership is the key to successfully implementing Six Sigma projects (ReVelle, 2004). An effective leader in the context of Six Sigma is a leader who has implemented projects that resulted in significant cost savings to the bottom line. Six Sigma is a process-focused, statistically based approach to business improvement that companies such as Motorola, General Electric, Tyco Electronics and American Express have used to produce millions of dollars in bottom-line improvements (Hoerl, Rodebaugh, & Snee, 2004). Edward J. Zander, Motorola CEO, stated that Six Sigma has saved his company more than $16 billion to date. General Electric's CEO, Jack Welch, wrote in the annual report that from 1996 to 1998 Six Sigma tactics had saved his company more than $2 billion. Tyco Electronics' CEO, Tom Lynch, wrote in the annual report that from 2003 to 2008 his company has saved more than $700 million. American Express Vice President, Rick Irving, stated that Six Sigma programs have delivered approximately one billion dollars in benefits annually since the launch in 1999. The implementation of Six Sigma strategies has resulted in significant savings for various organizations (Hahn, Hill, Hoerl, & Zinkgraf, 1999). Clearly, in times of economic uncertainty upper management need to be able to recognize the individuals who possess the needed traits for effective leadership. Champions, master black belts, black belts, green belts, and team members make up the core of Six Sigma (ReVelle, 2004). Champions and master black belts work behind the scenes to support people working on projects, as well as the overall initiative (Eckes, 2001). Without a strong and tireless black belt or green belt, Six Sigma teams are usually not effective (Goffnett, 2004). Black belts and green belts are characterized as "future business leaders" (Eckes, 2001) and "the backbone of Six Sigma culture" (Brue, 2002). The problem, then, resides in selecting a green belt or black belt with specific traits that relate to successfully implementing Six Sigma projects. The black belt and green belt must possess strong problem solving, the ability to collect and analyze data, organizational savvy, leadership and coaching experience, and good administrative sense (Kumar, Wolfe, & Wolfe, 2008). Moreover s/he must be adept at project management, the art and science of getting things done on time through the effort of others (Goffnett, 2004). Black belt and green belt candidates are described as disciplined problem solvers who possess a significant amount of technical ability, are comfortable with basic statistics, and are not afraid to question conventional wisdom (Adams, Gupta, & Wilson, 2003; Hoerl, 2001). Black belts and green belts have also been described as open minded change agents and project managers able to communicate effectively at all levels (Brue, 2002). Many experts have insisted that black belts and green belts be able to use a broad set of soft skills as well, such as meeting management and presentation methods (Breyfogle, Cupello, & Meadows, 2001; Eckes, 2001; Hoerl, 2001; Pyzdek, 2000). As a chosen leader, the black belt or green belt will guide a team through the Six Sigma process. The existing literature, however, does not explore the specific traits that black belts and green belts should possess to successfully implement Six Sigma projects. Selecting an effective green belt or black belt could save an organization millions of dollars in terms of their bottom line (Hoerl et al., 2004). This study addresses gaps in the literature, and its results can be used to help in developing future green belt and black belt Six Sigma leaders.

Theoretical Framework

Trait theory forms the theoretical framework for this study. Trait theory was developed from the "great man" theories, and was used to study effective leaders. Trait theory indicates that traits play a critical role in regard to effective leadership practices (Bass, 1990). This study employs trait theory by correlating leader traits (independent variables) such as: articulate, perceptive, self-confident, self-assured, persistent, determined, trustworthy, dependable, friendly, and outgoing; with hard cost savings (dependent variable) for the organization. Also, project experience, upper management support and skill set, which are the mediating variables, will be correlated with hard cost savings. Many Six Sigma practitioners believe the aforementioned mediating variables affect the success of completing Six Sigma projects.

Northouse (2004) notes that during the early part of the twentieth century, leadership traits were studied to determine what made certain people great leaders. Early studies of trait theory were known as "great man" theories because they focused on identifying the innate qualities and characteristics possessed by social, political and military leaders. It was believed that people were born with these traits and only the "great" people possessed them. During this time, research concentrated on determining the specific traits that clearly differentiated leaders from followers (Bass, 1990; Jago, 1982). In the mid-twentieth century, the trait approach was challenged by research that questioned the universality of leadership traits. In a major review in 1948, Stogdill suggested that no consistent set of traits differentiated leaders from non-leaders across a variety of situations. An individual with leadership traits who was a leader in one situation might not be a leader in another situation. Rather than being understood as a quality that individuals possessed, leadership was re-conceptualized as a relationship built within a social situation (Stogdill, 1948). Personal factors related to leadership continued to be important, but researchers contended that these factors were to be considered as relative to the requirements of the situation (Northouse, 2004). In recent years, there has been resurgence in interest in the trait approach in explaining how traits influence leadership (Bryman, 1992). For example, based on a new analysis of previous trait research, Lord, DeVader, and Alliger (1986) found that personality traits were strongly associated with individuals' perceptions of leadership. Similarly, Kirkpatrick and Locke (1991) have gone so far as to claim that effective leaders are actually distinct types of people in several key respects. Further evidence of renewed interest in the trait approach can be seen in the current emphasis given by many researchers to visionary and charismatic leadership (Bass, 1990; Bennis & Nanus, 1985; Tushman, O'Reilly, & Nadler, 1989; Zaleznik, 1977). In summary, the trait approach is alive and well. It began with an emphasis on identifying the qualities of great persons; next, it shifted to include the impact of situations on leadership; and most currently, it has shifted back to reemphasize the critical role of traits in effective leadership (Northouse, 2004).

Purpose of the Study

The purpose of this research is twofold. First, the research identifies specific leadership traits for green and black belt Six Sigma leaders that have a statistical relationship with the success of Six Sigma projects. Second, the study tests the reliability of a scale created from the Leadership Trait Questionnaire items. The LTQ, which is derived from the trait theory, will be used to assess black belt and green belt leadership traits. Independent variables in this study include the following:

- **Articulate:** Communicates effectively with others;
- **Perceptive:** Discerning and insightful;
- **Self-Confident:** Believes in self and one's ability;
- **Self-Assured:** Secure with self, free of doubts;
- **Persistent:** Stays fixed on the goal(s), despite interference;
- **Determined:** Takes a firm stand, acts with certainty;
- **Trustworthy:** Acts believable inspires confidence;
- **Dependable:** Is consistent and reliable;
- **Friendly:** Shows kindness and warmth;
- **Outgoing:** Talks freely, gets along well with others (Northouse, 2004);
- Project Experience;
- Upper Management Support; and
- Technical Skill Set.

The dependent variable is the actual cost savings that will be self-reported by Six Sigma leaders. The actual cost savings for green belt projects that are $50,000 or greater will be considered a successful project. The actual cost savings for black belt projects that are $250,000 or greater will be considered a successful project.

Hypotheses

The following hypotheses ground data analysis for this study. They are framed in terms of traditionally accepted null and alternative hypotheses.

1. **Null Hypothesis:** There is no statistical relationship between the traits of green belt leaders and the success of Six Sigma projects.
    a. **Alternative Hypothesis:** There is a statistical relationship between the traits of green belt leaders and the success of Six Sigma projects.
2. **Null Hypothesis:** There is no statistical relationship between the traits of black belt leaders and the success of Six Sigma projects.
    a. **Alternative Hypothesis:** There is a statistical relationship between the traits of black belt leaders and the success of Six Sigma projects.
3. **Null Hypothesis:** A scale created from the Leadership Trait Questionnaire items is not reliable.
    a. **Alternative Hypothesis:** A scale created from the Leadership Trait Questionnaire items is reliable.

Significance of Study

The existing literature does not explore the specific traits that black belts and green belts should possess to successfully implement Six Sigma projects. However, selecting an effective green belt or black belt could save an organization millions of dollars in terms of their bottom line (Hoerl et al., 2004). This study addresses gaps in the literature, and its results can be used to help in developing future green belt and black belt Six Sigma leaders. Finally, this study demonstrates that the Leadership Trait Questionnaire (LTQ) scale is reliable. Prior to this study the LTQ instrument developed by Peter Northouse had not been tested for reliability. The LTQ instrument offers another method of conceptualizing and operationalizing Six Sigma leaders' ability to assess their leadership traits.

BACKGROUND

Leadership is a topic that has been studied for centuries. It is perceived as a difficult phenomenon to understand because of its many facets. Many research practitioners and scholars in the field of leadership have accepted the challenge to better understand all the components that affect the leadership process. There are many ideologies surrounding leadership. However the following appear to be the core elements related to leadership: leadership is a process, leadership involves influence, leadership occurs in a group context, and leadership involves goal attainment (Northouse, 2007). Leadership is a topic that traces back to early Biblical times. Despite an abundance of research on this topic, practitioners and scholars find it difficult to exactly quantify exactly leadership, and how one accomplishes the leadership role successfully (Bulls, 2008).

The primary argument in the field of leadership surrounds whether leadership is an inherited trait, or a set of qualities and skills that can be learned. Many scholars argue that an individual is born with certain traits that define her/him as a leader. Other scholars view leadership as a learning process, meaning an individual can learn to become a leader. The literature recognizes that leadership as a trait is quite different from describing leadership as a process (Northouse, 2007).

The ideology of leadership from the trait perspective emphasizes that leaders have varying degrees of traits with which they are born. The degree to which an individual possesses these traits determines how effective that person can be as a leader. The ideology that leadership is a learned process based on education, experience and exposure is an inclusive view; from this perspective, leadership is open to all people, not just a set few who were born with certain traits (Jago, 1982). It is debatable whether leadership is a trait, process or both, however trait theory argues for the trait perspective. Leader traits are challenging to quantify, but there are numerous instruments such as the Myers-Briggs Type Indicator, Principles of Adult Learning Scale, Guglielmino, Leadership Trait Questionnaire, and the Campbell Leadership Instrument, that attempt to address and understand the characteristics of effective leaders (Bulls, 2008). Trait theory will be used as the foundation to address the following hypotheses:

1. **Null Hypothesis:** There is no statistical relationship between the traits of green belt leaders and the success of Six Sigma projects.
    a. **Alternative Hypothesis:** There is a statistical relationship between the traits of green belt leaders and the success of Six Sigma projects.
2. **Null Hypothesis:** There is no statistical relationship between the traits of black belt leaders and the success of Six Sigma projects.
    a. **Alternative Hypothesis:** There is a statistical relationship between the traits of black belt leaders and the success of Six Sigma projects.
3. **Null Hypothesis:** A scale created from the Leadership Trait Questionnaire items is not reliable.
    a. **Alternative Hypothesis:** A scale created from the Leadership Trait Questionnaire items is reliable.

Trait Approach

Leadership traits were studied during the early twentieth century in an effort to determine what elements constituted effective leadership. The “great man” theories characterized the first research completed on leadership traits. These theories argue that individuals are born with certain traits that make them leaders and that if an individual was not born with these traits, then s/he could not be a leader. Social leaders, political leaders and military leaders were perceived to possess these innate traits (Northouse, 2007). Research conducted during the early twentieth century demonstrated that leaders had certain traits that followers did not possess (Bass, 1990).

There were advocates and critics of trait theory. Researchers started to question the universal quality of leadership traits during the twentieth century. There were no consistent set of traits that distinguished leaders from followers (Stogdill, 1948). Stogdill’s research demonstrated that both the situation and the environment can contribute to the success or failure of a leader. Stogdill's researcher argues that rather than being an innate quality, a leadership trait evidences itself within the relationship that emerges between people and a social situation. Stogdill's (1948) perspective on trait theory argues that characteristics of individual leaders are evidenced in relationship to a given situation. The basis of this argument is that the leadership ability that is effective in one situation may not work in another.

The trait theory is still considered to be a valid construct as we enter the twenty-first century, and several researchers have focused on restoring trait theory. Bryman's (1992) research demonstrated that traits definitely influence leadership. Further, a person's perception of a leader has a lot to do with the perceived leader's personal characteristics (Lord et al., 1986). There are many self-assessment tools for leaders; however, the Leadership Trait Questionnaire (LTQ) is one of the few that considers the perception of the follower when assessing the leader.

Several leadership traits have emerged into new theories. Charismatic leadership is one of the most prestigious theories that originated from the charisma trait (Bennis & Nanus, 1985). Findings from the research of Kirkpatrick and Lock (1991) supported the view that leaders possess traits that are different from followers.

In summary, the trait approached is still being studied by scholars and practitioners today. The "great man" theories were the first theories to state that leaders were born with certain traits that determined who was destined for success in leadership. Social leaders, political leaders and military leaders were the individuals who were perceived to possess a certain set of traits; therefore they were often research subjects in the field of leadership (Bulls, 2008). Some scholars and practitioners were not advocates of the "great man" theories. Stogdill was a scholar and practitioner who argued that a person's leadership role depends on the environment. Stogdill's research supported the theoretical perspective that the leadership role changes with the environment. As of today the trait theory approach has shifted back to the perspective that traits play a critical role in regard to effective leadership practices.

Study of Major Leadership Traits

Ralph Stogdill conducted two extensive studies on leadership traits. Based on his findings effective leadership depends not only on an individual's traits, but also the situation. Stogdill's research on traits has been the foundation for many other trait research studies. Between 1904 and 1948 Stogdill reviewed and analyzed over 124 traits during his first study. He was able to identify a set of traits that he argued all leaders possessed in order to be effective (see

Table 1. Research traits and characteristics

Researcher(s)	Traits/Characteristics
Stogdill (1948)	intelligence, alertness, insight, responsibility initiative, persistence, self-confidence, sociability
Mann (1959)	intelligence, masculinity, adjustment, dominance, extroversion, conservatism
Stogdill (1974)	achievement, persistence, insight, initiative, self-confidence, responsibility, cooperativeness, tolerance, influence, sociability
Lord et al. (1986)	intelligence, masculinity, dominance, cognitive ability, task knowledge
Kirkpatrick and Locke (1991)	drive, motivation, integrity

Table 1). His research found that traits, as well as the relationship with team members, determined a leader's effectiveness (Stogdill, 1948).

Stogdill reviewed and analyzed 163 traits during his second survey from 1948 to 1970. He expanded the set of traits however; insight, responsibility, initiative, persistence, self-confidence and sociability were common to the first study. Achievement, cooperativeness, tolerance, and influence were the traits that differentiated the second from the first study. This study was noted as being more balanced with regard to describing the traits and their relationship to leadership.

The synopsis of Stogdill's two extensive studies on traits (Stogdill, 1974) is discussed. The leader is characterized by a strong drive for responsibility and task completion, vigor and persistence in pursuit of goals, venturesameness and originality in problem solving, drive to exercise initiative in social situations, self-confidence and sense of personal identity, willingness to accept consequences of decision and action, readiness to absorb interpersonal stress, willingness to tolerate frustration and delay, ability to influence other people's behavior, and capacity to structure social interaction systems to the purpose at hand. (p. 175)

The trait studies conducted by Stogdill inspired other scholars and practitioners to look at the leadership process from perspectives other than the "great man" theory. Mann (1959) reviewed and analyzed over 1,400 personality traits as he focused on the difference between those of leaders and those of non-leaders (see Table 1). Lord et al. (1986) were advocates of Mann's research and conducted a meta-analysis on the over 1,400 traits (see Table 1). Lord and Mann argued that traits could be used to discriminate between leaders and non-leaders (Bulls, 2008).

Kirkpatrick and Locke (1991) stated in their research that "it is unequivocally clear that leaders are not like other people" (p. 59). Drive, motivation, integrity, cognitive ability and task knowledge were the set of traits that they found were possessed by leaders only (see Table 1). They did not argue that only leaders were born with these traits; their perspective was that leadership traits could be innate, could be learned, or both (Northouse, 2007). Bass (1990) stated, "There is no overall comprehensive theory of the personality of leaders. Nonetheless, evidence abounds about particular patterns of traits that are of consequence to leadership, such as determination, persistence, self-confidence, and ego strength" (p. 87). Scholars of trait theories argued that leaders portrayed certain personality traits that were linked to the overall leadership process (Bulls, 2008).

The research on leadership traits does not list a common set of traits for all situations. However it does provide a guide to the type of traits that most leaders in western societies possess. Intelligence, self-confidence, determination, integrity and sociability are the common set of traits that were identified throughout these studies (Bulls, 2008).

The intelligence trait is the ability of the leader to comprehend information. Zaccaro, Kemp, and Bader (2004) found that leaders tend to have higher intelligence than non-leaders. The self-confidence trait includes both the self-esteem and self-assurance principles of the leader. The determination trait is the desire to get a task done. The integrity trait is defined as the act of carrying out the task in an ethical manner. The trait of sociability describes the ability of the leader to be courteous, friendly, tactful, and diplomatic. More recent studies based upon the trait approach tend to be quantitative, rather than qualitative, in approach (Bulls, 2008)

One of the biggest problems in past research relating personality to leadership is the lack of a structure for describing personality, leading to a wide range of traits being investigated under different labels. In recent years Judge, Bono, Ilies, and Gerhardt (2002) conducted research on the taxonomic structure for classifying and organizing traits. This taxonomic structure was called the five-factor model. The five-factor model of personality, often termed the Big Five, can be used to describe the most salient aspects of personality (Hurtz & Donovan, 2000). Proponents argue that the Big Five are heritable and stable over time. The dimensions comprising the five-factor model include Neuroticism, Extraversion, Openness to Experience, Agreeableness, and Conscientiousness (Judge & Bono, 2004). Neuroticism represents the tendency to exhibit poor emotional adjustment and experience negative effects such as anxiety, insecurity, and hostility (Judge et al., 2002). Individuals high in neuroticism tend to view the world through negative lens, score high in neuroticism, and tend to experience emotional distress, whereas those who score low on the trait are calm, even tempered, and relaxed (Judge & Bono, 2004). Recent work by Judge, Erez, Bono, and Thoresen (2002) revealed a strong association between neuroticism and low self-esteem and low general self-efficacy. It is unlikely individuals high in neuroticism will exhibit transformational leadership behaviors, such as idealized influence, inspirational motivation, or intellectual stimulation (Judge & Bono, 2004).

Extraversion represents the tendency to be sociable, assertive, active, and to experience positive effects such as energy and zeal. Positive emotionality is at the core of extraversion (Judge et al., 2002). Extraverts tend to exhibit inspirational leadership (e.g., has an optimistic view of the future). They are capable of generating confidence and enthusiasm among followers because of their positive ambitious and influential character. Extraverts also may score high on intellectual stimulation, as they tend to seek out and enjoy change (Judge & Bono, 2004). Openness to Experience is the disposition to be imaginative, nonconforming, unconventional, and autonomous (Judge et al., 2002). Individuals high in this trait are emotionally responsive and intellectually curious. They tend to have flexible attitudes and engage in divergent thinking. Openness to Experience is associated with transformational leadership because individuals with this trait are creative and are likely to score high in intellectual stimulation. Also, individuals high in openness to experience may exhibit inspirational leadership behaviors because they are imaginative and insightful. They are likely to be able to see a vision for an organization's future (Judge & Bono, 2004).

Agreeableness is the tendency to be trusting, compliant, caring, and gentle (Judge et al., 2002). Individuals high in agreeableness value affiliation and avoid conflict. They are modest, altruistic, and tend to be both trusting and trustworthy. There are several leadership behaviors that may be exhibited by individuals high in agreeableness. They are likely to be concerned with individuals' growth and development needs and are likely to be sure that individuals are rewarded appropriately and praised for work well done. They may score high in idealized influence and be seen as role models because of their trustworthiness and consideration for others. Finally, agreeable leaders are likely to be available when needed, leading to low scores on passive leadership (Judge & Bono, 2004).

Conscientiousness is comprised of two related facets: achievement and dependability (Judge et al., 2002). Conscientiousness has been one of the most commonly studied traits in the work of psychology. Conscientious individuals tend to have a strong sense of direction and work hard to achieve goals. They are also cautious, deliberate, self-disciplined, and tend to be neat and well organized, which suggests a link between conscientiousness and contingent reward. They may be more likely to engage in management by exceptionactive, which involves both setting and monitoring goals. Also, because they are dependable and unlikely to neglect their work responsibilities, conscientious individuals are unlikely to exhibit passive leadership behaviors, which involve lack of self-discipline and the default of leadership responsibilities (Judge & Bono, 2004).

The Big Five traits have been found to be relevant to many aspects of life, such as subjective well-being and even longevity. One of the most popular applications of the five-factor model has been to the area of job performance, in which eight meta-analyses have been conducted. The meta-analysis conducted by the authors of *Personality and Leadership: A Qualitative and Quantitative Review* concluded that the five-factor model has a multiple correlation of.48 with leadership, indicating strong support for the leader trait perspective when traits are organized according to the five-factor model (Judge et al., 2002).

SIX SIGMA OVERVIEW

Some scholars and practitioners have attempted to describe Six Sigma in one or two definitions (Breyfogle, Cupello, & Meadows, 2001; Dambolena & Rao, 1994). However, many have concluded that there are at least three definitions (Adams, Gupta, & Wilson, 2003; Brue, 2002; Eckes, 2001; Pande & Holpp, 2002). Six Sigma can be viewed as a metric, a mindset, and a methodology. The first logical and commonly heard definition for Six Sigma is that it is a statistical expression–a metric (Breyfogle et al., 2001; Brue, 2002; Dambolena & Rao, 1994; Harry, 1998; Pande & Holpp, 2002). The lowercase Greek symbol (sigma) is the metric or fundamental statistical concept that denotes a population's standard deviation and is a measure of variation or dispersion about a mathematical mean. Harry (1998) and Breyfogle et al. (2001), among others, explained how Six Sigma can be defined as a term for process performance that produces a mere 3.4 defects per million opportunities (DPMO). In layperson terms, Six Sigma is a metric representing a process that is performing virtually free of all defects.

As a second definition, Six Sigma is considered an organizational mindset that emphasizes customer focus and creative process improvement (Brue, 2002; Dambolena & Rao, 1994; Harry, 1998; Pande & Holpp, 2002). As Harry (1998) aptly stated, "The philosophy of Six Sigma recognizes there is a direct correlation between the number of product defects, wasted operating costs, and the level of customer satisfaction" (p. 60). With this mindset, individuals are prepared to work in teams in order to achieve Six Sigma and its ultimate goal of reducing process variation to no more than 3.4 defects per million opportunities. Adams, Gupta, and Wilson (2003) maintained that "Five sigma will not meet customer requirements, and seven will not add significant value." Six Sigma's 3.4 parts per million is close to perfection, and that makes it more attainable. Interestingly, the vast majority of processes found in U. S. companies are said to linger near four sigma or less (Breyfogle et al., 2001; Harry, 1998).

