View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by AFTI Scholar (Air Force Institute of Technology)

Air Force Institute of Technology
**AFIT Scholar**

Theses and Dissertations | Student Graduate Works

3-21-2013

# Continuous Process Improvement at Tinker Air Logistics Complex

Robert S. Rabon

Follow this and additional works at: https://scholar.afit.edu/etd

Part of the Business Administration, Management, and Operations Commons

Recommended Citation

Rabon, Robert S., "Continuous Process Improvement at Tinker Air Logistics Complex" (2013). *Theses and Dissertations*. 974.
https://scholar.afit.edu/etd/974

This Thesis is brought to you for free and open access by the Student Graduate Works at AFIT Scholar. It has been accepted for inclusion in Theses and Dissertations by an authorized administrator of AFIT Scholar. For more information, please contact richard.mansfield@afit.edu.

**Continuous Process Improvement at Tinker Air Logistics Complex**

THESIS


Robert S. Rabon, Captain, USAF


AFIT-ENS-13-M-16


**DEPARTMENT OF THE AIR FORCE**
**AIR UNIVERSITY**

**AIR FORCE INSTITUTE OF TECHNOLOGY**

**Wright-Patterson Air Force Base, Ohio**



APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

The views expressed in this thesis are those of the author and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the United States Government. This material is declared a work of the U.S. Government and is not subject to copyright protection in the United States.

AFIT-ENS-13-M-16

CONTINUOUS PROCESS IMPROVEMENT AT TINKER AIR LOGISTICS COMPLEX

THESIS

Presented to the Faculty

Department of Operational Sciences

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics and Supply Chain Management

Robert S. Rabon, BS

Captain, USAF

March 2013

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

AFIT-ENS-13-M-16

CONTINUOUS PROCESS IMPROVEMENT AT TINKER AIR LOGISTICS COMPLEX

Robert S. Rabon, BS
Captain, USAF

Approved:

____________________________________ ____________
Dr. Kenneth Schultz (Chairman) date

____________________________________ ____________
Dr. Alan Johnson (Member) date

AFIT-GLM-ENS-13-16


Abstract

The Air Logistics Complexes (ALC) represent the Air Force's largest Maintenance, Repair, and Overhaul (MRO) Operations. The ALCs strive to become leaner by reducing Work In Progress (WIP) inventory, reducing flow times, and increasing product quality to meet aircraft and engine demand levels. The Toyota Production System (TPS) is considered the best example of lean manufacturing by many. TPS utilizes the ingenuity of Toyota employees to generate Continuous Process Improvement (CPI). Achieving CPI can aid the ALCs in reducing operating capital while providing increased levels of service.

The Air Force as a whole has made several attempts to "get lean." Implementing lean tools without fully understanding their underlying philosophy has made it difficult to sustain process improvements. This thesis explores the softer, less tangible conditions that predicate successful CPI. A theoretical model was tested at Tinker ALC to identify focus areas for management. The researcher hypothesized that increased levels of the six conditions tested would be positively correlated with successful CPI. Focusing on creating these conditions may aid in sustaining improvements.

Our data show that only one condition is significantly positively correlated with success. The magnitude and statistical significance of the other variables is low. The data suggest that having Structured Improvement Processes most significantly impacts successful CPI. Anecdotal evidence also suggest that Drive for Improvement and Direction for Improvement also support CPI, although these conclusions were not statistically supported by the data. Formal Rapid Improvement Events (RIEs) seem to develop other conditions we tested. Air Logistics Complex managers should focus on those three conditions and RIEs to aid successful CPI efforts in the future.

*To my amazing wife and faithful dog.  Thanks for supporting my journey!*

**Acknowledgments**

I would like to express my sincere appreciation to my faculty advisor, Dr. Kenneth Schultz, for his guidance and support throughout the course of this thesis effort. He constantly challenged me and ensured my success. I will always remember that variability is the enemy. I also thank Dr. Alan Johnson who encouraged me to find a thesis that I enjoyed, and making this research possible. I'm deeply grateful to the senior leadership at Tinker Air Logistics Center who are heavily vested in educating the next generation of Air Force Leaders.

I am, also, indebted to the many maintenance professionals at Tinker ALC who spent their valuable time explaining their experiences with process improvement. This study would not have been possible without your honest feedback. Your dedication to the mission is truly one of the ALCs greatest strengths.

Robert S. (Bob) Rabon

# Table of Contents

## List of Figures

## List of Tables

Page

# CONTINUOUS PROCESS IMPROVEMENT AT TINKER AIR LOGISTICS COMPLEX

## I. Introduction

### Background

The United States Air Force (USAF), like commercial enterprise, is constantly looking for ways to improve operations. Performing the same missions faster, with less materiel investment, and higher quality outputs enables better sustainment of the war-fighting capability at a better value to the taxpayer. The USAF realized that Lean principles made popular by the success of Toyota Motor Company might guide the transition from a bulky sustainment enterprise to a responsive, modern production system. Pressure to improve business practices heightens at a time when the defense budget is shrinking and provides stimulus to lean out processes at the Air Logistics Complexes (ALCs).