As a third definition, Six Sigma is viewed as a strategic improvement methodology termed DMAIC (Breyfogle et al., 2001; Brue, 2002; Eckes, 2001; Harry, 1998; Pande & Holpp, 2002; Pande, Neuman, & Cavanagh, 2002). DMAIC is an abbreviation of the five systematic steps in the Six Sigma methodology. The steps used for breakthrough thinking and improvement are: define, measure, analyze, improve, and control (Hoerl et al., 2004). This methodology is used to carry out the structured philosophy of Six Sigma in places that include but are not limited to manufacturing, design, engineering, human resources, purchasing, and customer service (Benedetto, 2003; Zu, Fredendall, & Douglas, 2008).

The implementation of Six Sigma strategies has resulted in some significant savings for various organizations (Hahn et al., 1999). The CEO of Motorola stated that Six Sigma has saved his company more than $16 billion to date. General Electric's CEO, Jack Welch, wrote in the company's annual report that from 1996 to 1998, Six Sigma had saved his company more than $2 billion. Tyco Electronics' CEO, Tom Lynch, wrote in his annual report that from 2003 to 2008 his company saved more than $700 million. The Vice President of American Express stated that Six Sigma programs have delivered approximately one billion dollars in benefits annually since its launch in 1999.

Effective leadership is the key to successfully implementing Six Sigma methodologies. Champions, master black belts, black belts, green belts, and team members make up the core of Six Sigma (ReVelle, 2004). Champions and master black belts work behind the scenes to support people working on projects and the overall initiative (Eckes, 2001). Black belt and green belt candidates are described as disciplined problem solvers who possess a significant amount of technical ability, are comfortable with basic statistics, and are not afraid to question conventional wisdom (Hoerl, 2001; Adams et al., 2003). A black belt and green belt have also been described as open-minded change agents and project managers able to communicate effectively at all levels (Brue, 2002). Many experts have insisted that black belts and green belts use a broad set of soft skills such as meeting management and presentation methods (Brekyfogle et al., 2001: Eckes, 2001; Hoerl, 2001; Pyzdek, 2000). As a chosen leader, the black belt or green belt will guide a team through the DMAIC process.

Black belts and green belts are "future business leaders" (Eckes, 2001) and "the backbone of Six Sigma culture" (Brue, 2002). Adams et al. (2003) insisted that black and green belts should be selected based on management potential. They make up on average roughly 2% of an organization's workforce. Without a strong and tireless black belt or green belt Six Sigma teams are usually not effective. The black belt and green belt must possess many skills, including strong problem solving, the ability to collect and analyze data, organizational savvy, leadership and coaching experience, and good administrative sense (Kumar et al., 2008). Moreover s/he must be adept at project management, and the art and science of getting things done on time through the effort of others (Goffnett, 2004).

Brief History of Six Sigma

Six Sigma was first conceived by experts at Motorola in the early 1980's. Bob Galvin, who was chairperson of Motorola at the time, presented an incredibly demanding quality goal to his employees in 1981, which may have been the stimulus for Six Sigma. Around 1985 engineer Bill Smith's research regarding process capability and defect reduction became the basis for Six Sigma innovation. Leadership at Motorola later asked Mikel J. Harry, then part of Motorola's technical staff, to pioneer the strategic methodology that would soon become Six Sigma. Harry and his colleagues refined the Six Sigma strategy by decade's end (Goffnett, 2004). Six Sigma activities and achievements, seen mainly in large manufacturing operations, are also becoming more prevalent in small businesses, transactional business processes (e.g., human resources and purchasing), and in the service sector (Gnibus & Krull, 2003; Goh, 2002; Hammer & Goding, 2001; Harry, 1998; Smith, 2003). Smaller companies have had similar financial success compared to larger companies but on a smaller scale (Brue, 2002; Gnibus & Krull, 2003; Harry, 1998). From a financial perspective, Six Sigma has had a considerable impact on numerous organizations across a variety of industries.

Several comparable systems preceded Six Sigma, such as Statistical Process Control (SPC); and Lean, Kaizen, and Total Quality Management (TQM), which are utilized in industry and taught in academia. Statistical Process Control has been in use for decades, is an essential device integrated into Six Sigma (Goh, 2002), and can function independently of the aforementioned systems. Six Sigma, however, functions using many aspects of lean and quality control (Burton, n. d.; Drickhamer, 2002; Pyzdek, 2000), which indicates its ability to complement, or run parallel to, other initiatives and create cohesion between business processes (Bisgaard, Hoerl, & Snee, 2002). The primary differences between Six Sigma and the aforementioned quality systems are as follows (Antony, 2004):

1. Six Sigma strategy places a clear focus on achieving measurable and quantifiable financial returns to the bottom line of an organization. No Six Sigma project is approved unless the bottom line impact has been clearly identified and defined.
2. Six Sigma places an unprecedented importance on strong and passionate leadership and the support required for its successful deployment.
3. The Six Sigma methodology of problem solving integrates the human elements (culture change, customer focus, belt system infrastructure, etc.) and process elements (process management, statistical analysis of process data, measurement system analysis, etc.) of improvement.
4. Six Sigma methodology utilizes the tools and techniques for fixing problems in business processes in a sequential and disciplined fashion.
5. Six Sigma creates an infrastructure of champions, master black belts, black belts, and green belts that lead, deploy, and implement the approach.
6. Six Sigma emphasizes the importance of data and decision-making based on facts and data rather than assumptions and hunches.
7. Six Sigma utilizes the concept of statistical thinking and encourages the application of well-proven statistical tools and techniques for defect reduction through process variability reduction methods (e.g. statistical process control and design of experiments).

Six Sigma's DMAIC Methodology

DMAIC methodology is the systematic approach to implementing Six Sigma (Goffnett, 2004). Define (D) is the first step of the Six Sigma methodology in which leaders are expected to select projects, set initial goals or targets, and develop a project charter or statement of work (SOW). Costs of poor quality associated with the new or existing process being analyzed, are estimated. Improvement targets are set, often in terms of sigma and cost (Pande et al., 2002). Leadership selects the appropriate team members. The team then determines more precisely the criteria that are critical to the customer. Run chats, interviews or surveys, for example, are utilized to obtain leads and useable figures (Eckes, 2001). A high level process map of the existing process is to be developed with start and end points clearly illustrated. Strategic deliverables include a process map, a working project charter, a team roster, and the costs of poor quality. A progress report to leadership normally concludes each step (Eckes, 2001; Pande et al., 2002).

Measure is the second step of the Six Sigma methodology denoted by the capital letter M. In this step a baseline measure is taken using actual data (Eckes, 2001; Pande et al., 2002; Snee, 2003). The measure then becomes the origin from which the team can gauge improvement. The team develops measures or utilizes existing ones, such as Statistical Process Control data or database information, and pairs them according to critical customer criteria. Pareto diagrams and control charts, as well as methods mentioned above in the "define" step, are possible data sources for baseline measures. Testing repeatability and reproducibility (R&R) of a measurement system is recommended throughout a Six Sigma project wherever critical measures are taken. A data gathering plan or sampling plan can be followed for greater accuracy (Eckes, 2001; Pande et al., 2002). The project charter should be refined based on the data gathered in the measure step. The process map can be revised based on new discoveries of value added or non-value added steps in the existing process. Strategic deliverables for the measure step are baseline figures, R&R results, process capability, an improvement goal, a refined process map, and a refined project charter (Eckes, 2001; Pande et al., 2002).

The third step, A, is analyze. Here, teams identify several possible causes (X's) of variation or defects that are affecting the outputs (Y's) of the process. One of the most frequently used tools in the analyze step is the cause and effect diagram (Eckes, 2001; Snee, 2003). A Six Sigma team explores possible causes that might originate from sources such as people, machinery, equipment, environment, materials, and methods. Another highly effective technique to explore root cause is asking "why" to a possible cause at least five times (Eckes, 2001). Team member suggestions may need to be clarified before proceeding further, so each and every team member has a clear understanding of the cause being presented. The resulting list should be reduced to the most probable root causes. Causes can be validated using new or existing data and applicable statistical tools, such as scatter plots, hypothesis testing, ANOVA, regression, or design of experiments (DOE). Experts warn not to assume causation or causal relationships unless there is clear evidence. Furthermore, validating root causes can help teams avoid implementing ineffective "improvements" and wasting valuable resources (Eckes, 2001). Root cause is the number one team deliverable coming out of the analyze step (Eckes, 2001; Pande et al., 2002).

The team then enters the improve (I) stage. Here a team would brainstorm to come up with corrective actions that address validated root causes. The tool most preferred for this process is the affinity diagram, which is a brainstorming technique in which a topic or issue is presented to a small team who then quickly list ideas or solutions (Eckes, 2001). The team should narrow the list to one or two potential improvements that are step deliverables for small scale implementation. Improvements should be selected based on probability of success, time to execute, impact on resources, and cost (Eckes, 2001; Pande et al., 2002). If newly-gathered data indicate the small-scale implementation is a legitimate success, teams should proceed to full-scale implementation (Pande et al., 2002).

The final component for the Six Sigma leader is control, signified by the capital letter C. At this point devices should be put in place to give early signals as to when a process is heading out of control. Teams may develop poke-yokes or mistake-proof devices that utilize light sound, logic programming, or no-go design to help control a process (Breyfogle et al., 2001). The ultimate goal for this step is to reduce variation by controlling X's and monitoring Y's (Pande et al., 2002).

In approximately three to six months, the sigma levels or process capability figures that should be routinely measured and documented by workers are then checked by the process owner to make certain that the installed improvements are lasting. All documentation and project reports should be finalized. With a control plan in place, the project is delivered to the rightful owner who is usually the project champion or a sponsor from leadership. It is the owner's duty to then manage the new improved process (Eckes, 2001; Pande et al., 2002). If Six Sigma was not achieved, a separate project can be kicked off in the future to address any residual root cause.

Six Sigma Leadership Roles

Effective leadership is the key to successfully implementing Six Sigma methodologies. Champions, master black belts, black belts, green belts, and team members make up the core of Six Sigma (ReVelle, 2004). Champions and master black belts work behind the scenes to support people working on projects and the overall initiative (Eckes, 2001). The black belt is the fulltime person dedicated to handling critical change opportunities and driving them to achieve bottom line cost savings. The black belt leads, inspires, delegates, and manages the team to improve processes. The primary responsibility of the black belt is to keep the project moving to completion (Pande & Holpp, 2002). Black belts are typically chosen from the middle management ranking. They are removed from their full time position for 18 months to two years to work on a black belt Six Sigma project. They typically complete four to six projects during this time frame. Once their duration terminates they have an option to go back to their original position or take a position doing Six Sigma activities fulltime (Pande & Holpp, 2002). Master black belts (MBB) serve as coaches or mentors to black belts who work on a variety of projects. In most cases, MBBs are the experts in applying the Six Sigma tools. They often provide training to the other Six Sigma leaders (Pande & Holpp, 2002).

A green belt is a leader trained in Six Sigma skills, often to the same level as a black belt leader. However, the green belt works on her/his project part-time versus fulltime, and remains responsible for the activities of the permanent position as well. Green belt projects are typically less complex than black belts' because of the amount of time allotted to work on them. The role of the green belt is to bring the new concepts and tools of Six Sigma to the day-to-day activities of the business (Pande & Holpp, 2002). A champion is an executive or key manager who initiates and supports the Six Sigma project. S/he is key because this person typically belongs to senior management. The champion is responsible for making sure the project stays aligned with the overall business objectives, and providing direction when it doesn't. The champion also ensures that the project team has all the necessary resources such as money, time, people, etc. to complete the project (Pande & Holpp, 2002).

Summary

Trait research has come full circle because there is a renewed interest in focusing directly on the critical traits of leaders. There are several advantages to viewing Six Sigma leadership from the trait approach. First, it is intuitively appealing because it fits clearly into the popular idea that leaders are special people who are out front, leading the way. Second, there is a century's worth of research that validates the basis of this perspective. Third, by focusing exclusively on the leader, the trait approach provides an in-depth understanding of the leader component in the leadership process. Last, the trait approach has provided some benchmarks against which individuals can evaluate their own personal leadership attributes (Northouse, 2004).

MAIN FOCUS OF THE CHAPTER

There were primarily two purposes of this study. First, this study identified specific leadership traits for green and black belt Six Sigma leaders that have a statistical relationship with the success of Six Sigma projects. Second, the purpose was to test the reliability of a scale created from the Leadership Trait Questionnaire items. The reliability of the LTQ scale had never been tested until this study. It was hypothesized that within the sample population there would be a statistical relationship between the traits of green and black belt Six Sigma leaders, and the success of Six Sigma projects. The following hypotheses ground data analysis for this study. They were framed in terms of traditionally accepted null and alternative hypotheses:

1. **Null Hypothesis:** There is no statistical relationship between the traits of green belt leaders and the success of Six Sigma projects.
   a. **Alternative Hypothesis:** There is a statistical relationship between the traits of green belt leaders and the success of Six Sigma projects.
2. **Null Hypothesis:** There is no statistical relationship between the traits of black belt leaders and the success of Six Sigma projects.
   a. **Alternative Hypothesis:** There is a statistical relationship between the traits of black belt leaders and the success of Six Sigma projects.
3. **Null Hypothesis:** A scale created from the Leadership Trait Questionnaire items is not reliable.
   a. **Alternative Hypothesis:** A scale created from the Leadership Trait Questionnaire items is reliable.

Procedure

A sample population of Tyco Electronics Six Sigma leaders involved with completing green and black belt Six Sigma projects was asked to rate ten traits for their individual positions of leadership using the Leadership Trait Questionnaire (LTQ) instrument. The researcher did not ask team members to evaluate the Six Sigma leaders. Only the ratings from the Six Sigma leaders were utilized in this study. These ratings were used to examine whether the successful implementation of Six Sigma projects is affected by the Six Sigma leader's traits or characteristics.

Sample Description

Approximately 500 potential participants of Six Sigma leaders were selected from a Tyco Electronics database called Tyco Electronics Business Improvement Tracking (TBIT). The criteria for selecting the potential participants were as follows:

1. They were master black belts, black belts, green belts or lean practitioners;
2. Their projects were related to Six Sigma;
3. Their projects had a hard cost savings; and
4. They worked in North America, Asia or Europe, Middle East and Africa.

The researcher utilized Tyco Electronics' TBIT system to retrieve the potential participants' email addresses. Tyco Electronics' email system was used to invite each to participate in a study on leadership. The email included a cover letter and a Web link to the survey which was hosted by SurveyMonkey.com (2008). The cover letter and the Web-based survey, version 1.5 hosted by SurveyMonkey.com, was approved by the Institutional Review Board (IRB) at North Carolina Agricultural and Technical State University. The cover letter included an explanation of the study and the importance of the participants' contribution to leadership research.

Ethical Considerations

The researcher was granted access to the Tyco Electronics Business Improvement Tracking database and permission to send emails to Six Sigma leaders globally by Tom England, Global Director of Six Sigma Operations. The researcher provided a participant letter within each email. The participant letter was approved by the Institutional Review Board (IRB) at North Carolina Agricultural and Technical State University. It was communicated to all participants the purpose of the survey, the approximate time it would take to complete, their rights as participants, and with whom the data would be shared.

Instrumentation

This study used the Leadership Trait Questionnaire (LTQ). The instrument's design reflects the nature and demands of leadership, and measures related to personal characteristics or traits. The LTQ defines leadership as actions which focus resources to create desirable opportunities (Northouse, 2007). The researcher requested permission from Peter Northouse via email to use the LTQ instrument.

Northouse (2004) developed a quantitative survey using ten traits he found to be common to all leaders in any situation. The primary purpose of the LTQ survey was to allow the leaders to do a self-assessment and to allow the followers to do an assessment of their leader from a leadership process perspective (Northouse, 2004). Only the leaders in this study rated themselves on the ten traits on a five-point scale ranging from *Strongly Agree* to *Strongly Disagree* (Northouse, 2001). The instrument allows leaders to assess their strengths and weaknesses. According to Northouse (2007), the following are the ten traits that all effective leaders possessed in any situation:

- **Articulate:** Communicates effectively with others;
- **Perceptive:** Discerning and insightful;
- **Self-Confident:** Believes in oneself and one's ability;
- **Outgoing:** Talks freely, gets along with others;
- **Self-Assured:** Secure with self, free of doubts;
- **Persistent:** Stays fixed on the goals despite interference;
- **Determined:** Takes a firm stand, act with certainty;
- **Trustworthy:** Takes believably, inspires confidence;
- **Dependable:** Is consistent and reliable; and
- **Friendly:** Shows kindness and warmth (p. 33).

The researcher, who is a Six Sigma practitioner, saw the comprehensive ten traits of the LTQ as most applicable in the Six Sigma field. The researcher used the LTQ for participants to conduct a self-assessment of the traits for black belt and green belt leaders only. The team members did not assess the black belt and green belt leaders of their teams. The application of the LTQ in this manner allowed the researcher to establish the reliability of the LTQ scale as a measure of leadership traits for future research. It also allowed the researcher to examine the traits of the LTQ as predictive measures of actual cost savings in Six Sigma projects.

Summary of Variables

A summary of variables is presented in Table 2.

The first group of variables, independent variables I, are the ten leadership traits that are measured using the LTQ instrument. The LTQ instrument allows leaders to assess their strengths and weaknesses. The leaders rate the ten leadership traits on a five-point Likert scale ranging from *Strongly Agree* to *Strongly Disagree*. The ten traits are articulate, perceptive, self-confident, outgoing, self-assured, persistent, determined, trustworthy, dependable, and friendly. The second group of variables, independent variables II, includes project experience, upper management support, and technical skill set. Proj-

Table 2. Summary of variables

Variable	Traits/Characteristics
Independent Variables (i)	articulate, perceptive, self-confident, self-assured, persistent, determined, trustworthy, dependable, friendly, outgoing
Independent Variables (ii)	project experience, upper management support, skill set
Dependent Variable	hard cost savings

ect experience is measured based on the number of projects completed. Upper management support is measured using a three-point Likert scale ranging from *Strong Support* to *Weak Support*. Technical skill set is measured on a three-point Likert scale ranging from *Strong Technical Skill Set* to *Weak Technical Skill Set*. Six Sigma practitioners argue that the most successful projects will be impacted by these variables.

The third group of variables included only one, which is the dependent variable. The dependent variable is the actual cost savings self-reported by the Six Sigma leaders. Green belt projects equal to or greater than $50,000 are considered successful. Black belt projects equal to or greater than $250,000 are considered successful.

Validity and Reliability

Peter Northouse developed the Leadership Trait Questionnaire instrument to be used as a self-assessment tool. Northouse is the author of several books and many publications in professional journals. Some of the most recent books include:

- Introduction to Leadership Concepts and Practice;
- Leadership, Fifth Edition: Theory and Practice;
- Meeting the Ethical Challenges of Leadership, Third Edition; and
- Cases in Leadership, Second Edition.

Respected as a scholar and practitioner of leadership, Northouse has taught and provided consultant services for more than 20 years in the areas of leadership development, leadership education, conflict management, and health communication.

The LTQ instrument developed by Northouse has been used by many, even though it has not been tested for reliability and validity. Northouse argues that the LTQ is a quality instrument for the self-assessment of leadership traits. This current research project evaluates the LTQ instrument using Cronbach's alpha analysis to determine whether a scale created from the LTQ items is reliable.

Data Analysis

The Web-based version of the LTQ instrument was downloaded anonymously to the researcher from SurveyMonkey.com. The researcher obtained actual responses, without knowing the identity of the participants, and was in no way able to identify who responded and who did not. The responses to the questionnaire were analyzed using Minitab software version 15.0. The statistical analysis included Cronbach's reliability of measures, descriptive statistics, One-Way ANOVA, and Main Effects Plot analysis. First, the study determined whether a statistical relationship exists between the independent variables (see Figure 1) and the success of Six Sigma projects, which is measured by the dependent variable hard cost savings (see Figure 2). Second, the study determined whether a scale created from LTQ items was reliable.

Strengths and Limitations of the Design

The strengths of the current study include hard data to measure project success; the positive relationship the researcher has with participants, and the participants' extreme interest in the research findings. Most of the participants are in positions to hire green and black belt leaders. The major limitation of this design is the self-ratings of leadership traits.

Figure 1. Independent variables

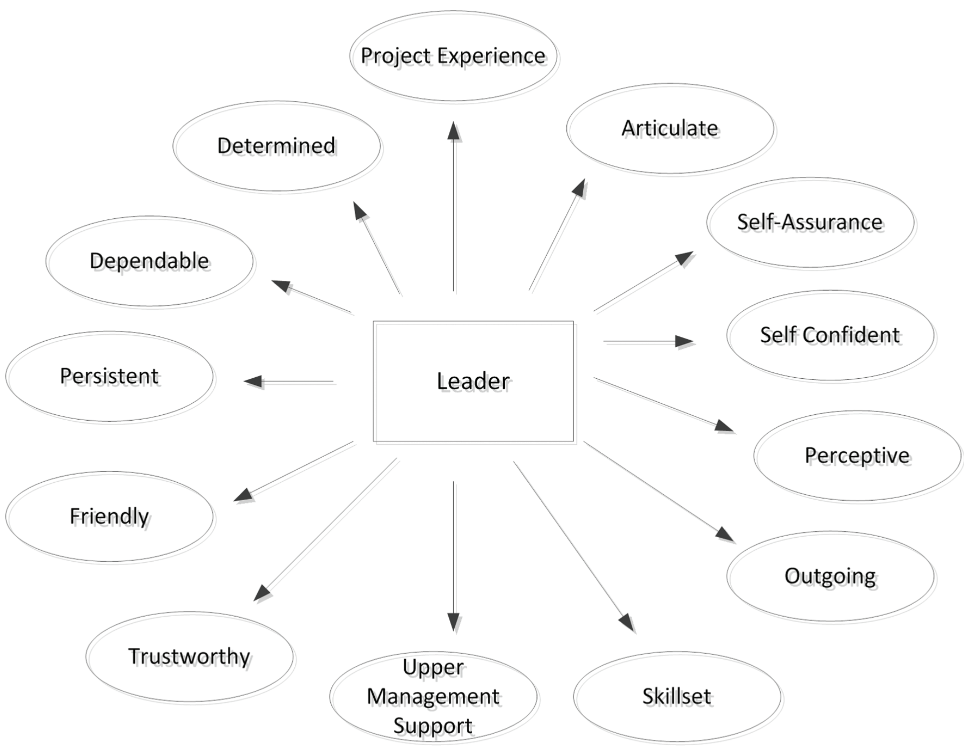
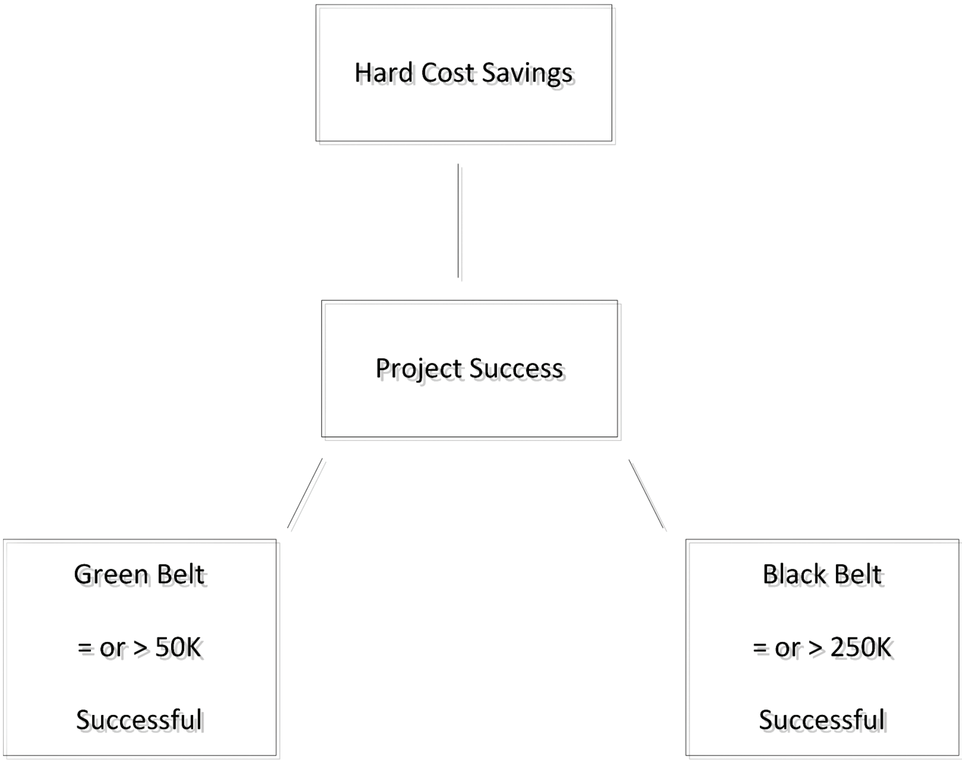


Figure 2. Dependent variables



SOLUTIONS AND RECOMMENDATIONS

There were five hypotheses employed to determine the reliability of measures and examine specific leadership traits that have a statistical relationship with the success of Six Sigma projects. Data were analyzed using descriptive statistics, Cronbach's reliability of measures, one way ANOVA, and Main Effects Plot analysis. Analyses of findings for each hypothesis are presented below.

Alpha Reliability Scores

While the Leadership Trait Questionnaire (LTQ) instrument was noted as being a quality instrument by its developer, Peter Northouse, it had not been tested for reliability until this study. The researcher used Cronbach Reliability to determine the reliability of a scale created from the LTQ items. Based on Cronbach an instrument's scale is reliable if the alpha is.70 or higher. The researcher conducted the reliability test separately for green and black belt leaders. For green belt leaders Cronbach's Alpha was.825. For black belt leaders Cronbach's Alpha was.766. Therefore, the researcher rejected the null hypothesis that a scale created from the Leadership Trait Questionnaire items is not reliable. The alternative hypothesis was accepted which states that a scale created from the Leadership Trait Questionnaire items is reliable. These findings allow scholars or/and practitioners to be confident in using this LTQ scale in assessing leadership traits for future research. The primary purpose of this study was to determine whether there are specific leadership traits for green and black leaders, therefore the analysis was conducted using individual LTQ items rather than the LTQ scale.

Descriptive Statistics of Sample

The Leadership Trait Questionnaire was sent to 500 hundred Six Sigma leaders globally within Tyco Electronics. A total of 165 participants responded for an overall response rate of 33%. There were 82 green belts (49.7% of the sample) and 83 black belts (50.3% of the sample) who completed the survey. In terms of the racial make-up of the sample, 121 were White (73.8%), 23 were African Americans (14%), 8 were Hispanic (4.9%), 6 were Asian (3.7%), 1 was Native American (0.6%), and 5 were other (3.0%). Males accounted for 89% (n=146) of the sample, with females representing 11% (n=18).

The majority 77.2% (n=129) of the respondents were located in the Americas, 20.4% (n=34) were from Europe, Middle East, and Africa (EMEA), and 2.4% (n=4) were from Asia. Thirty-eight percent 38.2% (n=63) of the Six Sigma leaders completing projects were between the ages of 40-49, with 37% (n=61) between the ages of 30-39. Black belts and green belts were equally represented in the sample, with black belts accounting for 49.7% (n=82), and green belts 50.3% (n=83)..

Analysis of Leadership Traits and Six Sigma Leaders

Green Belt Leaders: Descriptive statistics, One-Way ANOVA, and Main Effects Plot were conducted on the data to investigate the following hypotheses for green belt leaders:

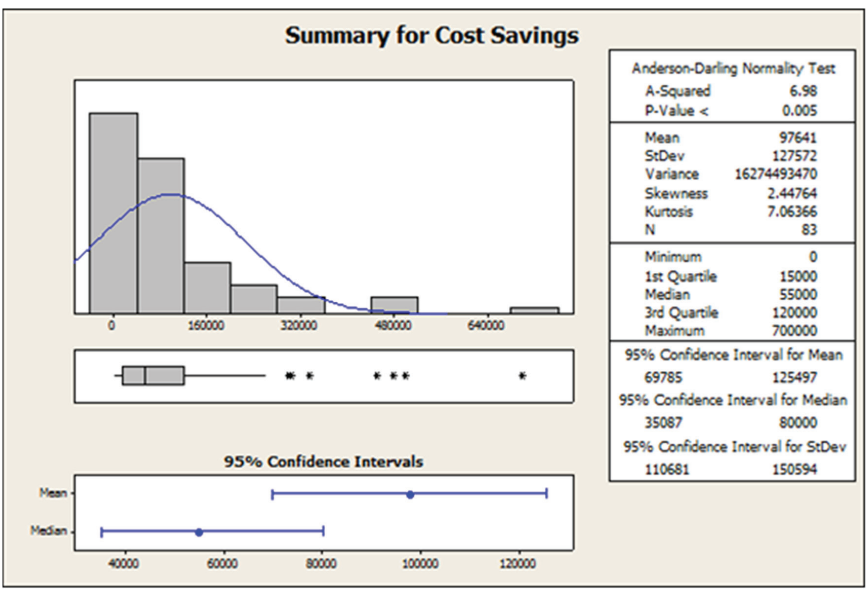
1. **Null Hypothesis:** There is no statistical relationship between the traits of green belt leaders and the success of Six Sigma projects.
2. **Alternative Hypothesis:** There is a statistical relationship between the traits of green belt leaders and the success of Six Sigma projects.

Descriptive Statistics for Green Belt: The survey was sent to 300 green belt leaders, of which 83 responded yielding a 28% response rate. LTQ item means and standard deviations for this sample are shown in (Table 3). The mean of the actual cost savings was 97,641. The standard deviation was 127,572. These data are reflected in (Figure 3).

Table 3. LTQ item means and standard deviations for green belts

Traits	Mean	Standard Deviation
Articulate	4.39	.583
Perceptive	4.13	.665
Self-confident	4.29	.687
Self-assured	4.13	.640
Persistent	4.27	.682
Determined	4.19	.721
Trustworthy	4.48	.593
Dependable	4.42	.615
Friendly	4.26	.676
Outgoing	4.32	.647

Figure 3. Green belt descriptive data



Analysis of Green Belt Leadership Traits: The researcher analyzed each independent variable to determine if it had a statistical relationship with the dependent variable. The independent variables (i) were articulate, perceptive, self-confident, self-assured, persistent, determined, trustworthy, dependable, friendly and outgoing. The independent variables (ii) were project experience, upper management support and technical skill set. Green belt projects equal to or greater than $50,000 is considered successfully. Black belt projects equal to or greater than $250,000 is considered successfully.

A One-Way Analysis of Variance was used to evaluate the relationship between the independent variables and hard cost savings for green belt leaders. The independent variables: Articulate, perceptive, self-confident, self-assured, determined, and upper management supports were significantly related to hard cost saving ($p < .05$). Therefore the researcher rejected the null hypothesis, and accepted the alternative hypothesis that these independent variables have a statistical relationship with the traits of green belt leaders and the success of Six Sigma projects.

There were no significant statistical findings for the following independent variables: persistent, trustworthy, dependable, friendly, outgoing, technical skill set, and project experience. For these variables the researcher accepted the null hypothesis. These independent variables had no statistical relationship with the success of Six Sigma projects. Table 4 summarizes these findings.

Table 4. One-way ANOVA summary

Source	df	ss	ms	F	R^2	p
Articulate	2	1.10990E+11	55495012699	3.39	7.80%	.04*
Perceptive	2	2.29482E+11	1.14741E+11	7.85	18.99%	<.01*
Self-confident	2	1.75865E+11	87932563494	5.70	14.55%	.01*
Self-assured	2	2.36587E+11	1.18294E+11	8.15	19.58%	<.01*
Determined	2	1.73919E+11	86959514259	4.87	13.22%	<.01*
Upper management support	2	2.62890E+11	1.31445E+11	9.47	21.54%	<.01*
Persistent	3	93613147548	31204382516	1.78	7.80%	.16
Trustworthy	2	73221803430	36610901715	1.81	5.59%	.17
Dependable	2	73952641042	36976320521	2.10	6.17%	.13
Friendly	2	1.15049E+11	57524295039	3.24	9.74%	.05
Outgoing	2	51813110471	25906555236	1.50	4.29%	.23
Technical skill set	2	45803919033	22901959517	1.35	3.75%	.27
Project Experience	7	1.05737E+11	15105267115	.086	8.68%	.55

Note: $p < .05$* is significant

The researcher conducted further analysis on the independent variables that were significantly related to hard cost savings. The researcher used the Main Effects Plot to compare the actual cost savings mean of the various groups of these independent variables. Based on the findings from the Main Effects Plot analysis, green belt leaders who self-reported the highest trait ratings also had the highest cost savings projects. The findings are summarized in Table 5 and Table 6. These findings are significant because now managers know that articulate, perceptive, self-confident, self-assured, and determined, are the traits associated with a green belt leader's successful completion of projects. Further, the study found that participants rated upper management support as critical to their successful project completion, as well.

Black Belt Leaders: Descriptive statistics, One-Way ANOVA, and Main Effects Plot were conducted on the data as the researcher investigated the following hypotheses for black belt leaders:

1. **Null Hypothesis:** There is no statistical relationship between the traits of black belt leaders and the success of Six Sigma projects.
2. **Alternative Hypothesis:** There is a statistical relationship between the traits of black belt leaders and the success of Six Sigma projects.

Descriptive Statistics for Black Belt: The survey was sent to 200 black belt leaders, of which 81 responded, yielding a 41% response rate. LTQ item means and standard deviations for this sample are shown in Table 7. The mean of the actual cost savings was 1,493,198. The standard deviation was 4,905,343. These data are reflected in Figure 4.

Table 5. Main effects plot summary for actual cost savings

Independent Variables (i)	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Articulate	149,305	77,752	21,797	-	-
Perceptive	184,302	72,633	28,348	-	-
Self-confident	161,550	73,239	24,006	-	-
Self-assured	183,418	70,329	28,509	-	-
Determined	167,323	74,360	32,226	-	-

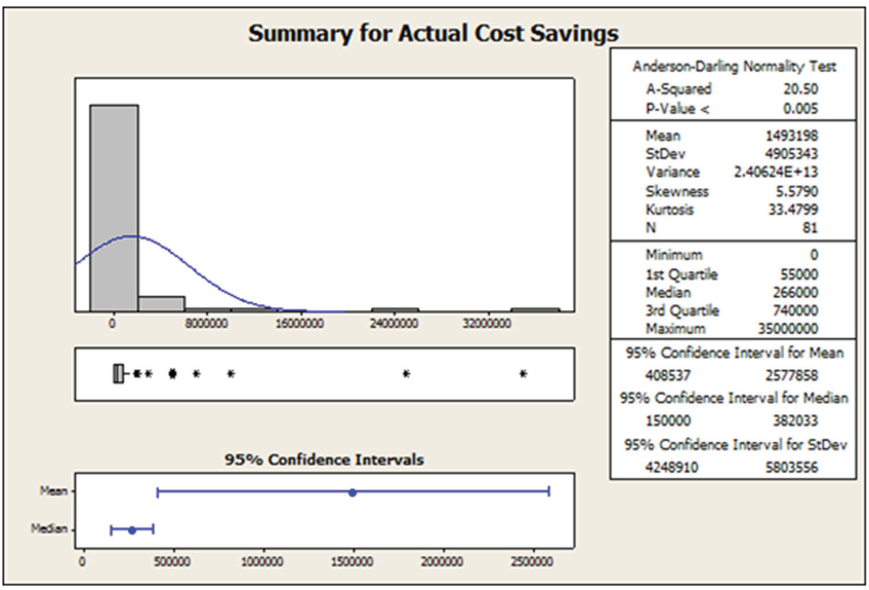
Table 6. Main effects plot summary for actual cost savings

Independent Variables (ii)	Strong	Moderate	Weak
Upper Management Support	173,021	73,443	18,506

Table 7. LTQ item means and standard deviations for black belts

		Standard
Traits	**Mean**	**Deviation**
Articulate	4.47	0.534
Perceptive	4.28	0.654
Self-confident	4.17	0.68
Self-assured	4.11	0.693
Persistent	4.34	0.695
Determined	4.17	0.68
Trustworthy	4.44	0.56
Dependable	4.39	0.657
Friendly	4.09	0.75
Outgoing	**4.23**	**0.792**

Figure 4. Black belt descriptive data



Analysis of Black Belt Leadership Traits: The researcher analyzed each independent variable to determine if there was a statistical relationship with the dependent variable. The independent variables (i) include articulate, perceptive, self-confident, self-assured, persistent, determined, trustworthy, dependable, friendly and outgoing. The independent variables (ii) were project experience, upper management support and technical skill set. Black belt projects equal to or greater than $250,000 are considered successfully.

A One-Way Analysis of Variance was used to evaluate the relationship between independent variables and hard cost savings for black belt leaders. The independent variables articulate, perceptive, self-confident, self-assured, determined, dependable, friendly, upper management support, and project experience were significantly related to hard cost savings ($p <.05$). Therefore the researcher rejected the null hypothesis and accepted the alternative hypothesis that these independent variables had an impact on black belt leaders' successfully completing their Six Sigma projects. There were no significant statistical findings for the following independent variables: persistent, trustworthy, outgoing, and technical skill set. Therefore the researcher accepted the null hypothesis: these independent variables had no impact on black belt leaders' completing their projects successfully. Table 8 summarizes these findings.

The researcher conducted further analysis on the independent variables that were significantly related to hard cost savings. The researcher used the Main Effects Plot to compare the actual cost savings mean of the various groups of these independent variables. Based on the findings from the Main Effects Plot analysis, black belt leaders who self-reported the highest rating also had the highest cost savings projects. The findings are summarized in

Table 8. One-way ANOVA summary

Source	df	ss	ms	F	R^2	p
Articulate	2	2.81671E+13	1.40836E+13	3.44	10.44%	.04*
Perceptive	3	3.77744E+13	1.25915E+13	3.15	14.01%	.03*
Self-confident	3	4.55090E+13	1.51697E+13	3.92	16.87%	.01*
Self-assured	2	4.34266E+13	2.17133E+13	5.66	16.10%	.01*
Determined	2	4.52519E+13	2.26259E+13	5.95	16.78%	<.01*
Dependable	2	2.83553E+13	1.41776E+13	3.47	10.51%	.04*
Friendly	2	3.31394E+13	1.65697E+13	4.13	12.29%	.02*
Upper Management Support	2	6.94751E+13	3.47376E+13	5.09	14.11%	.01*
Project Experience	17	2.17882E+14	1.28166E+13	2.19	44.25%	.02*
Persistent	2	1.05193E+13	5.25966E+12	1.2	3.90%	0.31
Trustworthy	2	2.08441E+13	1.04220E+13	2.47	7.73%	0.09
Outgoing	2	2.50504E+13	1.25252E+13	3.02	9.29%	0.06
Technical Skill Set	2	1.46785E+13	7.33926E+12	0.95	2.98%	0.39

Note: $p <.05*$ is significant

Table 9 and Table 10. Project experience was found to be statistically significant; however, the Main Effects Plot does not show a correlation in reference to the more projects a leader completed the higher the cost savings (refer to Figure 5).

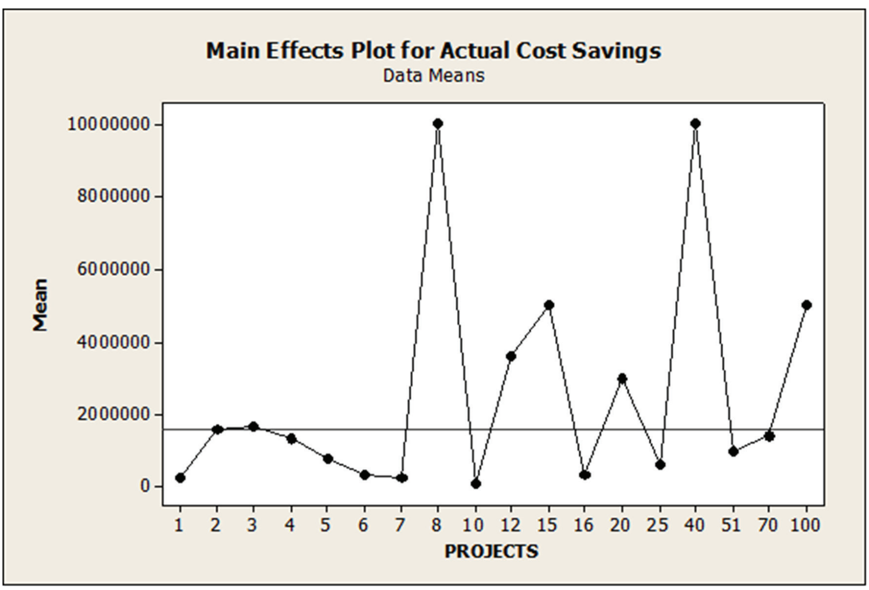
Table 9. Main effects plot summary for actual cost savings

Independent Variables (i)	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Articulate	**1,660,554**	239,814	170,000	-	-
Perceptive	**1,908,510**	375,367	156,667	214,000	-
Self-confident	**2,007,554**	299,529	285,000	150,000	-
Self-assured	**2,041,157**	390,630	162,000	-	-
Determined	**2,031,032**	348,821	106,667	-	-
Dependable	**1,696,289**	329686	100,000	-	-
Friendly	**1,796,735**	380,327	126,667	-	-

Table 10. Main effects plot summary for actual cost savings

Independent Variables (ii)	Strong	Moderate	Weak
Upper Management Support	2,428,646	341,743	65,000

Figure 5. Mean comparison of completed projects



These findings are significant because now managers know that articulate, perceptive, self-confident, self-assured, determined, dependable and friendly are the traits associated with a black belt leader's successful completion of projects. Further, the study found upper management support and project experience to be critical in successfully completing Six Sigma projects, as well.

CONCLUSION

The findings from this study suggest that self-reported traits are associated with effective leadership for green and black belt Six Sigma leaders. Also, a scale created from the LTQ items was found to be reliable in this study. These findings support the most recent research on leadership traits. Trait theory is still considered to be a valid construct as we enter the twenty-first century, and several researchers have focused on restoring the theory. Bryman (1992) discovered during his research that traits definitely influence leadership. The findings of Kirkpatrick and Lock (1991) supported the notion that leaders possessed traits that were different from followers. Northouse (2004) argues that the ten comprehensive traits used in his Leadership Trait Questionnaire play a critical role in effective leadership. This study found that a subset of the LTQ self-rated traits are significantly related to self-reported cost savings. Green belt leaders who rated themselves high on "perceptive" had the highest cost savings mean of $184,302. Black belt leaders who rated themselves high on "self-assured" had the highest cost savings mean of $2,041,157. These actual cost savings are significant as well as the examples cited in the research. Tyco Electronics' CEO, Tom Lynch, wrote in the annual report that from 2003 to 2008, his company saved more than $700 million. Edward J. Zander, Motorola CEO, stated that Six Sigma has saved his company more than $16 billion to date. General Electric's CEO, Jack Welch, wrote in the annual report that from 1996 to 1998 Six Sigma tactics had saved his company more than $2 billion.

This study also suggests from a practical perspective that a green and black belt technical skill set may affect the actual cost savings of Six Sigma projects. Green belt leaders in this study who self-reported as having a moderate to strong technical skill set had a total mean of $343,433 in actual cost savings. Black belt leaders in this study who self-reported as having a moderate to strong technical skill set had a total mean of $3,255,151 in actual cost savings. Six Sigma research agrees that having a significant amount of technical ability is important. The black belt and green belt must possess many skills including strong problem solving, the ability to collect and analyze data, organizational savvy, leadership and coaching experience, and good administrative sense (Kumar et al., 2008). Moreover, s/he must be adept at project management, the art and science of getting things done on time through the effort of others (Goffnett, 2004). Black belt and green belt candidates are described as disciplined problem solvers who possess a significant amount of technical ability, are comfortable with basic statistics, and are not afraid to question conventional wisdom (Hoerl, 2001; Adams, Gupta, & Wilson, 2003). Black belts and green belts have also been described as open-minded change agents and project managers who must be able to communicate effectively at all levels (Brue, 2002).

Finally, this study suggests that self-reports of upper management support towards green and black belt projects is associated with actual cost savings as well. Green belt leaders who reported receiving moderate to strong support from upper management had a total cost savings mean of $246,464. Black belt leaders who reported receiving moderate to strong support from upper management had a total cost savings mean of $2,770,389. Six Sigma research supports this finding. A champion is an executive or key manager who initiates and supports the Six Sigma project. S/he is key because this person typically belongs to senior management. The champion is responsible for making sure the project stays aligned with the overall business objectives and providing direction when it doesn't. Also, the champion's job is to ensure that the project team has all the necessary resources such as money, time, people, etc. to complete the project (Pande & Holpp, 2002).