The ALCs are in many ways similar to commercial production environments. Known demands for major items drive a production schedule where everything from engines to entire aircraft must be produced on-time and on-budget. The USAF realizing the similarity to industry attempted in the past to implement best practices that were taking place in other companies. One of the first corporate-wide improvement efforts, Quality Air Force (QAF), failed to produce sustainable improvements in Air Force depot environments. A squadron commander at Tinker AFB stated: “The ideas behind QAF were sound, but it failed because you were chasing metrics in a briefing instead of making actual changes.” The latest iteration of process improvements, Air Force Smart Ops for the 21st Century (AFSO21), was mostly based on principles of Lean thinking published by Womack and Jones (US Air Force, 2008). The goal of AFSO21 was to eliminate waste from organizational processes. In some cases "lean events" produced notable and sustainable improvements. However, few events lead to successful process improvements, and the efforts to lean out on a corporate scale have largely fallen flat. This thesis explores what conditions are necessary for Continuous Process Improvement in response to Air Force Materiel Command's (AFMC) search to eliminate waste and provide world-class depot sustainment operations.

**Problem Statement**

AFMC recognizes the need to improve depot operations by delivering fully mission capable aircraft and components on-time without exceeding its operating budget. This task becomes more difficult when the budget shrinks and delivery timelines are decreased. Therefore a problem AFMC faces is how to create Continuous Process Improvement (CPI) that yields shorter flow times without substantial capital or inventory investments. Past attempts have yielded process improvements, but some were due to "heroic" actions of improvement team members. The ALCs must find ways to deliver the same level of support to their customers using less capital and inventory to meet budgetary constraints. Process improvements are necessary to meet that objective, but beg the question, "How is Continuous Process Improvement created and sustained at Tinker Air Logistics Complex?" Addressing this problem is important to the ALCs because it provides a roadmap for how to sustain Maintenance, Repair and Overhaul (MRO) actions with less working capital. This problem needs to be addressed now to provide sustainable options to reduce Work In Progress (WIP) inventory and flow time. Those reductions can potentially increase repair capacity with the same or less inputs.

**Research Focus**

This research topic was chosen in response to AFMC A4D's request to examine ways to generate Continuous Process Improvement in ALC operations. The study began with the intent to find a way to address the variability of CPI success within two squadrons at Tinker ALC. The researcher spent several days on a site visit and noticed that several shop-level elements were more advanced in lean production and process improvements than others. Examination of processes in two squadrons allowed the researcher to make certain assumptions about the present work environment and hold those constant throughout analysis. One of those assumptions was that leadership created consistent conditions for their workforce. If the degree of successful CPI was not linked directly to leadership, then other elements must influence it. This research focused on some of the intangible conditions that predicate CPI and how the combination of those conditions lead to Continuous Process Improvement. Many qualitative studies have proposed conditions necessary for CPI in certain work environments, however there are fewer studies that test the application of these models. This research focuses on evaluating and extending one such model at the shop floor level of analysis. Research findings may help to substantiate the model's claims.

**Research Objective(s)**

The objective for this research is to identify what conditions lead to Continuous Process Improvement and to identify focus areas for Air Force managers. The research is based on a conceptual model proposed by Dr. Eduardo Lander (Figure 1). Validation of the model may show the methods and conditions for improvement can be extrapolated to other ALCs and Air Force processes.

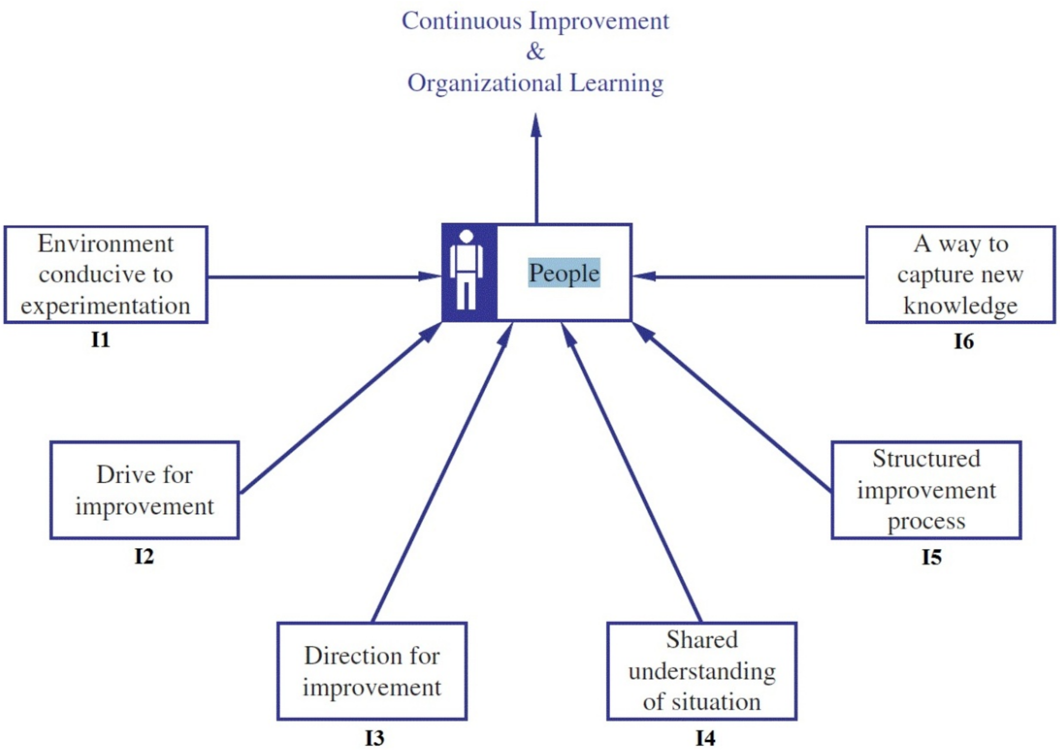


**Figure 1. Source Lander and Liker, 2007.**

This research objective gave rise to the following research question and hypothesis:

***Research Question:***

***(RQ)*** How is Continuous Process Improvement created and sustained at Tinker ALC?

This question was selected based on the researcher's conjecture of the best way to address the problem statement while observing work conditions at Tinker ALC. The ALC can potentially create a work environment where individual shops are motivated and capable of creating continuous process improvements. Such process improvements are potentially made possible by teams comprised of actual work cell members. Continuous Process Improvement in this work scenario might be created by empowered workers creating and enacting change in their daily work routines. The following hypotheses explores a bottom-up approach (floor-level employees) to CPI opposed to a top-down approach that was seen in TQM and AFSO21, and if that approach aids sustainable improvement.

***Hypothesis:***

***Each of the following conditions is positively correlated with (D1) Continuous Process Improvement.***

1. ***(H1) Environment conducive to experimentation***
2. ***(H2) Drive for Improvement***
3. ***(H3) Direction for Improvement***
4. ***(H4) Shared Understanding of situation***
5. ***(H5) Structured improvement process***
6. ***(H6) A way to capture new knowledge***

$\mathbf{H_o}$: $\boldsymbol{r \leq 0}$

$\mathbf{H_a}$: $\boldsymbol{r > 0}$

Dr. Lander developed his model while studying application of the Toyota Production System at a company that produced highly variable products. He observed that conditions we developed into independent variables I1-I6 led to "development of a continuous improvement system that promotes organizational learning are at least as important" as the tools of the TPS (Lander, 3693, 2007). An organization that creates CPI can find ways to exist in a fiscally constrained environment and increase efficiency. The objective of this research is to quantitatively evaluate Dr. Lander's conceptual model as shown in Figure 1, and test the influence of each of the conditions and determine if they lead to CPI. This research evaluates the applicability of the model in Air Force Depot Conditions.

**Research Design and Methodology**

A qualitative case-study based approach was used to answer the research question and address the proposed hypothesis. The unit of analysis was defined as an individual work group or "shop" that had a common purpose. These shops consisted of 12 to 25 individuals. The first step in this research design was definition of the dependent and independent variables. The dependent variable (D1) was described as a group that makes improvements, sustains those improvements, and continues to improve over time. The definition of "success" was developed based on Squadron-level leadership's opinion of CPI at Tinker ALC. Squadron leadership was involved in the definition to aid the applicability of any findings the study produced. Using their definition of the dependent variable helped drive the study to measure an outcome that was meaningful to the units being studied. The definition provided by leadership did not drastically differ from the definition provided by Liker in *The Toyota Way,* Lander used as the basis of his work. It was essential that both squadron leadership and the Lander model (figure 1) agreed on the definition of the dependent variable so the researcher was not only measuring success as predicted by the model, but described that success in terms that were useful in the context of the two squadrons who were studied.

We defined our independent variables based on the philosophies behind the Toyota Production System and definitions provided in Lander's study. Subsequently several elements were developed to look for evidence of and to evaluate the strength of the independent variables. For example, a unit that scores high on "Environment conducive to experimentation" would show evidence of "leadership that is ok with risk taking." Four to eight elements that should be present for a high-scoring independent variable were developed for each of the seven variables. The full listing is shown in Table 1 in the Article Manuscript.

I conducted semi-structured interviews during the data collection portion of the study to evaluate the influence of independent variables. Squadron leadership selected ten shops that had attempted process improvement within the last 24 months. Two members of that shop were selected to participate in the interviews in an attempt to measure a consensus of the entire target team. Several open-ended questions were developed to guide discussion between the researcher and the research subjects. Personal interviews took place in a one-on-two setting with the researcher and both participants present at the same time. The subject's responses were digitally recorded and later reviewed by the researcher. Several structured questions were asked, and the participants were encouraged to respond any way they wished to provide more depth to the data collection effort. The researcher used his judgment and knowledge of the variables to assign an objective 1-5 ranking to each of the independent variables, where a score of 5 showed more influence of the variable. The researcher's interpretation of the independent variables was a primary limitation to this study.

Personal interview was selected as the primary data collection method over survey because we did not think a survey could accurately capture the depth and of the independent variables. Intangible elements of leadership and group interactions at the worker team level are better captured through personal interview than other collection methods. A survey might better lend itself to *identification* of a "successful" or "unsuccessful" work area, but may fail to adequately capture the less tangible side of *how* a team becomes successful. We conjecture that survey data might better evaluate these constructs after we tested the interview approach.

Similarly, Squadron Leadership ranked the dependent variable "Successful Continuous Process Improvement" on a 1-5 scale. These rankings were provided to the researcher's thesis advisor and kept secret until evaluation of the independent variables to prevent bias while ranking the presence of I1-I6 during personal interviews.