This study found that black belt leaders had more independent variables related to the success of their Six Sigma projects than did green belt leaders. Dependable, friendly, and project experience were significantly related to project success for black belt leaders but not for green belt leaders. This difference in findings for green belt and black belt leaders may be due to black belt leaders' projects being more complex than green belt leaders' projects. Black belt leaders are removed from their fulltime position for 18 months to two years to work on a black belt Six Sigma project. They typically complete four to six projects during this time frame. Green belt leaders are not removed from their fulltime position; they have to work on their project part-time. Therefore, green belt leaders aren't expected to complete as many projects as black belt leaders. Black belt leaders have to be dependable and friendly because their responsibilities are greater. They are responsible for training green belt leaders and they interact with more people across various departments in an effort to successfully complete their projects. The number of projects black belt leaders complete is pertinent because of the complexity of their projects. The more projects they have under their belt the more effective and efficient they can be in completing future projects.

Implications of the Research

This study's findings can inform managers in hiring and developing green and black belt Six Sigma leaders. It is important to have an effective Six Sigma leader because of the millions of dollars in bottom-line improvements they lead teams to achieve. This study found a statistical relationship with specific leadership traits self-reported by green and black belt leaders that are associated with the successful completion of Six Sigma projects. Now that specific traits have been identified, managers can hire green and black belt leaders based on this information, as well as develop potential leaders to have these specific traits that correlate to successful completion of Six Sigma projects. An effective leader in the Six Sigma field relates to successfully completing projects that yield significant hard cost savings to the organization's bottom line.

This study addressed a gap in the Six Sigma literature. The literature did not discuss traits needed by Six Sigma leaders in order for them to successfully implement projects. The pre-existing literature discussed only the technical skill set that is needed.

Finally, this study demonstrated that a scale created from the Leadership Trait Questionnaire (LTQ) items is a reliable. Prior to this study the LTQ instrument developed by Peter Northouse was not tested for reliability. The LTQ instrument offers another method of conceptualizing and operationalizing a leader's ability to assess their leadership traits.

Limitations of this Study

In terms of limitations, this study has several that should be noted. First, all participants are from the researcher's company, Tyco Electronics. Therefore the researcher could only generalize about Six Sigma leaders within Tyco Electronics. Second, cost savings was the only output measure for success. However, there are other factors that could determine the success of a project when hard cost savings aren't obtainable, such as downtime reductions, quality improvements (especially customer issues), working capital improvements, waste reductions, cost avoidances, etc. Third, the non-leaders weren't asked to assess their leader using the Leadership Trait Questionnaire instrument. The researcher used the LTQ instrument primarily because of its 10 comprehensive traits which appeared to be very applicable in the context of Six Sigma leadership. The primary purpose of the LTQ is to assess the strengths and weaknesses of the leader. A fourth limitation is the response rate for green belt leaders, which was 28%, and the small sample size within the groups of each independent variable. These two factors potentially affected the statistical significance and analysis of this study. The fifth limitation is the large variation in cost savings data. This large variation may have statistically affected the outcome of this study's results. The researcher did remove self-reports of zero cost savings and outliers; however, there was no difference in the statistical significance of the findings. Finally, the sixth limitation is that 89% of the sample was males.

Future Research

Now that the LTQ has been tested to have a reliable scale, other studies related to the trait theories and Six Sigma leadership can be explored. One of the biggest problems in past research relating personality to leadership is the lack of a structure for describing personality, leading to a wide range of traits being investigated under different labels. Judge, Bono, et al. (2002) conducted recent research on the taxonomic structure for classifying and organizing traits. This taxonomic structure was called the five-factor model. The five-factor model of personality, often termed the Big Five, can be used to describe the most salient aspects of personality (Hurtz & Donovn, 2000). The Big Five are heritable and stable over time. The dimensions comprising the five-factor model are Neuroticism, Extraversion, Openness to Experience, Agreeableness, and Conscientiousness (Judge & Bono, 2004). The LTQ instrument may be utilized with the five-factor model in an effort to better understand traits and its effect on Six Sigma leadership.

Also, future research addressing the following factors could improve on this study to increase statistical and practical significance:

- Administer the survey to green and black belt Six Sigma leaders from various companies;
- Define more than one output variable to determine a successful Six Sigma project;
- Decrease the number of levels from 5 to 3 in an effort to increase sample sizes for each level; and
- Restate the cost savings question in an effort to reduce variability in reporting.

Concluding Remarks

As global competitiveness continues to increase, companies are seeking initiatives that will give them an edge. Six Sigma strategies have been at the forefront of these initiatives. Six Sigma strategies led by effective green and black belt leaders have produced millions of dollars in bottom-line improvements. In this study, effective green belt leaders self-identified as having the following traits: articulate, perceptive, self-confident, self-assured, and determined. They also reported that strong upper management support mattered, and this was found to be associated with their effectiveness as leaders of projects. In this study black belt leaders self-identified as having the following traits: articulate, perceptive, self-confident, self-assured, determined, dependable, and friendly. They, too, reported that strong upper management support and project experience mattered, and this was found to be associated with their effectiveness as project leaders. Clearly, in times of economic uncertainty and increasing global competiveness, managers need to be able to recognize the individuals who possess the needed traits to make their companies profitable.

REFERENCES

Adams, C. W., Gupta, P., & Wilson, C. E. Jr. (2003). *Six Sigma deployment*. Boston: Butterworth-Heinemann.

Antony, F. (2004). Some pros and cons of six sigma: An academic perspective. *The TQM Magazine*, *16*(4), 303–306. doi:10.1108/09544780410541945

Bass, B. M. (1990). *Bass and Stogdill's handbook of leadership: A survey of theory and research*. New York: Free Press.

Benedetto, A. R. (2003). Adapting manufacturing-based Six Sigma methodology to the service environment of a radiology film library. *Journal of Healthcare*, *48*(4), 263–280. PMID:12908226

Bennis, W. E., & Nanus, B. (1985). *Leaders: The strategies for taking charge*. New York: Harper and Row.

Bisgaard, S., Hoerl, R. W., & Snee, R. D. (2002). Improving business processes with Six Sigma. *Quality Congress*, 701-704.

Breyfogle, F. W., Cupello, J. M., & Meadows, B. (2001). *Managing Six Sigma: A practical guide to understanding, assessing, and implementing the strategy that yields bottom-line success*. New York: John Wiley & Sons.

Brue, G. (2002). *Six Sigma for managers*. New York: McGraw-Hill.

Bryman, A. (1992). *Charisma and leadership in organization*. London: Sage.

Bulls, W. K. (2008). *An examination of leadership traits that impact the development of web-based programs in institutions of higher education within the UNC system.* (Unpublished Doctoral Dissertation). North Carolina Agricultural and Technical State University, Greensboro, NC.

Burton, T. T. (n.d.). *Is this a Six Sigma, Lean, or Kaizen Project?* Retrieved from http://www.isixsigma.com/index.php?option=com_k2&view=item&id=1291&Itemid=1&Itemid=1

Campbell, D. (1991). *Manual for the Campbell Leadership Index*. Minneapolis, MN: National Computers Systems.

Chemers, M. M. (2000). Leadership research and theory: A functional integration. *Group Dynamics*, *4*(1), 27–43. doi:10.1037/1089-2699.4.1.27

Dambolena, I., & Rao, A. (1994). What is Six Sigma anyway? *Quality*, *33*(11), 10.

Drickhamer, D. (2002). Where lean meets Six Sigma. *Industry Week*, *251*(4), 55.

Duff, W. H. (2007, March). *Effective leaders do we have the right answers*. A notable speech to graduates of the Professional Executive Leadership School. Lynchburg, VA.

Eckes, G. (2001). *The Six Sigma revolution: How General Electric and others turned process into profits*. New York: John Wiley & Sons.

Fuqua, D. R., & Newman, J. L. (2005). Integrating structural and behavioral. *Consulting Psychology Journal*, *57*(2), 126–132. doi:10.1037/1065-9293.57.2.126

Glatthorn, A. (1998). *Writing the winning dissertation*. Thousand Oaks, CA: Sage Publications, Inc.

Gnibus, R. J., & Krull, R. (2003). Small companies see the money. *Quality*, *42*(8), 48–51.

Goffnett, S. P. (2004). Understanding Six Sigma implications for industry and education. *Journal of Information Technology*, *20*(4), 10–24.

Goh, T. N. (2002). A strategic assessment of Six Sigma. *Quality and Reliability Engineering International*, *18*(5), 403–410. doi:10.1002/qre.491

Hahn, G. J., Hill, W. J., Hoerl, R. W., & Zinkgraf, S. A. (1999). The impact of Six Sigma improvement–A glance into the future of statistics. *The American Statistician*, *53*(3), 208–215.

Hammer, M., & Goding, J. (2001). Putting Six Sigma in perspective. *Quality*, *40*(10), 58–62.

Harry, M., & Schroeder, R. (2000). *Six Sigma: The breakthrough management strategy revolutioning the world's top corporations*. New York: Currency Doubleday.

Harry, M. J. (1998). Six Sigma: A breakthrough strategy for profitability. *Quality Progress*, *31*(5), 60–64.

Hedricks, C. A., & Weinstein, H. P. (1999). The personality profile of a corporate leader. Paper presented on Caliper, Inc. Princeton, NJ.

Hoerl, R. W. (2001). Six Sigma black belts: What do they need to know? *Journal of Quality Technology*, *33*(4), 391–406.

Hoerl, R. W., Rodebaugh, W., & Snee, R. D. (2004). Six Sigma statistical leadership. *Quality Congress*, *58,* 385-389.

Hurtz, G. M., & Donovan, J. J. (2000). Personality and job performance: The Big Five revisited. *The Journal of Applied Psychology*, *85*(6), 869–879. doi:10.1037/0021-9010.85.6.869 PMID:11125652

Jago, A. G. (1982). Leadership: Perspective in theory and research. *Management Science*, *28*(3), 43–42. doi:10.1287/mnsc.28.3.315

Johnson, D. W., & Johnson, F. P. (2006). *Joining together: Group theory and group skills* (4th ed.). New York: Pearson A & B.

Judge, T. A., & Bono, J. E. (2000). Five-factor model of personality and transformational leadership. *The Journal of Applied Psychology*, *85*(5), 751–765. doi:10.1037/0021-9010.85.5.751 PMID:11055147

Judge, T. A., & Bono, J. E. (2004). Personality and transformational and transactional leadership: A meta-analysis. *The Journal of Applied Psychology*, *89*(5), 901–910. doi:10.1037/0021-9010.89.5.755 PMID:15506869

Judge, T. A., Bono, J. E., Illies, R., & Gerhardt, M. (2002). Personality and leadership: A qualitative and quantitative review. *The Journal of Applied Psychology*, *87*(4), 765–780. doi:10.1037/0021-9010.87.4.765 PMID:12184579

Judge, T. A., Erez, A., Bono, J. E., & Thoreaen, C. (2002). Discriminant and incremental validity of four personality traits: Are measures of self-esteem, neuroticism, locus of control, and generalized self-efficacy indicators of a common core construct? *Journal of Personality and Social Psychology*, *83*(3), 693–710. doi:10.1037/0022-3514.83.3.693 PMID:12219863

Kilburg, R. R. (2007). *Reverence and temperance: Foundations for virtuous leadership.* Paper presented at the American Psychological Association Convention. Baltimore, MD. doi:10.1037/e681502007-001

Kirkpatrick, S. A., & Locke, E. A. (1991). Leadership: Do traits matter? *The Executive*, *5*(2), 48–60. doi:10.5465/AME.1991.4274679

Kumar, S., Wolfe, A. D., & Wolfe, K. A. (2008). Using Six Sigma DMAIC to improve credit initiation process in a financial services operation. *International Journal of Productivity and Performance Management*, *57*(8), 659–676. doi:10.1108/17410400810916071

Lord, R. G., DeVader, C. L., & Alliger, G. M. (1986). A meta-analysis of the relation between personality traits and leadership perceptions: An application of validity generalization procedures. *The Journal of Applied Psychology*, *71*(3), 402–410. doi:10.1037/0021-9010.71.3.402

Mann, R. D. (1959). A review of the relationship between personality and performance in small groups. *Psychological Bulletin*, *56*(4), 241–270. doi:10.1037/h0044587

Maxwell, J. (1996). *Qualitative research design. An interactive approach*. Thousand Oaks, CA: Sage Publications.

Northouse, P. G. (2001). *Leadership: Theory and practice*. Thousand Oaks, CA: Sage Publications.

Northouse, P. G. (2004). *Leadership: Theory and practice* (3rd ed.). Thousand Oaks, CA: Sage Publications.

Northouse, P. G. (2007). *Leadership: Theory and practice* (4th ed.). Thousand Oaks, CA: Sage Publications.

Pande, P., & Holpp, L. (2002). *What is Six Sigma?* New York: McGraw-Hill.

Pande, P., Neuman, R. P., & Cavanagh, R. R. (2002). *The Six Sigma Way team fieldbook: An implementation guide for process improvement teams*. New York: McGraw-Hill.

Pyzdek, T. (2000). Six Sigma and lean production. *Quality Digest*, *14*, 20–34.

ReVelle, J. B. (2004). Six Sigma: Problem-solving techniques create safer, healthier worksites. *Professional Safety*, *49*(10), 38–46.

Smith, K. (2003, May). Six Sigma for the service sector. *Quality Digest.* Retrieved from http://www.qualitydigest.com/may03/articles/01_article.shtml

Stogdill, R. M. (1948). Personal factors associated with leadership: A survey of the literature. *The Journal of Psychology*, *25*(1), 35–71. doi:10.1080/00223980.1948.9917362 PMID:18901913

Stogdill, R. M. (1974). *Handbook of leadership: A survey of theory and research*. New York: Free Press.

Tushman, M., O'Reilly, C., & Nadler, D. (1989). *The management of organization: Strategies, tactics, analyses*. New York: Ballinger Pub. Co.

Tyco Electronics Inc. (2008, August 27). *Six Sigma DMAIC Green Belt Certification.* Retrieved from http://6sigma.us.tycoelectronics.com/default.htm

Tyco Electronics Inc. (2009, April 13). *Tyco Electronics business improvement tracking*. Retrieved from http://tebit.us.tycoelectronics.com/default.aspx

Zaccaro, S. J., Kemp, C., & Bader, P. (2004). Leader traits and attributes. In J. Antonakis, A. T. Cianciolo, & R. J. Sternberg (Eds.), *The nature of leadership* (pp. 101–124). Thousand Oaks, CA: Sage.

Zaleznik, A. (1977, May–June). Managers and leaders: Are they different? *Harvard Business Review*, *55*, 67–78. PMID:14723179

Zu, X., Fredendall, L. D., & Douglas, T. J. (2008). The evolving theory of quality management: The role of Six Sigma. *Journal of Operations Management*, *26*(5), 630–650. doi:10.1016/j.jom.2008.02.001

ADDITIONAL READING

Balzer, W. K. (2010). *Lean higher education: Increasing the value and performance of university processes*. New York: Productivity Press. doi:10.1201/EBK1439814659

Brussee, W. (2012). *Statistics for six sigma made easy*. New York: McGraw-Hill.

Jones, D., & Womack, J. (2005). *Lean solutions: How companies and customers can create value and wealth together*. New York: Free Press.

Kotter, J. P. (1996). *Leading change*. Boston: Harvard Business School Press.

KEY TERMS AND DEFINITIONS

Black Belt: Is a process improvement project team leader who is trained and certified in the principles of Six Sigma methodology and tools, and who is responsible for the most complex Six Sigma projects (Pande & Holpp, 2002).

Green Belt: Is a process improvement project team leader who is trained and certified in the principles and practices of Six Sigma methodology and tools, and who is responsible for projects in which the cost savings are less and the time to complete the project is less than the black belt (Pande & Holpp, 2002).

Hard Cost Savings: Have a direct impact on the Profit/Loss (P&L) statement for the business and are usually the result of improvements which reduce costs (also known as Green Savings or Reduction Savings) (http://tebit.us.tycoelectroncis.com/Default.aspx).

Project Success: Is hard cost savings for green belt projects equal to or greater than $50,000 is successful. Black belt projects equal to or greater than $250,000 is successful (http://6sigma.us.tycoelectronics.com/Default.htm).

Six Sigma: Is a process-focused, statistically based approach to business improvement (Hoerl et al., 2004).

Traits: Are innate or learned characteristics, or both (Northouse, 2007).

Tyco Electronics Business Improvement Tracking (TEBIT): A software application utilized within Tyco Electronics to track, maintain, and report price reductions or cost savings for projects involving External Supplier spend reductions and avoidances or Internal cost improvements (http://tebit.us.tycoelectronics.com/Default.aspx).

Compilation of References

Aberdeen Group. (2004). *The Lean Strategies Benchmark Report*. Retrieved on January 22, 2014, from http://www.synergyresources.net/pdf/Aberdeen_LeanBenchmark_Study06_2004.pdf

Aberdeen Group. (2007). *Early Lean Adopters Embrace Technology*. Retrieved on April 1, 2014, from http://www.slideshare.net/find-whitepapers/early-lean-adopters-embrace-technology-aberdeen-group-sector-insight

Aboelmaged, M. G. (2010). Six Sigma quality: A structured review and implications for future research. *International Journal of Quality & Reliability Management*, *27*(3), 269–318. doi:10.1108/02656711011023294

Aboelmaged, M. G. (2011). Reconstructing Six Sigma barriers in manufacturing and service organizations: The effects of organizational parameters. *International Journal of Quality & Reliability Management*, *28*(5), 519–541. doi:10.1108/02656711111132562

Abraham, S. (2012). Job Satisfaction as an Antecedent to Employee Engagement. *SIES Journal of Management*, *8*(2), 27–36.

Adams, C. W., Gupta, P., & Wilson, C. E. Jr. (2003). *Six Sigma deployment*. Boston: Butterworth-Heinemann.

Aghazadeh, S. (2002). Implementation of total quality management in the managed care industry. *The TQM Magazine*, *14*(2), 79–91. doi:10.1108/09544780210416694

Agus, A., Krishnan, S. K., & Kadir, S. L. S. A. (2000). The structural impact of total quality managementon financial performance relative to competitors through customer satisfaction: A study of Malaysian manufacturing companies. *Total Quality Management*, *11*(4-6), 808–819. doi:10.1080/09544120050008255

Ahire, S. L., & Dreyfus, P. (2000). The impact of design management and process management on quality: An empirical investigation. *Journal of Operations Management*, *18*(5), 549–575. doi:10.1016/S0272-6963(00)00029-2

Alberts, D. S., Garstka, J. J., Hayes, R. E., & Signori, D. T. (2001). *Understanding Information Age Warfare*. Washington, DC: CCRP Press, CCRP Publication Series.

Albinsson, P. (2004). *Interacting with command and control systems: Tools for operators and designers*. Linköpings Studies in Science and Technology, Thesis No. 1132, ISSN 0280-7971.

Alting, L. (1995). Sustainable industrial production/environmental issues in product development. In *Life Cycle Modelling for Innovative Products and Processes, Proceedings of the IFIP WG5.3 International Conference on Lifecycle Modelling for Innovative Products and Processes*. Berlin, Germany: Academic Press.

American Nuclear Society (2012). *ANS dosechart*. Author.

Analytic Systems. (2014). *What Lean Manufacturing Means to You and Analytic Systems*. Retrieved on January 29, 2014, from http://www.analyticsystems.com/about/lean.php

Andersson, R., Eriksson, H., & Torstensson, H. (2006). Similarities and differences between TQM, six sigma and lean. *The TQM Magazine*, *18*(2), 282–296. doi:10.1108/09544780610660004

Anonymous, . (1994). What is communication? *International Journal of Bank Marketing*, *12*(1), 19. PMID:7746874

Ansari, A., & Modarress, B. (1990). *Just-in-time purchasing*. New York, NY: Free Press.

Antony, J. (2008). What is the role of academic institutions for the future development of Six Sigma? *International Journal of Productivity and Performance Management, 57*(1). Retrieved from http://www.emeraldinsight.com/journals.htm?articleid=1641825

Antony, F. (2004). Some pros and cons of six sigma: An academic perspective. *The TQM Magazine*, *16*(4), 303–306. doi:10.1108/09544780410541945

Antony, J. (2006). Six Sigma for service processes. *Business Process Management Journal*, *12*(2), 234–248. doi:10.1108/14637150610657558

ASAP World Consultancy. (1996). Special Edition: Using Sap R/3. Indianapolis, IN: Que.

Azevedo, S. G., Carvalho, H., & Cruz-Machado, V. (2011). A proposal of LARG supply chain management practices and a performance measurement system. *International Journal of e-Education, e-Management Learning*, *1*(1), 7–14.

Badiru, A. B. (2011). Introduction to half-life learning curves. In M. Y. Jaber (Ed.), *Learning Curves Theory, Models and Applications* (pp. 129–161). Boca Raton, FL: CRC Press/Taylor and Francis Group. doi:10.1201/b10957-10

Baird, K., Hu, K. J., & Reeve, R. (2011). The relationships between organizational culture, total quality management practices and operational performance. *International Journal of Operations & Production Management*, *31*(7), 789–814. doi:10.1108/01443571111144850

Balogun, O. (2009). *Supporting Information Fusion Tasks in Emergency Command and Control Domains Using a Hybrid Fuzzy Cognitive Map and Dempster-Shafer Algorithms*. North Carolina Agricultural and Technical State University.

Bancroft, N., Seip, H., & Sprengel, A. (1997). *Implementing SAP R/3* (2nd ed.). Greenwich, CT: Manning Publications.

Bartholomew, B. (2004). *Lean vs. ERP*. Retrieved on January 1, 2014, from http://www.industryweek.com/articles/lean_vs_erp_413.aspx

Bartholomew, B. (2012). *Can Lean and ERP Work Together?* Retrieved on January 1, 2014 from http://www.industryweek.com/articles/can_lean_and_erp_work_together_27092.aspx

Bashkansky, M., Battle, P. R., Duncan, M. D., Kahn, M., & Reintjes, M. J. (1996). Subsurface defect detection in ceramics using an optical gated scatter reflectometer. *Journal of the American Ceramic Society*, *79*(5), 1397–1400. doi:10.1111/j.1151-2916.1996.tb08602.x

Bass, B. M. (1990). *Bass and Stogdill's handbook of leadership: A survey of theory and research*. New York: Free Press.

Bateman, N., & David, A. (2002). Process improvement programmes: A model for assessing sustainability. *International Journal of Operations & Production Management*, *22*(5), 515–526. doi:10.1108/01443570210425156

Batten, J. (1993). A total quality culture. *Management Review*, *83*(5), 61.

Beheshti, H. M., Oghazi, P., Mostaghel, R., & Hultman, M. (2014). Supply chain integration and firm performance: an empirical study of Swedish manufacturing firms. *Competitiveness Review: An International Business Journal Incorporating Journal of Global Competitiveness, 24*(1), 3-13.

Benedetto, A. R. (2003). Adapting manufacturing-based Six Sigma methodology to the service environment of a radiology film library. *Journal of Healthcare*, *48*(4), 263–280. PMID:12908226

Bennett, T. D., & Yu, F. (2005). A nondestructive technique for determining thermal properties of thermal barrier coatings. *Journal of Applied Physics*, *97*(1), 13520. doi:10.1063/1.1826217

Bennis, W. E., & Nanus, B. (1985). *Leaders: The strategies for taking charge*. New York: Harper and Row.

Berger, J., & Iyengar, R. (2013). Communication channels and word of mouth: How the medium shapes the message. *The Journal of Consumer Research*, *40*(3), 567–579. doi:10.1086/671345

Berman, R. (2010). *How Much Do Your Employees Know About Your Business?* Retrieved on December 30, 2013, from http://www.rob-berman.com/how-much-do-your-employees-know-about-your-business/

Bhasin, S. (2011). Performance of organisations treating lean as an ideology. *Business Process Management Journal*, *17*(6), 986–1011. doi:10.1108/14637151111182729

Birou, L., Germain, R. N., & Christensen, W. J. (2011). Applied logistics knowledge impact on financial performance. *International Journal of Operations & Production Management*, *31*(8), 816–834. doi:10.1108/01443571111153058

Bisconti, A. S. (2012). *Nuclear Energy: Upward Trends in U.S. Leadership*. Innovative Reactors.

Bisgaard, S., Hoerl, R. W., & Snee, R. D. (2002). Improving business processes with Six Sigma.*Quality Congress*, 701-704.

Biswas, G., Kapadia, R., & Yu, X. W. (1997). Combined qualitative-quantitative steady-state diagnosis of continous-valued systems. *IEEE Transactions on Systems, Man, and Cybernetics*, *SMC-27*(2), 167–185. doi:10.1109/3468.554680

Bititci, U. S., Suwignjo, P., & Carrie, A. S. (2001). Strategy management through quantitative modelling of performance measurement systems. *International Journal of Production Economics*, *69*(1), 15–22. doi:10.1016/S0925-5273(99)00113-9

Bjorklund, J. (2009). *10 Ways to use ERP to Lean the Manufacturing Supply Chain*. Retrieved on April 2, 2014, from http://download.ifsworld.com/shop/images/WP-10_Ways_Use_ERP_to_Lean_Supply_Chain.pdf

Block, M. (2007). *National Public Radio: Gatorade Inventor Robert Cade Dies*. Retrieved from http://www.npr.org/templates/story/story.php?storyId=16665667

BLS Handbook of Methods. (2014). *Productivity Measures: Business Sector and Major Subsectors*. Bureau of Labor Statistics.

Boyle, T. A., Scherrer-Rathje, M., & Stuart, I. (2011). Learning to be lean: The influence of external information sources in lean improvements. *Journal of Manufacturing Technology Management*, *22*(5), 587–603. doi:10.1108/17410381111134455

Bradford, B. (2013). *Are Mini-Reactors The Future Of Nuclear Power*. Academic Press.

Brady, J. E., & Allen, T. T. (2006). Six Sigma literature: A review and agenda for future research. *Quality and Reliability Engineering International*, *22*(3), 335–367. doi:10.1002/qre.769

Brah, S. A., Lee, S. L., & Rao, B. M. (2002). Relationship between TQM and performance of Singapore companies. *International Journal of Quality & Reliability Management*, *19*(4), 356–379. doi:10.1108/02656710210421553

Brence, J. R., & Brown, D. E. (2002). Data mining corrosion from eddy current non-destructive tests. *Computers & Industrial Engineering*, *43*(4), 821–840. doi:10.1016/S0360-8352(02)00142-0

Breyfogle, F. W., Cupello, J. M., & Meadows, B. (2001). *Managing Six Sigma: A practical guide to understanding, assessing, and implementing the strategy that yields bottom-line success*. New York: John Wiley & Sons.

Brue, G. (2002). *Six Sigma for managers*. New York: McGraw-Hill.

Brue, G., & Howes, R. (2006). *Six Sigma -The McGraw-Hill 36-hour course*. New York: McGraw-Hill.

Bryman, A. (1992). *Charisma and leadership in organization*. London: Sage.

Bulls, W. K. (2008). *An examination of leadership traits that impact the development of web-based programs in institutions of higher education within the UNC system.* (Unpublished Doctoral Dissertation). North Carolina Agricultural and Technical State University, Greensboro, NC.

Burt, D. N. (1989). Managing suppliers up to speed. *Harvard Business Review*, *67*(4), 127–135.

Burton, T. (2012). The generations of improvement. *Industrial Engineer, 44*(8), 46-50.

Burton, T. T. (n.d.). *Is this a Six Sigma, Lean, or Kaizen Project?* Retrieved from http://www.isixsigma.com/index.php?option=com_k2&view=item&id=1291&Itemid=1&Itemid=1

Bushman, J. B., Mitchell, C. M., Jones, P. M., & Rubin, K. S. (1993). ALLY: An operator's associate for cooperative supervisory control systems. *IEEE Transactions on Systems, Man, and Cybernetics*, *SMC-23*(1), 111–128. doi:10.1109/21.214771

Bushong S. C (1977). *Radiation Exposure in Our Daily Lives*. Academic Press.

Bushuev, M. A., & Guiffrida, A. L. (2012). Optimal position of supply chain delivery window: Concepts and general conditions. *International Journal of Production Economics*, *137*(2), 226–234. doi:10.1016/j.ijpe.2012.01.039

Buzolic, J., Mladineo, N., & Knezic, S. (2002). Decision support system for disaster communications in Dalatia. *International Journal of Emergency Management*, *21*, 34–41.

Byrne, G., Lubowe, D., & Blitz, A. (2007). *Driving operational innovation using Lean Six Sigma*. IBM Global Business Services. Retrieved from http://www-935.ibm.com/services/us/gbs/bus/pdf/g510-6331-01-leansixsigma.pdf

Byrne, J. (1998, June). How Jack Welch Runs GE. *BUSINESSWEEK.* Retrieved from: http://www.businessweek.com/1998/23/b3581001.htm

Byrne, G., Lubowe, D., & Blitz, A. (2007). Using a Lean Six Sigma approach to drive innovation. *Strategy and Leadership*, *35*(2), 5–10. doi:10.1108/10878570710734480

C'Shekhar, N., Shitole, O., Zahran, & Al-Nuaimy, W. (Eds.). (2006). *NDT 2006, the 45th Annual British Conference on NDT*. Stratford-upon-Avon, UK: NDT.

Campbell, D. (1991). *Manual for the Campbell Leadership Index*. Minneapolis, MN: National Computers Systems.

Capitol Hill Press Releases. (2005, October 6). *Jefford's statement on Hurricane Katrina response*. Federal Document Clearing House.

Carino, N. J. (2013). Training: Often the missing link in using NDT methods. *Journal of Construction and Building Materials*, *38*, 1316–1329. doi:10.1016/j.conbuildmat.2011.03.060

Carreira, B., & Trudell, B. (2006). *Lean Six Sigma That Works: A Powerful Action Plan for Dramatically Improving Quality, Increasing Speed, and Reducing Waste*. New York: American Management Association. EBSCOhost (accessed May 6, 2014).

Carter, J. P., Smeltzer, L., & Narasimhan, R. (1998). The role of buyer and supplier relationships in integrating TQM through the supply chain. *European Journal of Purchasing and Supply*, *4*(4), 223–234. doi:10.1016/S0969-7012(98)00013-6

CATS. (n.d.). Retrieved from http://www.esri.com/news/arcnews/fall99articles/07-catsemer.html

Chakrapani, S. K., Dayal, V., Krafka, R., & Eldal, A. (2012). Ultrasonic testing of adhesive bonds of thick composites with applications to wind turbine blades. *AIP Conference Proceedings*, *1430*, 1284–1290. doi:10.1063/1.4716366

Chan, F. T. S., Chan, H. K., & Qi, H. J. (2006). A review of performance measurement systems for supply chain management. *International Journal of Business Performance Management*, *8*(2/3), 110–131. doi:10.1504/IJBPM.2006.009032

Chan, F. T. S., Swarnkar, R., & Tiwari, M. K. (2006). Synchronisation issue of supply chains: A six-sigma constrained random search approach. *International Journal of Services Technology and Management*, *7*(5/6), 552–567. doi:10.1504/IJSTM.2006.011287

Chapman, P., Beron, M., & Haggett, P. (2011). Applying selected quality management techniques to diagnose delivery time variability. *International Journal of Quality & Reliability Management*, *28*(9), 1019–1040. doi:10.1108/02656711111172568

Chavern, D. (2013). *Greater Elkhart (IN) Chamber of Commerce: Manufacturing: Driving Growth at Home and Competition Abroad*. Retrieved from https://www.uschamber.com/speech/%E2%80%9Cmanufacturing-driving-growth-home-and-competition-abroad%E2%80%9D-remarks-david-chavern-chief

Chegg. (2013). *Bridge That Gap: Analyzing the Student Skill Index*. Retrieved from http://www.insidehighered.com/sites/default/server_files/files/Bridge%20That%20Gap-v8.pdf

Chemers, M. M. (2000). Leadership research and theory: A functional integration. *Group Dynamics*, *4*(1), 27–43. doi:10.1037/1089-2699.4.1.27

Chen, Z., Yusa, N., & Miya, K. (2009). Some advances in numerical analysis techniques for quantitative electromagnetic nondestructive evaluation. *Nondestructive Testing and Evaluation, 24*(1-2), 69-102.

Chertoff, M. (2005). Response to Hurricane Katrina, congressional testimony. *Federal Document Clearing House*. CoBRA 4.0. Retrieved from http://www.defencegroupinc.com/cobra/sw_cobra.htm

Choi, T. Y., & Eboch, K. (1998). The TQM paradox: Relations among TQM practices, plant performance, and customer satisfaction. *Journal of Operations Management*, *17*(1), 59–75. doi:10.1016/S0272-6963(98)00031-X

Choudhary, A. K., Singh, D. A., & Tiwari, M. K. (2006). A statistical tolerancing approach for design of synchronized supply chains. *Robotics and Computer-integrated Manufacturing*, *22*(4), 315–321. doi:10.1016/j.rcim.2005.07.003

Christensen, C. (2014). *Disruptive Innovation*. Retrieved from http://www.claytonchristensen.com/key-concepts/

Christopher, M. (1998). *Logistics and Supply Chain Management*. London: Pitman Publishing.

Christopher, M., & Lee, H. (2004). Mitigating supply chain risk through improved confidence. *International Journal of Physical Distribution & Logistics Management*, *34*(5), 388–396. doi:10.1108/09600030410545436

Clayton, J. C. (1993). *The Shippingport pressurized water reactor and light water breeder reactor*. Westinghouse Electric Corporation.

Cohen, S. (2011). *The Political Demise of Nuclear Power in the U.S.* Academic Press.

Columbus, L. (2013). *2013 ERP Market Share Update: SAP Solidifies Market Leadership*. Retrieved December 27, 2013, from http://www.forbes.com/sites/louiscolumbus/2013/05/12/2013-erp-market-share-update-sap-solidifies-market-leadership/

Command and Control. (1976). Computer-Aided Management of Emergency Operations (CAMEO). *US Marine Corps MCDP*, *6*, 33–60.

Cooke, M., & Buckley, N. (2008). Web 2.0, social networks and the future of market research. *International Journal of Market Research*, *50*(2), 267–292.

Cottyn, J. J., Van Landeghem, H. H., Stockman, K. K., & Derammelaere, S. S. (2011). A method to align a manufacturing execution system with Lean objectives. *International Journal of Production Research*, *49*(14), 4397–4413. doi:10.1080/00207543.2010.548409

Crabtree, S. (2013). *Northern America Leads the World in Workplace Engagement*. Gallup Poll Briefing.

Crate, S. (2006). *i Six Sigma: Historical Perspective of Lean*. Retrieved from http://www.isixsigma.com/new-to-six-sigma/history/historical-perspective-lean/

Crespo-Marquez, A., & Lung, B. (2008). A review of e-maintenance capabilities and challenges, *Journal of Systemics*, *Cybernatics and Informatics*, *6*, 62–66.

CrunchBase. (2014). *Elon Musk: Person Overview*. Retrieved from http://www.crunchbase.com/person/elon-musk

Current Developments in Non Destructive Testing. (1966). *Management Review, 55*(4), 28.

Cuthbertson, R., & Piotrowicz, W. (2011). Performance measurement systems in supply chains a framework for contextual analysis. *International Journal of Productivity and Performance Management*, *60*(6), 583–602. doi:10.1108/17410401111150760

Czerwinski, T. J. (2003). *Coping with bounds: Speculations on non-linearity in military affairs*. Washington, DC: CCRP Publisher.

Dalius Misiunas. (2008). Failure Monitoring and Asset Condition Assessment in Water Supply Systems. In *Proceedings of 7th International Conference on Environmental Engineering*, (pp. 648-655). Academic Press.

Dambolena, I., & Rao, A. (1994). What is Six Sigma anyway? *Quality*, *33*(11), 10.

Dan-Shang, W., & Chia-Chun, H. (2013). The effect of authentic leadership on employee trust and employee engagement. Social Behavior & Personality. *International Journal (Toronto, Ont.)*, *41*(4), 613–624. doi:10.2224/sbp.2013.41.4.613

Dasgupta, T. (2003). Using the six-sigma metric to measure and improve the performance of a supply chain. *Total Quality Management and Business Excellence*, *14*(3), 355–366. doi:10.1080/1478336032000046652

De Feo, J. (2010). *i Six Sigma: Ask the Expert: The Topic – Large and Small Deployments*. Retrieved from http://www.isixsigma.com/implementation/deployment-structure/ask-expert-large-small-deployments/

De Feo, J. A., & Early, J. F. (2010a). Continuous innovation using design for six sigma. In J. M. Juran & J. A. De Feo (Eds.), *Juran's quality handbook: The complete guide to performance excellence* (6th ed., pp. 407–438). New York, NY: McGraw Hill.

De Feo, J. A., & Early, J. F. (2010b). Six sigma: Improving process effectiveness. In J. M. Juran & J. A. De Feo (Eds.), *Juran's quality handbook: the complete guide to performance excellence* (6th ed., pp. 355–385). New York, NY: McGraw Hill.

De Koning, H., & Verver, J. P. S. (2006). Lean six sigma in healthcare. *Journal for Healthcare Quality*, *28*(2), 4–11. doi:10.1111/j.1945-1474.2006.tb00596.x PMID:16749293

Dean, J. W., & Bowen, D. E. (1994). Management theory and total quality: Improving research and practice through theory development. *Academy of Management Review*, *19*(3), 392–418.

Deflorin, P., & Scherrer-Rathje, M. (2012). Challenges in the transformation to lean production from different manufacturing-process choices: A path-dependent perspective. *International Journal of Production Research*, *50*(14), 3956–3973. doi:10.1080/00207543.2011.613862

Deis, P. (2006). Lean *and ERP-can they co-exist?* Retrieved on April 1, 2014, from http://www.articlesbase.com/strategic-planning-articles/lean-and-erp-can-they-coexist-47604.html

Deming, W. E. (2000). *Out of the Crisis*. Cambridge, MA: MIT Press.

Doerman, S. M., & Caldwell, R. K. (2010). Lean techniques: Improving process efficiency. In J. M. Juran & J. A. De Feo (Eds.), *Juran's quality handbook: the complete guide to performance excellence* (6th ed., pp. 327–354). New York, NY: McGraw Hill.

Dooley, K. (1996). A nominal definition of complex adaptive systems. *The Chaos Network*, *8*(1), 2–3.

Dow, D., Samson, D., & Ford, S. (1999). Exploding the myth: Do all quality management practices contribute to superior quality performance? *Production and Operations Management*, *8*(1), 1–27. doi:10.1111/j.1937-5956.1999.tb00058.x

Dowlatshahi, S. (1992). Purchasing's Role in a Concurrent Engineering Environment. *International Journal of Purchasing and Materials Management*, 21-25.

Downs, C. W., & Hazen, M. D. (1977). A factor analytic study of communication satisfaction. *Journal of Business Communication*, *14*(3), 63–73. doi:10.1177/002194367701400306

Dr. Pepper Success Stories. (2014). *TexasLeanSixSigma*. Retrieved from http://www.texasleansixsigma.com/success-stories/dr_pepper

Dragan, K., & Swiderski, W. (2010). Studying Efficiency of NDE Techniques Applied to Composite Materials in Aerospace Applications. *Acta Physica Polonica A*, *117*(5), 878–883.

Drickhamer, D. (2002). Where lean meets Six Sigma. *Industry Week*, *251*(4), 55.

Duff, W. H. (2007, March). *Effective leaders do we have the right answers*. A notable speech to graduates of the Professional Executive Leadership School. Lynchburg, VA.

Dumitrescu, C., & Dumitrache, M. (2011). The impact of lean six sigma on the overall results of companies. Economia. *Seria Management*, 535-544.

Duncan, M., Bashkansky, M., & Reintjes, J. (1998). Subsurface defect detection in materials using optical coherence tomography. *Optics Express*, *2*(13), 540–545. doi:10.1364/OE.2.000540 PMID:19381226

Durkin, J. (1994). *Expert Systems: Design and Development*. New York: Macmillan. Retrieved from http://www.hoise.com/vmw/04/articles/vmw/LV-VM-06-04-20.htm

Early, J. F., & Stockhoff, B. A. (2010). Accurate and reliable measurement systems and advanced tools. In J. M. Juran & J. A. De Feo (Eds.), *Juran's quality handbook: The complete guide to performance excellence* (6th ed., pp. 583–672). New York, NY: McGraw Hill.

Eckes, G. (2001). *The Six Sigma revolution: How General Electric and others turned process into profits*. New York: John Wiley & Sons.

Economic Snapshot. (2000). *The link between productivity growth and living standards*. Retrieved from http://www.epi.org/publication/webfeatures_snapshots_archive_03222000/

EDUCAUSE Center for Applied Research. (2002). *Enterprise Systems for Higher Education.* Retrieved on April 1, 2014, from http://net.educause.edu/ir/library/pdf/ERS0204/rs/ers02043.pdf

Ehie, I. C., & Madsen, M. (2005). Identifying Critical Issues in enterprise Resource Planning (ERP) Implementation. *Computers in Industry*, *56*(6), 545–557. doi:10.1016/j.compind.2005.02.006

Emanoil, M., Ramona, T., & Lucia, F. (2013). Efficient organizational communication- A key to success. *Studies In Business & Economics*, *8*(2), 74–78.

Eriksson, O. (2000). *Communication quality: Towards an intersubjective understanding of quality.* Report on Business and Informatics 2000.

ERSM. (n.d.). Retrieved from http://www.anl.gov/techtransfer/pdf/profile%20ERSM%209-16-04.pdf

Essex, L., & Kany, M. (1999). *Fast forward leadership.* Guildford, UK: Kings Lynn.

Fabrycky, W. J., & Blanchard, B. S. (1991). *Life Cycle Cost and Economic Analysis*. Englewood Cliffs, NJ: Prentice-Hall.

Faifer, M., Ferrara, L., Ottoboni, R., & Toscani, S. (2013). Low frequency electrical and magnetic methods for Non-destructive analysis of fiber dispersion in fiber reinforced cementitious composites: An Overview. *Sensors (Basel, Switzerland)*, *13*(1), 1300–1318. doi:10.3390/s130101300 PMID:23337334

Faifer, M., Ottoboni, R., Toscani, S., Ferrara, L., & Felicetti, R. (2009). A multi-electrode measurement system for steel fiber reinforced concrete materials monitoring. In *Proceedings of IEEE International Instrumentation and Measurement Technology Conference*, (pp. 303–308). IEEE. doi:10.1109/IMTC.2009.5168466

Fening, F. A., Pesakovic, G., & Amaria, P. (2008). Relationship between quality management practices and the performance of small and medium size enterprises (SMEs) in Ghana. *International Journal of Quality & Reliability Management*, *25*(7), 694–708. doi:10.1108/02656710810890881

Flynn, B. B., Schroeder, R. G., & Sakakibara, S. (1994). A framework for quality management research and an associated measurement instrument. *Journal of Operations Management*, *11*(4), 339–366. doi:10.1016/S0272-6963(97)90004-8

Flynn, B. B., Schroeder, R. G., & Sakakibara, S. (1995). The impact of quality management practices on performance and competitive advantage. *Decision Sciences*, *26*(5), 659–691. doi:10.1111/j.1540-5915.1995.tb01445.x

Forslund, H., Jonsson, P., & Mattsson, S. (2009). Order-to-delivery performance in delivery scheduling environments. *International Journal of Productivity and Performance Measurement*, *58*(1), 41–53. doi:10.1108/17410400910921074

Forza, C., & Filippini, R. (1998). TQM impact on quality conformance and customer satisfaction: A causal model. *International Journal of Production Economics*, *55*(1), 1–20. doi:10.1016/S0925-5273(98)00007-3

Fuqua, D. R., & Newman, J. L. (2005). Integrating structural and behavioral. *Consulting Psychology Journal*, *57*(2), 126–132. doi:10.1037/1065-9293.57.2.126

Galdabini, G. (2013, February 12). *Re: FreeEnterprise.com, U.S. Manufacturing: The World's Third Largest Economy*. Retrieved from http://www.freeenterprise.com/economy-taxes/us-manufacturing-worlds-third-largest-economy

Gallo, A. (2013). *Act like a leader before you are one*. Harvard Business Review.