I developed a correlation matrix using a statistical software package to determine the correlation between I1-I6 and D1 during the data analysis portion of the study to test the degree of linear influence each predictor had on the dependent variable. I also used linear regression to extend the findings of the correlational relationships between the independent and dependent variables. Significance of the regression parameters and overall fit of the multiple regression model were evaluated to test the theoretical model as a predictor of CPI success.

## Assumptions

Personal interviews of Group and Squadron leaders helped identify their philosophy. Those conditions led to development of the research assumptions and limitations.

Several assumptions of this effort stem from the 4-P Toyota model proposed by Liker (2004). Toyota is often considered the industry leader in lean manufacturing. Many companies have tried to emulate the success of the Toyota Production System with few successes (Liker J. K., 2004). The ALCs present areas that might well adopt a Toyota-like mindset and way of conducting business. Liker suggests that to reach a state where a corporation has CPI, based on the 4-P model, that every step in the pyramid represents a necessary and sufficient condition for other steps to occur.

**Assumption 1**: Senior leadership (Colonel (O-6) and the GS-15 level) have an understanding of basic lean philosophies or some version of them. In some form these are translated and understood at the Squadron Commander and to some extent the shop supervisor level. A general understanding of Lean concepts was assumed constant across several levels of leaders. Leadership must support Lean business principles to develop CPI.

**Assumption 2**: A process must first be stable before it can be improved upon (Liker J. K., 2004). Most of the processes within the ALC have waste in them. However, the researcher assumed that the processes examined were stable and robust enough to benefit from improvement projects. Most organizations are at the "Process" phase of their Lean Transformation (Liker, 2004). While this condition may be true at the ALCs, this research examines the second and four tiers of the 4-P model as a means to eliminate waste via Continuous Process Improvement.

**Assumption 3:** Squadron leadership's evaluation of D1 is accurate. Even though the definition of success was developed with Squadron leadership, and buy-in was accomplished prior to their evaluation, there was the potential that they did not fully understand the ranking structure. Faulty rankings of the dependent variable could skew the end results. Therefore the ratings they provided were assumed accurate so further analysis could take place. Likewise the researcher's ratings of H1-H6 were assumed accurate.

**Limitations**

The study took place in a production based environment with a high probability of known demand. It is the intent of the researcher that the information produced in the thesis is generic enough to be applied across both production and service oriented organizations in a variety of Air Force work settings. However, extrapolating the research findings to other work environments may be limited. Direct application of thesis findings may be more limited in service organizations while findings should be easily applied to ALC production systems.

The study was also limited by the researcher's interpretation and assignment of scores to the independent variables. Using interviews as the primary data collection method afforded opportunity to capture depth of responses not present in other methods. There were inherent disadvantages to interview research as well. There were chances for bias to be introduced while the researcher was acting as the research instrument. Care was taken to prevent bias, but it cannot be totally eliminated, thus somewhat limiting the overall results of the study.

Correlation and Regression analysis was limited by small amounts of variability in both the independent and dependent variables due to small sample size.  Larger standard deviations would show more variability across scores.  The small amount of variance limited the explanatory power of independent variables thus lowering the degree of relationships suggested by the data.

**Implications**

The findings of this study may help leadership at all levels in the Air Logistics Center focus efforts to ensure Continuous Process Improvement.  Additionally it may help to predict the success and feasibility of Process Improvements using the theoretical model as a basis for those conclusions.  Of the conditions tested, the research showed which elements of the model were more influential and thus are more essential to sustainment of CPI.  Managers might be able to apply this knowledge to upcoming CPI events to aid in their successful outcome.

The research also validated the model proposed by Drs. Lander and Liker.  Their model was appropriate to use across both the private sector where they conducted their research and the public sector where this research took place.  The application of the model in different scenarios added further evidence to the universality of the Toyota Production System.  Validation of the model provided further evidence that moving the Air Force depots to a “Toyota-like” system is a beneficial way to steer change in the future.  The use of Toyota’s methodology may aid the Air Force depots, and specifically Tinker Air Logistics Complex increase competitiveness with the private sector in a more fiscally constrained environment.

## II. Literature Review

### Origin of Quality Movement and Toyota Production System

Dr. W. Edwards Deming published Out of the Crisis in 1982 to provide American managers a roadmap to become more competitive in the global market (Deming, 1982). He had taken his ideas on management principles to Japan prior to his efforts to revolutionize manufacturing in the U.S. He developed 14 Points for Management that were adapted by Taiichi Ohno to help improve the Toyota Corporation in Japan. Deming's 14 points in several ways represented a departure from the traditional American view of assembly line work. Continuous improvement through the use of the Plan, Do, Check, Act (PDCA) cycle proposed by Deming became essential to the Toyota way of conducting business. He proposed organizations should "Improve Constantly and forever the system of production and service, to improve quality and productivity, and thus constantly decrease costs," in the fifth of the 14 Points (Deming, 32, 1982). Ohno was able to build a highly successful corporation even as Japan was emerging from World War II by embracing continuous improvement as a hallmark of his business model.

Ford and General Motors were largely using the Alfred Sloan model of management as Ohno was developing a leaner, faster, automotive production system. The Sloan model and the scientific division of labor enabled American corporations to enjoy a competitive advantage for many years. Ohno observed piles of inventory as he toured Ford's facilities in the 1950s. Work in progress (WIP) inventory ensured that assembly line workers always had something to do, but represented a costly waste to Ohno, and he viewed it as area for improvement in the Ford system. Ford was arguably stagnating in their production methods and still viewed shop floor level workers as incapable of thought or motivation of how to improve their process (Hammer & Champy, 2001). Ohno used what he observed at Ford Motor Company and Deming's teaching to develop The Toyota Production System (TPS).

**Toyota Production System as an example of Lean**

The Toyota Production system began to gain international notice as Toyota was able to weather the 1970s oil crisis better than other auto manufacturers (Lander & Liker, 2007). That success spurred the curiosity of firms in the West and led to further examination. J.P. Womack observed Japanese manufacturing firms and techniques and synthesized the term 'lean' to describe the next evolution of manufacture past mass production (Womack, Jones, & Roos, 1991). Womack continues to define lean as elimination of waste and production of value for a customer. Toyota became the standard for lean production opposed to the mass production mindset. But the new question was: What is 'lean?'

Defining lean production begins with identifying what is valued by the customer. The customer can be an end user of a product or service, or simply the next step in an assembly or repair process. A determination of what that customer values is the next step. Maybe the customer values a car that does not break down, or fan blade that is within tolerance. The second step is identifying the product's value stream. A detailed analysis of the whole process is necessary to clearly identify the value stream. It is during this outline that non-value added steps can be identified and sometimes eliminated to reduce waste. The subsequent step is ensuring a smooth and steady flow of the product down the value stream.

This smooth flow sometimes represents a departure from a traditional batch-and-queue method of product movement. After flow is established, the next iteration in the lean transformation is introducing a pull system to prevent over or underproduction.  A much shorter timeline of value delivery to the customer can be realized if they pull the product through the value stream.  That quicker timeline can be a source of competitive advantage for any company.  The final step in the lean journey is to strive for perfection.  Perfection is the firm's focus on "the Art of the Possible," where it constantly seeks a better way to deliver its value to the customer.  This focus on perfection parallels the journey of continuous improvement, and represents a highly evolved 'lean' corporation (Womack & Jones, 1996).

Toyota was highlighted as paradigm of lean production as these principles became more widely known.  However understanding the lean principles really did not describe HOW to create or sustain lean production.  Many firms view the TPS as a set of tools to eliminate waste, but this view is flawed and will likely lead to an unsuccessful lean transformation (Lander & Liker, 2007).

**TPS in the United States**

The key to implementing a Toyota-like system is building a culture of continuous improvement.  Many companies have tried to implement CPI initiatives, the U.S. Air Force included.  Generally the push results in a few improvements but eventually loses steam and is discarded as programs that were tried and failed (Choi & Liker, 1995).  Some American managers may equate the challenge of implementing CPI with a difference between Japanese and American work force cultures.  However, Toyota built and staffed a plant in Kentucky comprised of American managers and workers based on the TPS philosophies that had been successful in their Japanese based operations.  The Kentucky plant served as a test bed to see if the Japanese business culture could be transferred to America.  Fujio Cho, president of

Toyota Motor Manufacturing remained optimistic about the universality of the TPS and the Kentucky plant would be just as successful as those in Japan (Mishina & Takeda, 1995). They would have to teach the philosophies and culture of the TPS to Americans if the plant was to be successful. The Kentucky plant was able to reach production and quality standards of the Japanese plant after an initial start-up period.

Toyota has proven that TPS could successfully be implemented in the U.S. by constructing a greenfield plant in Kentucky (Mishina & Takeda, 1995). That implementation provided proof that the culture of continuous improvement could be taught to American workers. However, American managers might still ask, why does my CPI project still fall flat? Lander argues that "In practice, the TPS is most often viewed as a set of tools to remove 'waste' from processes. Individual tools have been explained …yet companies often struggle when attempting to apply lean novel circumstances" (Lander & Liker, 3682, 2007). What might explain this struggle? The Air Force like most companies has tried to instill a culture of CPI, but with limited success. Several suggest that TPS cannot be simply used as a toolkit (Liker J. K., 2004) (Lander & Liker, 2007). The TPS is not a formulaic system to approach manufacturing, but more culture that uses the right tool at the right time (Hallam, Muesel, & Flannery, 2010). A management philosophy that creates the culture accompanied by powerful tools, not tools accompanied by culture is something missed by American companies (Hallam, Muesel, & Flannery, 2010).

With an understanding that the success of TPS is deeply rooted in organizational culture, American managers might wonder how they can create or change their corporate culture to be more like that of Toyota. A successful lean transition is more likely if a company has both facets of TPS, the tools and the culture. There is more literature on application of TPS tools, than creation of the culture. Lean tools and techniques on their own are somewhat abstract and hard to learn, yet not impossible at the shop floor level. Hallam, et. al. suggest “few companies have been able to fully mimic or adopt Lean tools in the way Toyota has – it is a cultural model a century in the works, and successfully changing organizational culture, especially in large established companies, is one of the hardest management tasks to achieve” (Hallam, Muesel, & Flannery, 2010). Acknowledging the difficulty of creating a Toyota-like culture that generates CPI, Air Force leaders, especially those at Air Logistics Complexes, still realize the usefulness of TPS. We conjecture Air Force managers both military and civilian at Tinker ALC, have largely embraced the challenge to create a CPI culture that makes incremental process improvements over time using lean manufacturing tools and techniques based on conversation prior to this study.