Garg, D., Naraharai, Y., & Viswanadham, N. (2006). Achieving sharp deliveries in supply chains through variance reduction. *European Journal of Operational Research*, *171*(1), 227–254. doi:10.1016/j.ejor.2004.08.033

Garnand, L. (2012). *Can cloud computing make manufacturing compliance easier?* Retrieved on January 29, 2014 from http://searchmanufacturingerp.techtarget.com/feature/Can-cloud-computing-make-manufacturing-compliance-easier

George, M. L. (2002). *Lean Six Sigma: Combining Six Sigma Quality with Lean Speed*. New York: McGraw-Hill.

Gerst, R. (2013). Understanding Employee Engagement and Trust. *Journal for Quality and Participation*, *35*(4), 32–36.

Giannantonio, C. M., & Hurley-Hanson, A. E. (2011). Frederick Winslow Taylor: Reflections on the Relevance of The Principles of Scientific Management 100 Years Later. *Journal Of Business & Management*, *17*(1), 7–10.

Glasgow, J. M., Scott-Caziewell, J. R., & Kaboli, P. J. (2010). Guiding inpatient quality improvement: A systematic review of Lean and Six Sigma. *Joint Commission Journal of Quality Qual Patient Saf*, *36*(12), 533–540. PMID:21222355

Glatthorn, A. (1998). *Writing the winning dissertation*. Thousand Oaks, CA: Sage Publications, Inc.

Gnibus, R. J., & Krull, R. (2003). Small companies see the money. *Quality*, *42*(8), 48–51.

Goetsch, D. L., & Davis, S. B. (1997). *Introduction to total quality: Quality management for production, processing, and services*. Englewood Cliffs, NJ: Prentice-Hall.

Goffnett, S. P. (2004). Understanding Six Sigma implications for industry and education. *Journal of Information Technology*, *20*(4), 10–24.

Goh, T. N. (2002). A strategic assessment of Six Sigma. *Quality and Reliability Engineering International*, *18*(5), 403–410. doi:10.1002/qre.491

Goldsmith, M. (2010). *Empowering your employees to empower themselves. Harvard Business Review*.

Gopal, P. R. C., & Thakkar, J. (2012). A review on supply chain performance measures and metrics: 2000-2011. *International Journal of Productivity and Performance Measurement*, *61*(5), 518–547. doi:10.1108/17410401211232957

Gordelier, S., & Cameron, R. (2010). *Comparing Nuclear Accident Risks with Those from Other Energy Sources*. Academic Press.

Goris, J. (2007). Effects of satisfaction with communication on the relationship between individual-job congruence and job performance/satisfaction. *Journal of Management Development*, *26*(8), 737–752. doi:10.1108/02621710710777255

Gotzamani, K. D., & Tsiotras, G. D. (2001). An empirical study of the ISO9000 standards' contribution towards total quality management. *International Journal of Operations & Production Management*, *21*(10), 1326–1342. doi:10.1108/EUM0000000005972

Graebsch, M. (2005). *Information and communication in lean product development.* (Diploma thesis). Technical University of Munich, Munich, Germany.

Grant, R. M., Shani, R., & Krishnan, R. (1994). TQM's challenge to management theory and practice. *Sloan Management Review*, *35*(2), 25–35.

Green, R. (2000). *Reshaping Six Sigma at Honeywell - Dedicated teams successfully merge two divergent quality systems.* Quality Digest. Retrieved from: http://www.qualitydigest.com/dec00/html/honeywell.html

Green, M. R., Henneke, E., & Reifsnider, K. (1981). Thermographic investigations of high-power ultrasonic, heating in materials. *Ultrasonics*, *7*, 159–163.

Guide, V., Daniel, R., Vaidy, J., & Linton, J. D. (2003). Building contingency planning for closed-loop supply chains with product recovery. *Journal of Operations Management*, *21*(3), 259–279. doi:10.1016/S0272-6963(02)00110-9

Guiffrida, A. L., Chen, L., Liang, H., Ngniatedema, T., & Tanai, Y. (2013). Modeling supply chain delivery performance: A literature review. In *Proceedings of the 2013 International Academy of Business and Economics Conference*, (pp. 11-20). Academic Press.

Guiffrida, A. L. (2014). Recent trends in supply chain delivery models. *International Journal of Social, Management*. *Economics and Business Engineering*, *8*(4), 1809–1812.

Guiffrida, A. L., & Nagi, R. (2006). Cost characterizations of supply chain delivery performance. *International Journal of Production Economics*, *102*(1), 22–36. doi:10.1016/j.ijpe.2005.01.015

Gunasekaran, A., & Kobu, B. (2007). Performance measures and metrics in logistics and supply chain management: A review of recent literature (1995-2004) for research and application. *International Journal of Production Research*, *45*(12), 2819–2840. doi:10.1080/00207540600806513

Gunasekaran, A., Patel, C., & McGaughey, R. (2004). A framework for supply chain performance measurement. *International Journal of Production Economics*, *87*(3), 333–347. doi:10.1016/j.ijpe.2003.08.003

Hackman, J. R., & Wageman, R. (1995). Total quality management: Empirical, conceptual, and practical issues. *Administrative Science Quarterly*, *40*(2), 203–270. doi:10.2307/2393640

Hafeez, K., Malak, N., & Abdelmeguid, H. (2006). A framework for TQM to achieve business excellence. *Total Quality Management*, *17*(9), 1213–1229. doi:10.1080/14783360600750485

Hahn, G. J., Hill, W. J., Hoerl, R. W., & Zinkgraf, S. A. (1999). The impact of Six Sigma improvement—A glance into the future of statistics. *The American Statistician*, *53*(3), 208–215.

Hamel, G. (2012). What Matters Now. *What Matters Now, 1*.

Hamel, G. (2013). High Engagement? *Leadership Excellence*, *30*(2), 3–4.

Hammer, M., & Goding, J. (2001). Putting Six Sigma in perspective. *Quality*, *40*(10), 58–62.

Handfield, R., Ghosh, S., & Fawcett, S. (1998). Quality-driven changes and its effects on financial performance. *Quality Management Journal*, *5*(3), 13–30.

Han, J., Trienekens, J. H., & Omta, S. W. F. (2009). Integrated information and logistics management, quality management and firm performance of pork processing industry in China. *British Food Journal*, *111*(1), 9–25. doi:10.1108/00070700910924209

Harrell, E. (2011). Bury Our Nuclear Waste-Before It Buries Us: Belfer Center Programs or Projects: Managing the Atom. *Time*.

Harris, G., & Donatelli, A. (2005). *Value-stream mapping as a lean management tool*. Huntsville, AL: University of Alabama.

Harry, M. J. (1998). Six Sigma: A breakthrough strategy for profitability. *Quality Progress*, *31*(5), 60–64.

Harry, M., Mann, P., Hodgins, O., Hulbert, R., & Lacke, C. (2010). *Practioner's Guide to Statistics and Lean Six Sigma for Process Improvements*. Hoboken, NJ: John Wiley & Sons.

Harry, M., & Schroeder, R. (2000). *Six Sigma: The breakthrough management strategy revolutioning the world's top corporations*. New York: Currency Doubleday.

Hasin, M. A. A., Seeluangsawat, R., & Shareef, M. A. (2001). Statistical measures of customer satisfaction for health care quality assurance: A case study. *International Journal of Health Care Quality Assurance*, *14*(1), 6–13. doi:10.1108/09526860110366214

Hasle, P., Bojesen, A., Per, L. J., & Bramming, P. (2012). Lean and the working environment: A review of the literature. *International Journal of Operations & Production Management*, *32*(7), 829–849. doi:10.1108/01443571211250103

Hayes Roth, B., & Hayes Roth, F. (1979). A Cognitive Model of Planning. *Cognitive Science*, *3*(4), 275–310. doi:10.1207/s15516709cog0304_1

Hayes, J., & Phillips-Hahn, A. (2003). Explore: Research at the University of Miami. In *Gatorade: The Idea that Launched an Industry*. Retrieved from http://research.ufl.edu/publications/explore/v08n1/gatorade.html

Haywood, M., & Peck, H. (2003). An investigation into the management of supply chain vulnerability in UK aerospace manufacturing. In *Proceedings of the EUROMA/POMS Conference*, (*Vol. 2*, pp. 121-30). EUROMA/POMS.

HAZUS-MH. (n.d.). Retrieved from http://www.fema.gov/hazus

Heckert, L. (2013). *Lean Six Sigma at Alliant Energy*. Available at: http://www.alliantenergy.com/wcm/groups/wcm_internet/@int/@ae/documents/document/mdaw/mdmy/~edisp/032825.pdf

Hedricks, C. A., & Weinstein, H. P. (1999). The personality profile of a corporate leader. Paper presented on Caliper, Inc. Princeton, NJ.

Hellsten, U., & Klefsjö, B. (2000). TQM as a management system consisting of values, techniques and tool. *The TQM Magazine*, *12*(4), 238–244. doi:10.1108/09544780010325822

Helper, S. (1996). Lean thinking. *Sloan Management Review*, *38*(1), 114.

Helton, J. C. (1997). Uncertainty and sensitivity analysis in the presence of stochastic and subjective uncertainty. *Journal of Statistical Computation and Simulation*, *57*(1-4), 3–57. doi:10.1080/00949659708811803

Hendricks, K. B., Singhal, V. R., & Stratman, J. K. (2007). The Impact of Enterprise Systems on Corporate Performance: A Study of ERP, SCM, and CRM System Implementations. *Journal of Operations Management*, *25*(1), 65–82. doi:10.1016/j.jom.2006.02.002

Hesami, S., Nikookar, I., & Harsej, F. (n.d.). *Integrated model of six sigma and lean on organization productivity*. Retrieved June 10, 2014, from Asia Pacific Industrial Engineering and Management System: http://apiems.net/conf2013/1083.pdf

Ho, D. C. K., Duffy, V. G., & Shih, H. M. (1999). An empirical analysis of effective TQM implementation in the Hong Kong electronics manufacturing industry. *Human Factors and Ergonomics in Manufacturing*, *9*(1), 1–25. doi:10.1002/(SICI)1520-6564(199924)9:1<1::AID-HFM1>3.0.CO;2-L

Hoerl, R. W. (2001). Six Sigma black belts: What do they need to know? *Journal of Quality Technology*, *33*(4), 391–406.

Hoerl, R. W., Rodebaugh, W., & Snee, R. D. (2004). Six Sigma statistical leadership. *Quality Congress*, *58,*385-389.

Holland, J. H. (1994). Echoing emergence: Objectives, rough definitions, and speculations for ECHO-class models. In G. Cowan, D. Pines, & D. Melzner (Eds.), *Complexity: Metaphors, Models, and Reality*. Adisson-Wesley.

Hong-Bae, J., Kiritsis, D., & Xirouchakis, P. (2007). Product Life-Cycle Metadata Modeling and its Application with RDF. Knowledge and Data Engineering. *IEEE Transactions on Knowledge and Data Engineering, 19*(12), 1680–1693. doi:10.1109/TKDE.2007.190661

Horsager, D. (2012). Author shares 8 pillars to getting ‘The Trust Edge’. *Inside Tucson Business, 22*(14), 14.

Horsager, D. (2014). The Trust Edge. *Trust Edge, 1*.

Horsager, D. (2013). Employee Trust. *Leadership Excellence*, *30*(1), 5.

Hsu, B.-M., Hsu, L.-Y., & Shu, M.-H. (2013). Evaluation of supply chain performance using delivery-time performance analysis chart approach. *Journal of Statistics and Management Systems*, *16*(1), 73–87. doi:10.1080/09720510.2013.777568

Huang, D., Swanson, E. A., Lin, C. P., Schuman, J. S., Stinson, W. G., & Chang, W. et al. (1991). Optical coherence tomography. *Science*, *254*(5035), 1178–1181. doi:10.1126/science.1957169 PMID:1957169

Hugos, M. H. (2011). *Essentials of Supply Chain Management* (vol. 62). Wiley.

Huo, B. (2012). The impact of supply chain integration on company performance: An organizational capability perspective. *Supply Chain Management: An International Journal*, *17*(6), 596–610. doi:10.1108/13598541211269210

Hurtz, G. M., & Donovan, J. J. (2000). Personality and job performance: The Big Five revisited. *The Journal of Applied Psychology*, *85*(6), 869–879. doi:10.1037/0021-9010.85.6.869 PMID:11125652

Ibarra-Castanedo, C., Piau, J. M., Guibert, S., Avdelidis, N. P., Genest, M., Bendada, A., & Maldague, A. (2009). Comparative study of active thermography techniques for the nondestructive evaluation of honeycomb structures. *Res. Nondestructive. Evaluation.*, *20*(1), 1–31. doi:10.1080/09349840802366617

Idris, M. A., & Zairi, M. (2006). Sustaining TQM: A synthesis of literature and proposed research framework. *Total Quality Management*, *17*(9), 1245–1260. doi:10.1080/14783360600750535

Industrial Revolution. (2014). In *Encyclopaedia Britannica*. Retrieved from http://www.britannica.com/EBchecked/topic/287086/Industrial-Revolution

Ingram, B. L., & Chung, R. S. (1997). Client satisfaction data and quality improvement planning in managed mental health care organizations. *Health Care Management Review*, *22*(3), 40–52. doi:10.1097/00004010-199707000-00005 PMID:9258695

Iseri-Say, A., Toker, A., & Kantur, D. (2008). Do popular management techniques improve performance? Evidence from large businesses in Turkey. *Journal of Management Development*, *27*(7), 660–677. doi:10.1108/02621710810883580

Ittner, C. D., & Larcker, D. F. (1995). Total quality management and the choice of information and reward systems. *Journal of Accounting Research*, *33*, 1–34. doi:10.2307/2491371

Jaber, M. Y. (2011). *Learning Curves Theory, Models, and Applications*. Boca Raton, FL: CRC Press/Taylor and Francis Group. doi:10.1201/b10957

Jago, A. G. (1982). Leadership: Perspective in theory and research. *Management Science*, *28*(3), 43–42. doi:10.1287/mnsc.28.3.315

Jailia, E., Sujata, M., Jailia, M., & Agarwal, M. (2011). Lean software development ("as a survival tool in recession"). *International Journal of Software Engineering and its Applications*, 63-70.

Jayamaha, N. P., Grigg, N. P., & Mann, R. S. (2008). Empirical validity of Baldrige criteria: New Zealand evidence. *International Journal of Quality & Reliability Management*, *25*(5), 477–493. doi:10.1108/02656710810873880

Jesse, G., & Moles, M. (2005). Portable phased array applications. *Materials Evaluations, 63* (4), 394-404.

Jobs, S. (2005). *You've got to find what you love, Jobs says*. Retrieved from http://news.stanford.edu/news/2005/june15/jobs-061505.html

Johnson, D. W., & Johnson, F. P. (2006). *Joining together: Group theory and group skills* (4th ed.). New York: Pearson A & B.

Johnson, M., & Templar, S. (2011). The relationships between supply chain and firm performance. *International Journal of Physical Distribution & Logistics Management*, *41*(2), 88–103. doi:10.1108/09600031111118512

Joiner, T. A. (2007). Total quality management and performance - The role of organization support and co-worker support. *International Journal of Quality & Reliability Management*, *24*(6), 617–627. doi:10.1108/02656710710757808

Jones, C., Medlen, N., Merlo, C., et al. (n.d.). *The lean enterprise.* Retrieved June 5, 2014, from CiteSeer: http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.26.8316

Joyce, M., & Schechter, B. (2004). *The Lean Enterprise-A Management Philosophy at Lockheed Martin.* Retrieved from: http://handle.dtic.mil/100.2/ADA435279

Judge, T. A., & Bono, J. E. (2000). Five-factor model of personality and transformational leadership. *The Journal of Applied Psychology*, *85*(5), 751–765. doi:10.1037/0021-9010.85.5.751 PMID:11055147

Judge, T. A., & Bono, J. E. (2004). Personality and transformational and transactional leadership: A meta-analysis. *The Journal of Applied Psychology*, *89*(5), 901–910. doi:10.1037/0021-9010.89.5.755 PMID:15506869

Judge, T. A., Bono, J. E., Illies, R., & Gerhardt, M. (2002). Personality and leadership: A qualitative and quantitative review. *The Journal of Applied Psychology*, *87*(4), 765–780. doi:10.1037/0021-9010.87.4.765 PMID:12184579

Judge, T. A., Erez, A., Bono, J. E., & Thoreaen, C. (2002). Discriminant and incremental validity of four personality traits: Are measures of self-esteem, neuroticism, locus of control, and generalized self-efficacy indicators of a common core construct? *Journal of Personality and Social Psychology*, *83*(3), 693–710. doi:10.1037/0022-3514.83.3.693 PMID:12219863

Juran, J. M., & De Feo, J. A. (2010). *Juran's quality handbook: the complete guide to performance excellence* (6th ed.). New York, NY: McGraw Hill.

Kahn, W. A., & Heaphy, E. D. (2014). Relational contexts of personal engagement at work. In Employee engagement in theory and practice (pp. 82-96). Academic Press.

Kahn, W. A., & Fellows, S. (2013). Employee engagement and meaningful work. In B. J. Dik, Z. S. Byrne, & M. F. Steger (Eds.), *Purpose and meaning in the workplace* (pp. 105–126). Washington, DC: American Psychological Association. doi:10.1037/14183-006

Kamrani, A. K., & Sa'ed, S. M. (2001). *Product Design for Modularity. Springer*.

Kanji, G. K., & Yui, H. (1997). Total quality culture. *Total Quality Management*, *8*(6), 417–428. doi:10.1080/0954412979424

Kasemsap, K. (2014). The role of lean production on organizational performance. In V. Modrak & P. Semanco (Eds.), *Handbook of research on design and management of lean production systems* (pp. 358–388). Hershey, PA: IGI Global. doi:10.4018/978-1-4666-5039-8.ch017

Kaynak, H. (2003). The relationship between total quality management practices and their effects on firm performance. *Journal of Operations Management*, *21*(4), 405–435. doi:10.1016/S0272-6963(03)00004-4

Keyton, J., Caputo, J., Ford, E., Fu, R., Leibowitz, S. A., & Liu, T. et al. (2013). Investigating verbal workplace communication behaviors. *Journal of Business Communication*, *50*(2), 152–169. doi:10.1177/0021943612474990

Khan, S. (2011). *A lean communication model for product management.* Retrieved June 5, 2014, from http://onproductmanagement.net/wp content/uploads/2011/03/Lean-Communication.pdf

Khot, D., Nahmens, J., & Ikuma, L. (n.d.). *The impact of lean methods on organizational communication in homebuilding*. Retrieved June 5, 2014, from Associated Schools of Construction: ascpro.ascweb.org/chair/paper/CPRT124002010.pd

Kilburg, R. R. (2007). *Reverence and temperance: Foundations for virtuous leadership.* Paper presented at the American Psychological Association Convention. Baltimore, MD. doi:10.1037/e681502007-001

Kilpatrick, J. (2003). *Lean principles.* Retrieved June 5, 2014, from Utah Manufacturing Extension Partnership: http://yourcareeracademy.com/yca/assets/uploads/lib_file/Lean%20Principles%20-%20overview.pdf

Kim, S. W. (2009). An investigation of the direct and indirect effect of supply chain integration on firm performance. *International Journal of Production Economics*, *119*(2), 328–346. doi:10.1016/j.ijpe.2009.03.007

Kirchgaessner, S. (2013). *'Obamacare' rollout issues raise concerns*. Retrieved on April 3, 2014, from www.ft.com/cms/s/0/b81e566e-35b8-11e3-952b-00144feab7de.html

Kiritsis, E., Georgios, K., Tetradis, N., Tomarasad, N., & Zarikas, V. (2003). Cosmological evolution with brane-bulk energy exchange. Institute of Physic Publishing for SISSA/ISAS.

Kirkpatrick, S. A., & Locke, E. A. (1991). Leadership: Do traits matter? *The Executive*, *5*(2), 48–60. doi:10.5465/AME.1991.4274679

Kleijnen, J. P. (2005). Supply chain simulation tools and techniques: A survey. *International Journal of Simulation and Process Modeling*, *1*(1/2), 82–89.

Knowles, G., Whicher, L., Femat, J. H., & Canales, F. D. C. (2005). A conceptual model for the application of Six Sigma methodologies to supply chain improvement. *International Journal of Logistics: Research and Applications*, *8*(1), 51–65. doi:10.1080/13675560500067459

Kokkranikal, A. J., Kosgi, H., & Losekoot, E. (2013). Barriers and challenges in the application of Six Sigma in the hospitality industry: Some observations and findings. *International Journal of Productivity and Performance Management*, *62*(3), 317–322. doi:10.1108/17410401311309203

Kongchan, A. (1985). Communication satisfaction, job satisfaction, and organizational commitment of business college faculty. (Order No. 8602582, Arizona State University). ProQuest Dissertations and Theses, 267-267.

Kovács, G. (2012). Productivity improvement by lean manufacturing philosophy. *Acta Technica Corviniensis - Bulletin of Engineering, 5*(1), 41-45.

Krajewski, L. J., & Ritzman, L. P. (2001). *Operations management: Strategy and analysis*. Upper Saddle River, NJ: Prentice-Hall.

Krause, H. J., & Kreutzbruck, M. V. (2002). Recent developments in SQUID NDE. *Physica C*, *470* (23), 2079-2126.

Krause, D. R. (1998). The antecedents of buying firms' efforts to improve suppliers. *Journal of Operations Management*, *17*(2), 205–224. doi:10.1016/S0272-6963(98)00038-2

Krause, T. (2009). Facilitating teamwork with lean six sigma and web-based technology. *Business Communication Quarterly*, *72*(1), 84–90. doi:10.1177/1080569908330374

Krieger, J., Krause, H.-J., Gampe, U., & Sawade, G. (1991). Magnetic field measurements on bridges and development of a mobile SQUID system. In *Proc. Intl. Conf. on NDE Tech. Aging Infrastr.*, (pp. 229-239). Newport Beach, CA: Academic Press. doi:10.1117/12.339929

Kumar, M., & Sankaran, S. (2007). Indian culture and the culture for TQM: A comparison. *The TQM Magazine*, *19*(2), 176–188. doi:10.1108/09544780710730014

Kumar, R. L., Bhat, M. R., & Murthy, C. R. L. (2013). Non-destructive evaluation of degradation in bond line of glass fiber reinforced polymer composite adhesive lap joints. *International Journal of Aerospace Innovations*, *5*(3 & 4), 61–71. doi:10.1260/1757-2258.5.3-4.61

Kumar, S., Wolfe, A. D., & Wolfe, K. A. (2008). Using Six Sigma DMAIC to improve credit initiation process in a financial services operation. *International Journal of Productivity and Performance Management*, *57*(8), 659–676. doi:10.1108/17410400810916071

Kumar, V., Choisne, F., Grosbois, D., & Kumar, U. (2009). Impact of TQM on company's performance. *International Journal of Quality & Reliability Management*, *26*(1), 23–37. doi:10.1108/02656710910924152

Kurtz, C. F., & Snowden, D. J. (2003). The new dynamics of strategy: Sense-making in a complex and complicated world. *IBM Systems Journal*, *42*(3), 462–483. doi:10.1147/sj.423.0462

Kwak, Y. H., & Anbari, F. T. (2006). Benefits, obstacles, and future of Six Sigma approach. *Technovation*, *26*(5-6), 708–715. doi:10.1016/j.technovation.2004.10.003

LaMonica, M. (2011). *A reality check on nuclear fusion at MIT*. Academic Press.