**How to build a culture of CPI in a military setting**

Military managers must first understand the principles of TPS. Looking at the principles behind the tools of the TPS creates a richer understanding of why the tools work. The ideas tools of the TPS need to be customized to each scenario where they are applied. But taking a process based approach helps develop an understanding of why things are done and if they agree with one of the 14 principles of the TPS (Lander & Liker, 2007). The concept of CPI requires constantly learning at all levels of the organization. Learning more about the firm’s processes can highlight areas of waste and areas for improvement. Institutionalizing a worker’s good idea into formal business rules is the final step in an iteration of improvement. Looking at processes to identify waste and suggest ways to eliminate it shows the presence of organizational learning. It is the struggle to find improvements, not a certain tool, that enables the success of TPS (Lander & Liker, 2007).

How are those ideas generated and who do they come from? It is most often from workers within the firm itself. People are at the heart of the TPS. One of Ohno's 14 principles of the Toyota Way is "Develop exceptional people and teams who follow your company's philosophy" (Liker, 39, 2004). He also realized that underutilizing employee's personal skills and ideas is a waste that should be eliminated. They realize that shop-floor level employees might be closer to mistakes and should have the authority to address problems.

Toyota really believes that its true competitive edge lies in its people. Ken Kreafle, senior executive for Toyota Motor Engineering Manufacturing North America Inc., explains, true lean is about "people doing the work, improving their own work through problem solving with support from management and in accordance with company goals and objectives" (Badurdeen & Gregory, 50, 2012). Thus in advanced lean environments, floor level workers are respected enough and trained to make process improvements. A no-blame workplace is one of Toyota's cultural hallmarks and shows respect for workers in a firm. Badureen and Gregory note that "Toyota's human system is the most complicated and the most difficult for others to replicate when pursing true lean; it also is important to understanding the missing but necessary pillar for success in lean transformations" (51). The hard side (tools and techniques) clearly is central to making continual improvements in quality, cost reduction and delivery times. But it's clear that a soft side that encourages people involvement is equally, or even more important." There is much evidence to suggest that having both a deep understanding of the principles of the TPS and involving the firm's workers in the lean transition is essential to making process improvements. Employing both sides of the TPS is the key to building sustained, incremental process improvements in both military and private sector firms. The root of TPS is about supporting and encouraging people to constantly search for better ways to do their job (Lander & Liker, 2007).

**Measuring the Softer Side of Lean**

The softer side of lean may be just as important as the harder side to continuous process improvement, but it is more difficult to measure. A firm can visually see if they have level flow or a pull system in place simply by walking around their production facilities. Large amounts of WIP inventory are cues that the process is not fully leaned out. A repair process in the depot can be broken down in modular workstations in an attempt to level-load the workflow, or achieve the *heijunka* principle of TPS. Simply implementing these tools with a less than full understanding of the consequences can actually slow production and de-motivate employees to try further process improvements in the future. We can assume that even if the firm has a very good understanding of the tools of TPS and their application, they may be lacking in the softer side that is necessary to sustain lasting CPI success and achieve a more advanced Toyota-like system.

Drs. Lander and Liker examined a company that they argue made a successful transition to lean system over a 2.5 year period. The company made highly customized decorative tiles in an environment very different than a Toyota assembly plant. The highly variable nature of Motawi tile's products produced several challenges to implementing a lean system. It was by developing a deep understanding of the principles of the TPS that Motawi was able to successfully transform. Success was captured in performance metrics, yet was noticeable outside of the numbers.

The drastic shift was marked by employees working on a takt time, and from improving in spurts to improving continuously as part of the job (Lander & Liker, 2007). The old batch-and-queue method of doing business was replaced by a pull system. Workers seemed to be able to focus on the future improvements instead of struggling to keep up with the required production pace. Employees were even seeking the root causes of problems so they could be eliminated and prevented in the future. These improvements really represented a departure from an old business model to a more modern lean system. Additionally, it showed a much deeper understanding of the Toyota system (Lander & Liker, 2007).

Motawi did use the tools of the TPS to become lean, but the change in understanding of work practices and development of a continuous improvement system were just as important. Dr. Lander proposed a general model for the continuous improvement system that seemed to work at Motawi. These six conditions that were necessary to achieve CPI were shown earlier in Figure 1. We chose to evaluate this general model to see how well it predicts successful continuous process improvement in a Department of Defense run maintenance and repair facility at the Tinker ALC.

These conditions make it possible for the people of the company to make and sustain incremental changes to their workplace. It was the principle-based understanding that allowed Motawi to sustain its performance gains. The tools would languish or fail to adapt to future conditions or suffer performance losses had the understanding not been developed. Dr. Lander states “By understanding Toyota’s system at a principles level we can make the right choices to ensure that the tools implemented fit the organization and support its people while achieving the objectives they were designed for. The principles provide a foundation of understanding and thus should be the guiding force behind every TPS transformation" (Lander & Liker, 3696, 2007). An understanding of the principles must come first and the tools provide a means for testing it. A firm must experience its own learning process that sustains a Toyota-like system. If the firm does not learn for itself the system stagnates and improvements are lost (Lander & Liker, 2007).

Our research seeks to use the proposed model as a measurement of both the level of understanding of the principles of TPS and the use of its tools as the Air Force seeks to become leaner in its production facilities. The model was evaluated at the shop floor level of analysis to measure the current depth of understanding. These workers often understand the details of what is causing production slowdowns or missed delivery dates that are discussed in Squadron and Group level production meetings, and often have ideas an ways to make process improvements. If the lowest level employee is able to make and understand the principles of TPS, then continuous improvement is certainly possible in the ALCs.

**Correlation analysis**

Correlation is the measure of linear relationship between one or more variables, and is measured by a coefficient ranging from -1 to 1. The Pearson product moment correlation, Pearson's *r*, is used to measure the degree of relationship between independent and dependent variables. A positive coefficient indicates a positive linear relationship between the variables (Leedy & Ormrond, 2010). The researchers speculated that positive linear relationship existed between I1-I6 and D1. The correlation itself indicates the strength of the relationship, but not necessarily the degree of the relationship. Correlation coefficients and scatter plots yield a general understanding of the data, but they cannot be relied upon alone to tell us which independent variables are related to the dependent variables because of multicollinearity. Multicollinearity exists in regression when the independent variables are related to each other (Bowerman, O'Connell, & Koehler, 2005). Correlation matrices and scatter plots are useful tools to detect the presence of multicollinearity in a linear regression model. Confidence intervals can also be generated about the point prediction of the correlation coefficients at a chosen α-level, where α is the acceptable level of type I-error. A Type I error occurs if the researcher rejects the null hypothesis in favor of the alternative hypothesis when in fact, the null is true. The probability of committing a type-I error is denoted by α (McClave, Benson, & Sincich, 2011). The null hypothesis in this case is that the correlation coefficient is not statistically significant from zero. Thus a p-value less than .05 suggests a significant coefficient.

Coefficient values suggested by (Hinkle, Wiersma, & Jurs, 1982) were used to determine the strength of the relationships between I1-I7 and D1: (a) very high (.90 -1.0); (b) high (.70 - .90); (c) moderate (.50 - .70); (d) low (.30 - .50); and (e) little if any correlation (.00 - .30). Correlational analysis alone is not enough to fully evaluate the interactions between the independent variables, and how those interactions affected the theoretical model. The relationships were also tested through multiple linear regression to test their interactions and combined influence.

**Multiple Regression Analysis**

The researchers' evaluation of seven independent variables lends itself to multiple linear regression. A least squares estimate using statistical software was used to generate a regression equation of the overall form:

$D1 = \beta_o + \beta_1(I1) + \beta_2(I2) + \beta_3(I3) + \beta_4(I4) + \beta_5(I5) + \beta_6(I6) + \beta_7(I7)$

Analysis of variance (ANOVA) was used to evaluate the usefulness of the model. The multiple coefficient of determination, $R^2$, gave a sense of the overall fit of the explanatory ability of the model. The overall F-test for significance of the regression relationship was conducted to test if at least one of the regression parameters $\beta_{1\text{-}7}$ were significant at the $\alpha$ =.05 level. Additionally, t-tests were conducted generating p-values for significance of each of the regression parameters was conducted, and confidence intervals around the point predictions of $\beta_{1\text{-}7}$ were generated. P-values of t-tests greater than .05 indicated the parameter $\beta_x$ was not statistically significant from zero. (Bowerman, O'Connell, & Koehler, 2005). Use of multiple linear regression gave the researchers a better overall impression of the influence of each of the independent variables and their interaction effects when included in the same model.

# IV. Article Manuscript

## Abstract

We conducted this study to help identify some less tangible facets of organizational culture that lead to successful lean transitions and Continuous Process Improvement. We evaluated a conceptual model proposed by Lander and Liker (2007) during their study of the Motawi tile company's lean transformation. Our study population was at Tinker Air Logistics Complex, Oklahoma City where similar lean transformations were taking place. We found one condition proposed by the model, Structured Improvement Processes, to be statistically significantly correlated with successful CPI. We found no evidence to refute the other conditions although our data do not support their correlation. We further found that having Structured Improvement Processes seems to develop the other conditions proposed in the model.

## I. Introduction

Commercial enterprises are constantly looking for ways to improve operations. Performing the same missions faster, with less materiel investment, and higher quality outputs enables development of competitive advantage. Many production-based corporations realized that lean principles made popular by the success of Toyota Motor Company might guide the transition from a bulky sustainment enterprise to a responsive, modern system. Pressure to improve business practices heightens at a time when working budgets shrink, but higher returns on investment are expected.

Acknowledgement: The research team wishes to thank Col Robert Helgeson, Mr. Mike Barrett, Mr. Ed Arnold, Mr. Jason Reed, and Mr. Raul Rodriguez of the 76th Propulsion Maintenance Group at Tinker Air Logistics Complex for allowing us to study their workforce. We further thank Mrs. Joanne Karras for her independent evaluation of our interview data.

**Problem**

Implementing lean production practices is difficult to do well (Badurdeen & Gregory, 2012; Lander & Liker, 2007; Choi & Liker, 1995). Many major companies are interested in developing lasting lean practices. Some are able to do so better than others, but the question remains how. Many companies have toured and studied Toyota's methods, but were unable to experience major success. Simply applying the tools of the Toyota Production System without fully understanding the softer side yields limited sustained improvements (Lander & Liker, 2007). The soft side of lean can be summarized as corporate culture that includes mutual understanding for people and a teamwork approach to problem solving (Badurdeen & Gregory, 2012)

The soft side of lean is less understood than the hard side (Badureen and Gregory, 2012). Limited successes in lean transitions highlight the need for a deeper understanding of the soft side. How does one measure motivation to get lean? How influential a structured improvement process is on the outcome of the improvement effort? Identifying soft elements like these might bridge the gap between formulaic applications of lean principles to develop a customized, tailorable approach to lean out organizations.