Laurinavicius, L. (2014). Simple microwave technique for non-destructive testing of electrical properties of magnetized materials. *Acta Physica Polonica A*, *125*(2), 205–207. doi:10.12693/APhysPolA.125.205

Lean Six Sigma Maturity at Lockheed Martin. (2007, November 6). *Quality Digest*. Retrieved from http://www.qualitydigest.com/inside/six-sigma-news/lean-six-sigma-maturity-lockheed-martin

Lee, K. L. (2002). *Critical Success Factors of Six Sigma Implementation and the Impact on Operations Performance*. (Dissertation). Cleveland State University, Cleveland, OH.

Lee, M. C., & Chang, T. (2010). Developing a lean design for Six Sigma through supply chain methodology. *International Journal of Productivity and Quality Management*, *6*(4), 407–434. doi:10.1504/IJPQM.2010.035891

Leuschner, R., Rogers, D. S., & Charvet, F. F. (2013). A meta-analysis of supply chain integration and firm performance. *Journal of Supply Chain Management*, *49*(2), 34–57. doi:10.1111/jscm.12013

Lin, L.-C., & Li, T.-S. (2010). An integrated framework for supply chain performance measurement using six-sigma metrics. *Software Quality Journal*, *18*(3), 387–406. doi:10.1007/s11219-010-9099-2

Lockamy, A., & McCormack, K. (2004). Linking SCOR planning practices to supply chain performance: An exploratory study. *International Journal of Operations & Production Management*, *24*(12), 1192–1218. doi:10.1108/01443570410569010

Lokesh, R. (2010). *Eight Steps to a Successful Lean Six Sigma Implementation*. Retrieved from http://www.isixsigma.com/implementation/success-factors/8-steps-successful-lean-six-sigma-implementation/

Lopato, P., & Chady, T. (2013). Terahertz detection and identification of defects in layered polymer composites and composite coatings. *Nondestructive Testing and Evaluation, Taylor & Francis*, *28*(1), 28–43. doi:10.1080/10589759.2012.694882

Lord, R. G., DeVader, C. L., & Alliger, G. M. (1986). A meta-analysis of the relation between personality traits and leadership perceptions: An application of validity generalization procedures. *The Journal of Applied Psychology*, *71*(3), 402–410. doi:10.1037/0021-9010.71.3.402

Lubowe, D., & Blitz, A. (2008, September). Driving Operational Innovation Using Lean Six Sigma. *Business Finance - Best Practices for Finance Executives*. Retrieved from http://businessfinancemag.com/business-performance-management/driving-operational-innovation-using-lean-six-sigma

Mader, D. P. (2009). 3.4 per million. *The Right Decision*, 50-51.

Magnusson, K., Kroslid, D., Bergman, B., Häyhänen, P., & Mills, D. (2003). *Six Sigma: The Pragmatic Approach*. Lund: Studentlitteratur.

Mann, R. D. (1959). A review of the relationship between personality and performance in small groups. *Psychological Bulletin*, *56*(4), 241–270. doi:10.1037/h0044587

Manyika, J., Chui, M., Bughin, J., Dobbs, R., Blisson, P., & Marrs, A. (2013). *Disruptive technologies: Advances that will transform life, business and the global economy*. McKinsey & Company: Insights and Publications. Retrieved from http://www.mckinsey.com/insights/business_technology/disruptive_technologies

Marodin, G., & Saurin, T. (2013). Implementing lean production systems: Research areas and opportunities for future studies. *International Journal of Production Research*, *51*(22), 6663–6680. doi:10.1080/00207543.2013.826831

Martinez, P. (2009). *Campus Using Six Sigma to Improve Business Operations*. The University of Arizona UA News. Retrieved from http://uanews.org/story/campus-using-six-sigma-improve-business-operations

Martin, P. R., & Patterson, J. W. (2009). On measuring company performance within a supply chain. *International Journal of Production Research*, *47*(9), 2449–2460. doi:10.1080/00207540701725604

Matthew, L. W. (2010, December 7). Nuclear ‘Renaissance’ Is Short on Largess. *The New York Times*.

Maurer, R. (2013). Will lean work in your organization? *Journal for Quality and Participation*, *36*(2), 27–31.

Maxwell, J. (1996). *Qualitative research design. An interactive approach*. Thousand Oaks, CA: Sage Publications.

McAdam, R., & Henderson, J. (2004). Influencing the future of TQM: Internal and external driving factors. *International Journal of Quality & Reliability Management*, *21*(1), 51–71. doi:10.1108/02656710410511696

McBride, D. (2003). Design for Manufacturability. *EMS Consulting Group*. Retrieved from http://www.emsstrategies.com

MCDP6. (1996). *Command and Control*. US Marine Corps MCDP 6.

Mendonça, D., Berroggi, G. E. G., & Wallace, W. A. (2001). Decision support for improvision during emergency response. *International Journal of Emergency Management*, *1*(1), 30–41. doi:10.1504/IJEM.2001.000507

Mika, G. (2005). *Kaizen event implementation manual*. Society of Manufacturing Engineers.

Misiunas, D., Lambert, M. F., Simpson, A. R., & Olsson, G. (2006). *Condition assessment of water transmission pipelines using hydraulic transients*. Water Management.

Monroe, D. J. (2010). Root cause analysis to maintain performance. In J. M. Juran & J. A. De Feo (Eds.), *Juran's quality handbook: The complete guide to performance excellence* (6th ed., pp. 387–405). New York, NY: McGraw Hill.

Mortenson, T. G. (2012). *State Funding: A Race to the Bottom and Presidency*. Retrieved from: http://0ehis.ebscohost.com.sheba.ncat.edu/ehost/pdfviewer/pdfviewer?sid=655cfa93-26d5-4d43-b684-82d0af468cd0%40sessionmgr104&vid=4&hid=102

Nabhani, F., & Shokri, A. (2009). Reducing the delivery lead time in a food distribution SME through the implementation of six sigma methodology. *Journal of Manufacturing Technology Management*, *20*(7), 957–974. doi:10.1108/17410380910984221

Nautilus. (1970). *Dictionary of American Naval Fighting Ships*. Naval History & Heritage Command.

Nave, D. (2002, March). How To Compare Six Sigma, Lean and the Theory of Constraints. *Quality Progress*, 73-78.

Nayak, B. (n.d.). *Lean manufacturing and value management convergence of divergent tools*. Retrieved June 10, 2014, from Save International: http://www.value-eng.org/knowledge_bank/attachments/200629.pdf

Ngai, E. W. T., Law, C. C. H., & Wat, F. K. T. (2008). Examining the critical success factors in the adoption of enterprise resource planning. *Computers in Industry*, *59*(6), 548–564. doi:10.1016/j.compind.2007.12.001

Nicholas, J. (2012). An Integrated Lean-Methods Approach to Hospital Facilities Redesign. *Hospital Topics*, *90*(2), 47–55. doi:10.1080/00185868.2012.679911 PMID:22671435

Niculescu, M. (2001). *Sensor fusion algorithms for unmanned air vehicle: Aerosonde Robotic Aircraft Notting Hill*. Victoria.

Nivola, P. (2004). *The Political Economy of Nuclear Energy in the United States*. Academic Press.

Noonan, M., & Panebianco, J. (2013, March). *9 ways leaders' actions can sustain lean progress.* Retrieved June 5, 2014, from TBMCG: http://www.tbmcg.com/whitepaper_assets/managementbriefing_9ways_leaders_actions.pdf

Normalm, T. (2011). *Achieving lean software development: Implementation of agile and lean practices in a manufacturing-oriented organization*. (Student thesis). Uppsala University, Uppsala, Sweden.

Northouse, P. G. (2001). *Leadership: Theory and practice*. Thousand Oaks, CA: Sage Publications.

Ntuen, C.A., Balogun, O., Boyle, E., & Turner, A. (2006). Supporting command and control in emergency management domain using cognitive systems engineering. *Journal of Ergonomics, 49*(12), 12–13, 1415–1436.

Ntuen, C. A., & Park, E. H. (1995). An experiment in scheduling and planning of non-structured jobs: Lessons learned from artificial intelligence and operational research toolbox. *European Journal of Operational Research*, *84*(1), 96–115. doi:10.1016/0377-2217(94)00320-C

Nuclear Regulatory Commission. (2012). *Occupational Radiation Exposure at Commercial Nuclear Power Reactors*. NUREG.

Oakland, J. S. (1995). *Total quality management: The route to improving performance*. Oxford, UK: Butterworth-Heinemann.

Obama, B. (2014). Think and Do. *NC State University Manufacturing Innovation*. Retrieved from http://www.ncsu.edu/power/

Oguz, C., Hutchinson, K. J., & Han, S. (2012). Implementing lean six sigma: a case study in concrete panel production. In *Proceedings for the 20th Annual Conference of the International Group for Lean Construction*. San Diego, CA: Montezume Publishing.

Oh, T., Kee, S., Arndt, R., Popovics, J., & Zhu, J. (2013). Comparison of NDT Methods for Assessment of a Concrete Bridge Deck. *J. Eng. Mech., 139*, 305–314.

Olkkonen, R., Tikkanen, H., & Alajoutsijarvi, K. (2000). The role of communication in business relationships and networks. *Management Decision*, *38*(6), 403–409. doi:10.1108/EUM0000000005365

Opara, L. U. (2003). Traceability in agriculture and food supply chain: A review of basic concepts, technological implications, and future prospects. *Journal of Food Agriculture and Environment*, *1*(1), 101–106.

Ozyurt, N., Mason, T. O., & Shah, S. P. (2006). Nondestructive monitoring of fiber orientation using AC-IS: An industrial scale application. *Cement and Concrete Research*, *36*(9), 1653–1660. doi:10.1016/j.cemconres.2006.05.026

Palacios-Marques, D., Saldaña, A., & Vila, J. (2013). What are the relationships among Web 2.0, market orientation and innovativeness? *Kybernetes*, *42*(5), 754–765. doi:10.1108/K-03-2013-0057

Pande, P., & Holpp, L. (2002). *What is Six Sigma?* New York: McGraw-Hill.

Pande, P., Neuman, R. P., & Cavanagh, R. R. (2002). *The Six Sigma Way team fieldbook: An implementation guide for process improvement teams*. New York: McGraw-Hill.

Paton, S. (2000, September 1). No Small Change: Making Quality Job 1 Again. *Quality Digest*. Retrieved from http://www.qualitydigest.com/sept01/html/ford.html

Paul, G. (2012). Creating an Excellence Oriented Post-merged Organisational Culture through a Structured Approach to Employee Engagement. *Africa Insight*, *42*(2), 136–156.

Pearson, N. R., Mason, J. S. D., & Priewald, R. H. (2012). The influence of maintenance on the life cycle of above-ground storage tanks. *Journal of Insights*, *54*(6), 311–315. doi:10.1784/insi.2012.54.6.311

Peck, H. (2005). Drivers of supply chain vulnerability: An integrated framework. *International Journal of Physical Distribution & Logistics Management*, *35*(4), 210–232. doi:10.1108/09600030510599904

Pei, C., Chen, Z., Wu, W., & Mao, Y. (2010). IOS Press Method improvement of EMAT signals simulation and its applications in TBC inspection. *International Journal of Applied Electromagnetics and Mechanics*, *33*, 1077–1085.

Pepper, M. P. J., & Spedding, T. A. (2010). The evolution of lean Six Sigma. *International Journal of Quality & Reliability Management*, *27*(2), 138–155. doi:10.1108/02656711011014276

Perrow, C. (2003). *Disaster prevention and mitigation*. Unpublished manuscript. Yale University.

Perry, M. (2012). *Manufacturing's Declining Share of GDP is a Global Phenomenon, and It's Something to Celebrate*. U. S. Chamber of Commerce Foundation. Retrieved from http://www.uschamberfoundation.org/blog/2012/03/manufacturing%E2%80%99s-declining-share-gdp

Perry, M. J. (2013, February 9). *Re: If top 500 US manufacturing firms were a separate country, they would have been the third largest economy last year* [Web log comment]. Retrieved from http://www.aei-ideas.org/2013/02/if-top-500-us-manufacturing-firms-were-a-separate-country-they-would-have-been-the-third-largest-country-last-year/

Peter D. Hart Research Associates, Inc. (2006). *How Should Colleges Prepare Students to Succeed in Today's Global Economy?* Retrieved from http://www.americanprogress.org/wp-content/uploads/issues /2012/06/pdf/workforce_training.pdf

Pfeiffer, W. (1998). *Conditions that hinder effective communication. The Pfeiffer Library, 6 (2).*

Pigeau, R., & McCann, C. (2002, Spring). Re-conceptualizing command and control. *Canadian Military Journal,* 53–64.

Potts, A., McNab, A., Reilly, D., & Toft, M. (2000). Presentation and Analysis enhancements of the NDT workbench: A software package for ultrasonic NDT data, CP509, Review of progress in Quantitative Nondestructive Evaluation. (D. O. Thompson & D. E. Chimenti, Eds.). American Institute of Physics.

Powell, D. (2013). ERP Systems in Lean Production: New Insights for a Review of Lean and ERP Literature. *International Journal of Operations & Production Management*, *33*(11/12).

Powell, D., Alfnes, E., Strandhagen, J., & Dreyer, H. (2012). *ERP Support for Lean Production. In Advances in Production Management Systems. Value Networks: Innovation* (Vol. 384). Technologies, and Management IFIP Advances in Information and Communication Technology.

Powell, D., Alfnes, E., Strandhagen, J., & Dreyer, H. (2013). The Concurrent Application of Lean Production and ERP: Towards an ERP-based Lean Implementation Process. *Computers in Industry*, *64*(3), 324–335. doi:10.1016/j.compind.2012.12.002

Powell, T. C. (1995). Total quality management as competitive advantage: A review and empirical study. *Strategic Management Journal*, *16*(1), 15–37. doi:10.1002/smj.4250160105

Prajogo, D. I., & McDermott, C. M. (2005). The relationship between total quality management practices and organizational culture. *International Journal of Operations & Production Management*, *25*(11), 1101–1122. doi:10.1108/01443570510626916

Psomas, E. L., & Fotopoulos, C. V. (2010). Total quality management practices and results in food companies. *International Journal of Productivity and Performance Management*, *59*(7), 668–687. doi:10.1108/17410401011075657

Puvanasvaran, P., Megat, H., Hong, T. S., & Razali, M. M. (2008). The roles of communication process for an effective lean manufacturing implementation. In *The roles of communication process for an effective lean manufacturing implementation*, (pp. 128-152). Academic Press.

Pyzdek, T. (2010). *A Roadmap for Deploying Six Sigma in Small Businesses*. Retrieved from http://www.isixsigma.com/implementation/basics/roadmap-deploying-six-sigma-small-businesses/

Pyzdek, T. (2000). Six Sigma and lean production. *Quality Digest*, *14*, 20–34.

Qaddoumi, N., Bigelow, T., Zoughi, R., & Brown, L. (2002). Reduction of sensitivity to surface roughness and slight standoff distance variations in microwave testing of thick composite structures. *American Society for Nondestructive Testing Inc, ASNT*, *60*(2), 165–170.

Raghunathan, S. (1997). Qualitative reasoning in quantitative modeling. *IEEE Transactions on Systems, Man, and Cybernetics*, *SMC-27*, 683–690. doi:10.1109/3468.618267

Rahani, E. K., Kundu, T., Wu, Z., & Xin, H. (2011). Mechanical Damage Detection in Polymer Tiles by THz Radiation. *IEEE Sensors Journal*, *11*(8), 1720–1725. doi:10.1109/JSEN.2010.2095457

Rahman, S., & Sohal, A. S. (2002). A review and classification of total quality management research in Australia and an agenda for future research. *International Journal of Quality & Reliability Management*, *19*(1), 46–66. doi:10.1108/02656710210413444

Ralson, J. E. (2010). Using national awards for excellence to drive and monitor performance. In J. M. Juran & J. A. De Feo (Eds.), *Juran's quality handbook: The complete guide to performance excellence* (6th ed., pp. 387–405). New York, NY: McGraw Hill.

Ramaa, A., Subramanya, K. N., & Rangaswamy, T. M. (2013). Performance measurement of supply chain – an empirical study. *International Journal of Business Performance and Supply Chain Modelling*, *5*(4), 343–360. doi:10.1504/IJBPSCM.2013.058202

Ramakrishnan, S. (2013). Vital missing link in organizational transformation. *Industrial Management (Des Plaines)*, *55*(1), 8–9.

Rampersad, H., & Anwar, E. (2007). *TPS-Lean Six Sigma linking human capital to Lean Six Sigma: a new blueprint for creating high performance companies*. Retrieved from: http://www.books24x7.com/marc.asp?bookid=27102

RAMS. (n.d.). Retrieved from http://www.ornl.gov/info/ornlreview/v33_3_00/software.htm

Ransom, C. (2012). Why lean? In *Proceedings of Lean Alliance Annual Meeting*. Greenville, SC: Lean Alliance.

Rao, C. M., Rao, K. P., & Muniswamy, V. V. (2011). Delivery performance measurement in an integrated supply chain: Case study in batteries manufacturing firm. *Serbian Journal of Management*, *6*(2), 205–220. doi:10.5937/sjm1102205M

Rathod, V. R., Anand, R. S., & Ashok, A. (2012). Comparative analysis of NDE techniques with image processing. *Nondestructive Testing and Evaluation*, *27*(4), 305–326. doi:10.1080/10589759.2011.645820

ReVelle, J. B. (2004). Six Sigma: Problem-solving techniques create safer, healthier worksites. *Professional Safety*, *49*(10), 38–46.

Rose, J. L. (2010). Guided wave successes and challenges for ultrasonic testing in NDT and SHM. *Materials Evaluation*, *68*(5), 495–500.

Rose, J. L. (2011). The upcoming revolution in ultrasonic guided waves. *Proceedings of the Society for Photo-Instrumentation Engineers*, *7983*, 798302, 798302-30. doi:10.1117/12.897025

Roy, M., Gupta, R. K., & Dasgupta, T. (2013). A technique for determining the optimal mix of logistics service providers of a make-to-order supply chain by formulating and solving a constrained nonlinear cost optimization problem. *Decision Sciences Letters*, *2*(1), 1–14.

Rubinacci, G., Tamburrino, A., & Ventre, S. (2009). Fast numerical techniques for electromagnetic nondestructive evaluation. *Nondestructive Testing and Evaluation*, *24*(1-2), 165–194. doi:10.1080/10589750802195568

Ruebhausen, O. M., & von Mehren, R. B. (1953, June). The Atomic Energy Act and the Private Production of Atomic Power. *Harvard Law Review*, *66*(8), 1450. doi:10.2307/1336868

SA8000. (1997). *SA 8000 Standard: 2008*. Retrieved from http://www.sa-intl.org/index.cfm?fuseaction=Page.ViewPage&PageID=937

Sacket, P. J., & Holbrook, A. E. K. (1988). DFA as a primary process decreases design deficiencies", Emerald Insight. *Assembly Automation*, *8*(3), 137–140. doi:10.1108/eb004710

Safaei, M., Issa, S., Seifert, M., Thoben, K.-D., & Lang, W. (2013). A method to estimate the accumulated delivery time uncertainty in supply networks. In H.-J. Kreowski, B. Scholz-Reiter, & K.-D. Thoben (Eds.), *Dynamics in Logistics, Lecture Notes in Logistics* (pp. 337–347). Berlin: Springer-Verlag. doi:10.1007/978-3-642-35966-8_28

Sake, H., & Hahn, B. (2013, April 18). *Applying lean, six sigma, BPM, and SOA to drive business results.* Retrieved June 10, 2014, from IBM RedBooks: http://www.redbooks.ibm.com/redbooks.nsf/RedbookAbstracts/redp4447.html?Open

Salaheldin, S. I. (2009). Critical success factors for TQM implementation and their impact on performance of SMEs. *International Journal of Productivity and Performance Management*, *58*(3), 215–237. doi:10.1108/17410400910938832

Salah, S., Rahim, A., & Carretero, J. A. (2011). Implementation of Lean Six Sigma (LSS) in supply chain management (SCM): An integrated management philosophy. *International Journal of Transitions and Innovation Systems*, *1*(2), 138–162. doi:10.1504/IJTIS.2011.039622

Salas, E., Dickinson, T. L., Converse, S. A., & Tannebaum, S. I. (1992). Toward an understanding of team performance and training. In R. J. Sweezey & E. Salas (Eds.), *Teams: Their training and performance* (pp. 3–29). Norwood, NJ: Ablex Publication.

Sallis, E. (2002). *Total quality management in education*. London, UK: Kogan Page.

Sambasivan, M., Mohamed, Z. A., & Nanden, T. (2009). Performance measures and metrics for e-supply chains. *Journal of Enterprise Information Management*, *22*(3), 346–360. doi:10.1108/17410390910949751

Samson, D., & Terziovski, M. (1999). The relationship between total quality management practices and operational performance. *Journal of Operations Management*, *17*(4), 393–409. doi:10.1016/S0272-6963(98)00046-1

SAP. (2011). *SAP Corporate Profile*. Retrieved on April 1, 2014, from http://chemicalsbestpractices.sap.com/Files/2_SAP_In_The_Chemical_Industry/SAP_Corporate_Profile.pdf

SAP. (2012). *Co-Innovation at SAP*. Retrieved on April 2, 2014, from http://www.sap.com/index.html

SAP. (2013). *Improve Performance in Manufacturing, R & D, and Sustainability.* Retrieved on January 29, 2014, from http://www.sap.com/solution/lob/manufacturing.html

SAP. (2014a). *Almost Instant Gratification for Thirsty Consumers*. Retrieved on January 29, 2014, from http://www.sap.com/customer-testimonials/consumer/nongfu-spring.html

SAP. (2014b). *SAP Software & Solutions*. Retrieved on April 2, 2014, from http://www.sap.com/index.html

Sarkis, J. (2003). A strategic decision framework for green supply chain management. *Journal of Cleaner Production, 11*, 397.409

Sarros, J. C., Gray, J., Densten, I. L., & Cooper, B. (2005). The organizational culture profile revisited and revised: An Australian perspective. *Australian Journal of Management*, *30*(1), 159–182. doi:10.1177/031289620503000109

Sathe, V. (1985). *Culture and related corporate realities*. Homewood, IL: Irwin.

Savage, G. (2007). Failure prevention in bonded joints on primary load bearing structures. *Engineering Failure Analysis*, *14*(2), 321–348. doi:10.1016/j.engfailanal.2005.11.013

Schein, E. (1985). *Organizational culture and leadership*. San Francisco, CA: Jossey-Bass.

Schmidt, M. A. R., Oswald-Tranta, B., & Schledjewski, R. (2014). Non-Destructive Thermography Analysis of Impact Damage on Large-Scale CFRP Automotive Parts. *Materials (Basel)*, *7*(1), 413–429. doi:10.3390/ma7010413

Schneiderman, A. M. (1996). Metrics for order fulfillment process (part I). *Journal of Cost Management*, *10*(2), 30–42.

Schoop, M., Köhne, F., & Ostertag, K. (2010). Communication quality in business negotiations. *Group Decision and Negotiation*, *19*(2), 193–209. doi:10.1007/s10726-008-9128-8

Schroeder, R. G., Linderman, K., Liedtke, C., & Choo, A. S. (2008). Six Sigma: Definition and underlying theory. *Journal of Operations Management*, *26*(4), 536–554. doi:10.1016/j.jom.2007.06.007

Senge, P. M. (1990). *The fifth discipline: The art and practice of the learning organization*. New York, NY: Doubleday.

Shade, G. F. (2009). Response to Counterfeit Integrated Circuit Components in the Supply Chain: Part II Insight Analytical Labs. *EDFAAO*, *1*, 14–21.

Shanley, C. (2014). Minding Your Social Media Ps and Qs. *Illinois Banker*, *99*(1), 28–29.

Shattuck, L. G., & Woods, D. D. (2000). Communication of intent in military command and control systems. In C. McCann & R. Pigeau (Eds.), *The Human in Command: Exploring the Modern Military Experience, (pp. 279–91)*. New York: Plenum. doi:10.1007/978-1-4615-4229-2_19

Shepherd, C., & Günter, H. (2006). Measuring supply chain performance: Current research and future directions. *International Journal of Productivity and Performance Management*, *55*(3/4), 242–258. doi:10.1108/17410400610653219

Shi, M., & Yu, W. (2012). Supply chain management and financial performance: Literature review and future directions. *International Journal of Operations & Production Management*, *33*(10), 1283–1317. doi:10.1108/IJOPM-03-2012-0112

Shorr, B. A., & Wong, A. (2013). Two Faces of Economic Development: The Ethical Controversy Surrounding U.S.-Related Sweatshops in Developing Asian Countries. In Ethical Challenges in Trans-Pacific Relations: Selected Essays. Academic Press.

Sigma, G. L. (2012). *The basics of lean six sigma*. Retrieved June 10, 2014, from Go Lean Six Sigma: http://www.goleansixsigma.com/the-basics-of-lean-six-sigma/

Silverstein, D. (2010). *The Topic – Deploying and Implementing Six Sigma*. Retrieved from http://www.isixsigma.com/implementation/deployment-structure/ask-expert-deploying-implementing-six-sigma/

Singh, J., & Singh, H. (2013). Continuous Improvement Strategies: An Overview. *IUP Journal of Operations Management*, *12*(1), 32–57.

Smith, K. (2003, May). Six Sigma for the service sector. *Quality Digest.* Retrieved from http://www.qualitydigest.com/may03/articles/01_article.shtml

Smith, M., & Downs, S. (1975). Trainable assessments for apprentice selection in shipbuilding. *Journal of Occupational Psychology*, *48*(1), 39–42. doi:10.1111/j.2044-8325.1975.tb00295.x

Social Accountability International. (1997). *SA8000 Standard: 2008*. Retrieved from http://www.sa-intl.org/index.cfm?&viewpage&pageid=473

Sorenson, S. (2013). How Employee Engagement Drives Growth. *Gallup Business Journal, 1*.

Sovacool, B. (2011). *Second Thoughts About Nuclear Power*. National University of Singapore.

Sower, V., Quarles, R., & Broussard, E. (2007). Cost of quality usage and its relationship to quality system maturity. *International Journal of Quality & Reliability Management*, *24*(2), 121–140. doi:10.1108/02656710710722257

Spinks, N., & Wells, B. (1995). Quality communication: A key to quality leadership. *Training for Quality*, *3*(2), 14–19. doi:10.1108/09684879510087486

Stamm, C. L., & Golhar, D. Y. (1993). JIT purchasing: Attribute classification and literature review. *Production Planning and Control*, *4*(3), 273–282. doi:10.1080/09537289308919445

Standard, C., & Davis, D. (2000). Lean thinking for competitive advantage. *Automotive Manufacturing and Production*, *12*, 1–3.

Stanke, A. K. (2001). *A Framework for achieving lifecycle value in product development*. (Unpublished Master's thesis). Massachusetts Institute of Technology, Cambridge, MA. Retrieved from http://hdl.handle.net/1721.1/28239

Stata, R. (1986). Organization learning – the key to management innovation. *Sloan Management Review*, (Spring): 63–74.

Steinlicht, C. L. (2010). Lean production and the organizational life cycle: A survey of lean tool effectiveness in young and mature organizations (Order No. 3412450, Capella University). *ProQuest Dissertations and Theses,*, 218-n/a.

Stephen, S., & Soares, L. (2012). *Let's Get Serious About Our Nation's Human Capital-A Plan to Reform the U.S. Workforce Training System*. Retrieved from http://www.americanprogress.org/wp-content/uploads/issues/2012/06 /pdf/ workforce_training.pdf

Stockhoff, B. A. (2010). Core tools to design, control, and improve performance. In J. M. Juran & J. A. De Feo (Eds.), *Juran's quality handbook: The complete guide to performance excellence* (6th ed., pp. 583–672). New York, NY: McGraw Hill.

Stogdill, R. M. (1948). Personal factors associated with leadership: A survey of the literature. *The Journal of Psychology*, *25*(1), 35–71. doi:10.1080/00223980.1948.9917362 PMID:18901913

Stogdill, R. M. (1974). *Handbook of leadership: A survey of theory and research*. New York: Free Press.

Stoll, H. W. (1990). *Simultaneous Engineering*. In C. W. Allen (Ed.), *Design for Manufacturing,* (pp. 23–29). SME Press.

Stone, K. B. (2012). Four decades of lean: A systematic literature review. *International Journal of Lean Six Sigma*, *3*(2), 112–132. doi:10.1108/20401461211243702

Strupe, M. (2009). *Lean vs Six Sigma: What's the Difference*? The Ultimus BPM Blog. Retrieved from http://www.ultimus.com/Blog/bid/33875/Lean-vs-Six-Sigma-What-s-the-Difference

Sun, S. (2011). The strategic role of lean production in SOE's development. *International Journal of Business and Management*, *6*(2), 160–168. doi:10.5539/ijbm.v6n2p160

Su, Q., Li, Z., Zhang, S. X., Liu, Y. Y., & Dang, J. X. (2008). The impacts of quality management practices on business performance: An empirical investigation from China. *International Journal of Quality & Reliability Management*, *25*(8), 809–823. doi:10.1108/02656710810898621

Suwignjo, P., Bititci, U. S., & Carrie, A. S. (2000). Quantitative models for performance measurement system. *International Journal of Production Economics*, *64*(1), 231–241. doi:10.1016/S0925-5273(99)00061-4

Taghizadegan, S. (2006). *Essentials of lean six sigma* (Science Direct Reader version). Retrieved from: http://www.sciencedirect.com/science/article/pii/B9780123705020500047

Tan, K. C., Lyman, S. B., & Wisner, J. (2002). Supply chain management: A strategic perspective. *International Journal of Operations & Production Management*, *22*(6), 614–631. doi:10.1108/01443570210427659

Tari, J. J. (2005). Components of successful total quality management. *The TQM Magazine*, *17*(2), 182–194. doi:10.1108/09544780510583245

Tariq, P. S., & Alina-Alexandra, B. (2009). Robotic system for inspection of test objects with unknown geometry using NDT methods. *Industrial Robot: An International Journal*, *36*(4), 340–343. doi:10.1108/01439910910957093

Tata, J., & Prasad, J. (1998). Cultural and structural constraints on total quality management implementation. *Total Quality Management*, *9*(8), 703–710. doi:10.1080/0954412988172

Tavrin, Y., Siegel, M., & Hinken, J. H. (1999). Standard method for detection of magnetic defects in aircraft engine discsusing a HTS SQUID gradiometer. *IEEE Transactions on Applied Superconductivity*, *9*(2), 3809–3812. doi:10.1109/77.783857

Terziovski, M., & Samson, D. (1999). The link between total quality management practice and organizational performance. *International Journal of Quality & Reliability Management*, *16*(3), 226–237. doi:10.1108/02656719910223728

Tetteh, E. G., Eyob, E., & Amewokunu, Y. (2013). *Evaluation of Key Metrics for Performance Measurement of a Lean Deployment Effort*. Hershey, PA: IGI Global.

The Association of American Colleges And Universities. (2014). *It Takes More than a Major: Employer Priorities for College Learning and Student Success.* Retrieved from http://www.aacu.org/leap/documents/2013_EmployerSurvey.pdf

The Economist. (2012). *Manufacturing: The Third Industrial Revolution*. Retrieved from http://www.economist.com/node/21553017

The Economist. (2013). *When giants slow down: Emerging economies*. Retrieved from http://www.economist.com/news/briefing/21582257-most-dramatic-and-disruptive-period-emerging-market-growth-world-has-ever-seen#sthash.03wd8L5K.dpbs

The Skills and Qualities Employers Value Most in Their New Hires. (2014). Retrieved from http://www.naceweb.org/press-releases.aspx

The Tesla Motors Team. (2014, April 24). *Re: 100 Supercharger Stations* [Web log comment]. Retrieved from http://www.teslamotors.com/blog/100-supercharger-stations

Tian, W., Li, Q., & Jin, Z. (2003). Sensor fusion in remote sensing satellites using a modified Kalman filter. *Measurement Science & Technology*, *14*(3), 356–357. doi:10.1088/0957-0233/14/3/315

Toremen, F., Karakus, M., & Yasan, T. (2009). Total quality management practices in Turkish primary schools. *Quality Assurance in Education*, *17*(1), 30–44. doi:10.1108/09684880910929917

Tushman, M., O'Reilly, C., & Nadler, D. (1989). *The management of organization: Strategies, tactics, analyses*. New York: Ballinger Pub. Co.

Tyco Electronics Inc. (2008, August 27). *Six Sigma DMAIC Green Belt Certification*. Retrieved from http://6sigma.us.tycoelectronics.com/default.htm

Tyco Electronics Inc. (2009, April 13). *Tyco Electronics business improvement tracking*. Retrieved from http://tebit.us.tycoelectronics.com/default.aspx

U.S. Department of Defense, Department of the Army. (2014). *2014 Annual Report on Business Transformation - Providing Readiness at Best Value* (Ref ID: 6-2837C37). Retrieved from http://www.army.mil/article/118302/2014_Army_Business_Transformation_Report__Providing_readiness_at_best_value/

ULTRA Consultants. (2012). *Lean, Six Sigma and ERP: Putting it all together for Improved Performance*. Retrieved on December 27, 2013, from http://www.ultraconsultants.com/

Umble, E. J., Haft, R. R., & Umble, M. M. (2003). Enterprise resource planning: Implementation procedures and critical success factors. *European Journal of Operational Research*, *146*(2), 241–257. doi:10.1016/S0377-2217(02)00547-7

Upadhye, N., Deshmukh, S. G., & Garg, S. (2010). Lean manufacturing for sustainable development. *Global Business and Management Research*, *2*(1), 125–137.

Uyar, A. (2009). Quality performance measurement practices in manufacturing companies. *The TQM Journal*, *21*(1), 72–86. doi:10.1108/17542730910924763

Vachon, S., & Klassen, R. D. (2002). An exploratory investigation of the effects of supply chain complexity on delivery performance. *IEEE Transactions on Engineering Management*, *49*(2), 218–230. doi:10.1109/TEM.2002.803387

Vavilov, V. P., Almond, D. P., Busse, G., Grinzato, E., Krapez, J. C., & Maldague, X. et al. (1998). Infrared thermographic detection and characterization of impact damage in carbon fibre composites: results of the round robin test. In *Proceedings of the 4th Conference on Quantitative Infrared Thermography (QIRT)*. Lodz, Poland: QIRT.

Viaene, J., & Verbeke, W. (1998). Traceability as a key instrument towards supply chain and quality management in Belgian poultry meat chain. *Supply Chain Management: An International Journal*, *3*(3), 139–141. doi:10.1108/13598549810230868

Vijayakumar, R. L., Bhat, M. R., & Murthy, C. R. L. (2012). Nondestructive evaluation of adhesively bonded carbon fiber reinforced composite lap joints with varied bond quality. *AIP Conference Proceedings*, *1430*, 1276–1283. doi:10.1063/1.4716365

Vivekananthamoorthy, H., & Sankar, S. (2011). Lean six Sigma. In A. Coskun, T. C. Inal, & M. E. Serteser (Eds.), *Six Sigma Projects and Personal Experiences* (pp. 1-23). Rijeka, Croatia: Intech. Retrieved from http://www.esi911.com

Voehl, F. (2014). *The lean six sigma black belt handbook tools and methods for process acceleration*. Retrieved from http://site.ebrary.com/lib/nyulibrary/Doc?id=10722362

Vragel, P. (2013). Creating an Employee Engagement Culture. *Ceramic Industry*, *163*(10), 27–28.

Wagner, S. M., Grosse-Ruyken, P. T., & Erhun, F. (2012). The link between supply chain fit and financial performance of the firm. *Journal of Operations Management*, *30*(4), 340–353. doi:10.1016/j.jom.2012.01.001

Wallace, T., & Kremzar, M. (2001). *ERP: Making IT Happen: The Implementer's Guide to Success with Enterprise Systems Planning*. Hoboken, NJ: John Wiley & Sons.

Wang, F. K., & Du, T. C. (2007). Applying capability index to the supply chain network analysis. *Total Quality Management*, *18*(4), 425–434. doi:10.1080/14783360701231807

Wang, F. K., Du, T. C., & Li, E. Y. (2004). Applying Six-Sigma to supplier development. *Total Quality Management and Business Excellence*, *15*(9/10), 1217–1229. doi:10.1080/1478336042000255596

Wang, I. (2010). The application of third part logistics to implement the Just-In-Time system with minimum cost under a global environment. *Expert Systems with Applications*, *37*(3), 2117–2123. doi:10.1016/j.eswa.2009.07.030

Ward, D. R., & Matzkanin, G. A. (1997). Nondestructive Evaluation (3rd ed.). Nondestructive Testing Information Analysis Center.

Weaver, C. N. (1995). *Managing the four stages of TQM: How to achieve world-class performance*. Milwaukee, WI: ASQ Quality Press.

Weinstock, H., & Nisenoff, M. (1986). Article. In D. O. Thompson & D. Chimenti (Eds.), Defect detection with a SQUID magnetometer Review of Progress in QNDE 6 (pp. 669–704). New York: Plenum.

Weinstock, A. (1991). A review of SQUID magnetometry applied to nondestructive evaluation. *IEEE Transactions on Magnetics*, *27*(2), 3231–3236. doi:10.1109/20.133898

Westbrook, J. D., & Utley, D. R. (1995). TQM – The effect of culture on implementation. *Engineering Management Journal*, *7*(2), 31–34.

Westkamper, E., Alting, L., & Arndt, G. (2000). A keynote paper on Life cycle management and assessment: Approaches and visions towards sustainable manufacturing. *Proceedings - Institution of Mechanical Engineers*, *215*.

What is EPICS? (n.d.). Retrieved from http://www.epics.astcorp.com

Widman, J., Hua, S. Y., & Ross, S. C. (2010). Applying lean principles in software development process—a case study. *Issues in Information Systems*, 635–639.

Wiesauer, K., Pircher, M., Goetzinger, E., Hitzenberger, C. K., Engelke, R., & Ahrens, G. et al. (2006). Transversal ultrahigh-resolution polarization-sensitive optical coherence tomography for strain mapping in materials. *Optics Express*, *14*(13), 5945–5953. doi:10.1364/OE.14.005945 PMID:19516764

Wiesauer, K., Pircher, M., Götzinger, E., Bauer, S., Engelke, R., & Ahrens, G. et al. (2005). En-face scanning optical coherence tomography with ultra-high resolution for material investigation. *Optics Express*, *13*, 1015–1024. doi:10.1364/OPEX.13.001015 PMID:19494965

Wilkinson, A., Redman, T., Snape, E., & Marchington, M. (1998). *Managing with total quality management – Theory and practice*. Basingstoke, UK: Palgrave Macmillan.

Wohl, J. G., Entin, E. E., Kleinman, D. L., & Pattipati, K. (1989). Human decision processes in military command and control. In W. B. Rouse (Ed.), Advances in Man-Machine Systems, (vol. 1, pp. 261–307). Academic Press.

Wolter, K. J., Oppermann, M., Heuer, H., Kohler, B., Schubert, F., & Netzelmann, U. et al. (2007). *Micro and Nano-NDE for Micro-Electronics*. IV Conferencia Panamericana de END.

Wong, W., Ignatius, J., & Soh, K. (2014). What is the leanness level of your organisation in lean transformation implementation? An integrated lean index using ANP approach. *Production Planning and Control*, *25*(4), 273–287. doi:10.1080/09537287.2012.674308

Wood, B., & Janssen, A. (2010). Bookmarking: Defining best practices for market leadership. In J. M. Juran & J. A. De Feo (Eds.), *Juran's quality handbook: The complete guide to performance excellence* (6th ed., pp. 439–466). New York, NY: McGraw Hill.

World Nuclear Association. (2013). *Nuclear Power in the USA*. Author.

Wu, H., Siegel, M., & Ablay, S. (2003). Sensor fusion using Dempster-Shafer theory II: Static weighting and Kalman filter-like dynamic weighting. In *Proceedings of Instrument and Measurement Technology Conference*. Vail, CO: Academic Press.

Wu, H., Siegel, M., Stiefelhagen, R., & Yang, J. (2002). Sensor fusion using Dempster-Shafer theory. In *Proceedings of IEEE Instrumentation and Measurement TechnologyConference*, (pp. 21–23). IEEE.

Wu, G. B., & Busse, G. (1998). Lock-in thermography for nondestructive evaluation of materials. *Revue Generale Thermique*, *37*(8), 693–703. doi:10.1016/S0035-3159(98)80047-0

Wu, J., Li, J., Wang, S., & Cheng, T. C. E. (2009). Mean-variance analysis of the newsvendor model with stockout cost. *Omega*, *37*(3), 724–730. doi:10.1016/j.omega.2008.02.005

Xerox Corp. (2011). *Lean Six Sigma - Delivering measureable results our customers value*. Retrieved from http://www.xerox.com/assets/pdf/2012_GRC_LeanSixSigma_Brochure.pdf

Yadav, L. (2013). The Commitment Conundrum. *IUP Journal of Soft Skills*, *7*(3), 23–30.

Yalabik, Z. Y., Popaitoon, P., Chowne, J. A., & Rayton, B. A. (2013). Work engagement as a mediator between employee attitudes and outcomes. *International Journal of Human Resource Management*, *24*(14), 2799–2823. doi:10.1080/09585192.2013.763844

Yang, H. M., Choi, B. S., Park, H. J., Suh, M. S., & Chae, B. (2007). Supply chain management six sigma: A management innovation methodology at the Samsung Group. *Supply Chain Management: An International Journal*, *12*(2), 88–95. doi:10.1108/13598540710737271

Yapa, S. (2012). Total quality management in Sri Lankan service organizations. *The TQM Journal*, *24*(6), 505–517. doi:10.1108/17542731211270070

Yashchin, A. (2014). *The Blog: Redefining Education to Close the Workforce Skills Gap*. Retrieved from http://www.huffingtonpost.com/avi-yashchin/redefining-education-to-c_b_4676818.html

Yazid, H., Arof, H., & Yazid, H. (2012). Automated thresholding in radiographic image for welded joints. *Nondestructive Testing and Evaluation*, *27*(1), 69–80. doi:10.1080/10589759.2011.591795

Yin, X., Hutchins, D. A., Chen, G., & Li, W. (2013). Preliminary studies on the design principles of capacitive imaging probes for non-destructive evaluation. *International J. Appl. Electromagnetics and Mechanics*, *42*, 447–470.

Zaccaro, S. J., Kemp, C., & Bader, P. (2004). Leader traits and attributes. In J. Antonakis, A. T. Cianciolo, & R. J. Sternberg (Eds.), *The nature of leadership* (pp. 101–124). Thousand Oaks, CA: Sage.

Zaleznik, A. (1977, May–June). Managers and leaders: Are they different? *Harvard Business Review*, *55*, 67–78. PMID:14723179

Zeitz, G., Johannesson, R., & Ritchie, J. E. (1997). An employee survey measuring total quality management practices and culture – Development and validation. *Group & Organization Management*, *22*(4), 414–444. doi:10.1177/1059601197224002

Zhang, W., Hill, A. V., & Gilbreath, G. H. (2011). A research agenda for Six Sigma research. *Quality Management Journal*, *18*(1), 39–53.

Zhu, Y. K., Tian, G. Y., Lu, R.-S., & Zhang, H. (2011). A review of optical NDT technologies. *Sensors (Basel, Switzerland)*, *11*(12), 7773–7798. doi:10.3390/s110807773 PMID:22164045

Zu, X., Fredendall, L. D., & Douglas, T. J. (2008). The evolving theory of quality management: The role of Six Sigma. *Journal of Operations Management*, *26*(5), 630–650. doi:10.1016/j.jom.2008.02.001

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