Some corporations are more successful with process improvement than others. Assuming their leadership is knowledgeable and supportive of change, then some other factor contributes to differentiation. How then do managers develop a deeper understanding of lean principles in their people? How can they extract the most improvement for their efforts? The answer lies in developing a deeper understanding of the "softer side of Lean."

The Air Force has also struggled with lean transformation. One of the first corporate-wide improvement efforts, Quality Air Force (QAF), failed to produce sustainable improvements in Air Force depot environments. A squadron commander at Tinker AFB stated: "The ideas behind QAF were sound, but it failed because you were chasing metrics in a briefing instead of making actual changes." The latest iteration of process improvements, Air Force Smart Ops for the 21$^{st}$ Century (AFSO21), was mostly based on principles of Lean thinking published by Womack and Jones (US Air Force, 2008). The goal of AFSO21 was to eliminate waste from organizational processes. In some cases "lean events" produced notable and sustainable improvements. However, few events lead to successful process improvements, and the efforts to lean out on a corporate scale have largely fallen flat. This paper explores what conditions are necessary for successful Continuous Process Improvement (CPI).

**Theory**

Lander and Liker suggested six conditions resulting from their study of the Motawi tile company that influence successful CPI (Lander & Liker, 2007). They developed these conditions after watching the company undergo a lean transition, however they did not articulate any priority or causal relationship between the conditions and CPI. These conditions are not tools to improve processes, but less tangible things that might influence the people performing those improvements. The company used hard lean tools, but they proposed something else was influencing the successful transition from batch-and-queue methods to a smoother flowing lean system. These conditions were anecdotally suggested after they observed the company for several years. Lander and Liker developed their model in a large case study. This is appropriate methodology for developing theory. However, after development, theory needs to be tested. We have been unable to find any independent test of the proposed theory. We provide such a test here.

Review of literature did not show evaluation of the model. Nor did Lander and Liker suggest a degree or significance of the relationship. Testing the influence of these conditions in a production environment might highlight significant influence on successful CPI efforts. A data collection instrument to measure these six conditions had not been proposed thus leaving gaps to be filled by this research. Their paper did not fully develop the constructs of the conditions proposed leaving room for this research to further develop and test the conditions.

Our research was conducted in a large job shop that remanufactures aircraft parts. This production facility is undergoing a lean transition similar to Motawi tile company, thus providing an appropriate venue to test the influence of these conditions. The proposed theory seemed the most adequate to use based on Air Force attempts to directly apply lean tools through AFSO21. Many Air Force leaders and managers had developed a basic understanding of the tools, but understand less about how to make the tools successful. The Lander and Liker study proposed a way to bridge the gap between current and future Air

Force improvement efforts. Managers at Tinker Air Logistics Complex could not explain why some teams were more successful than others at process improvement. Leadership and available support were constant across all groups suggesting some other factors were driving success.

**Objective of the paper**

The objective of this paper is to evaluate the model proposed by Lander and Liker. That evaluation may provide insight into the softer elements that explain why some groups are able to more successfully improve their processes. This information should be valuable to both military and civil companies seeking to become lean. Segregation of less tangible effects on CPI provides managers focus areas outside of the lean tools. Combining the tools and cultural aspect of lean influences a deeper understanding and should positively influence successful process improvements.

**Methodology**

We further developed the constructs suggested by Lander and Liker through review of the literature. We developed a method of measuring the independent and dependent variables grounded in the constructs. We developed 1-5 measurement scale was developed to assess the degree of independent variables in different groups that were attempting to improve. Nineteen groups were assembled for evaluation by two separate Squadron Directors at Tinker ALC. The first author conducted face-to-face interview with 2 members of job-shop level units to assess independent variables. The Squadron Directors measured successful CPI on their respective groups, which was categorized into the dependent variable.

We used correlation and regression analysis to identify which independent variables had the most influence on successful CPI.

**Contributions of this paper**

This study found one of six conditions, Structured Improvement Process, of the Lander and Liker model is positively correlated with success at $\alpha = .05$. All correlation coefficients were positive as hypothesized, but not statistically significant. Our data show a Structured Improvement Process has more influence on successful CPI than the other elements tested. Anecdotal data suggest the drive for improvement also influences CPI. Our data also suggest there was an unmeasured unified construct that influenced team success. Air Force managers should focus their efforts having a highly structured improvement effort and motivating their employees to continually improve their processes.

**Outline from here**

The remainder of this paper focuses on describing why some groups are more successful at CPI than others. The literature review further describes the Lander and Liker model. We review the constructs proposed in the model with published literature. The conceptual model is also proposed in this section. The following section describes data collection and variable evaluation, followed by data analysis. Section V contains our findings where we discuss how Structured Improvement Processes, along with Drive for Improvement provide focus areas for managers. We also discuss how an unknown construct may influence CPI. Suggestions for further research and concluding remarks follow.

## II.  Literature Review

Dr. W. Edwards Deming published Out of the Crisis in 1982 to provide American managers a roadmap to become more competitive in the global market (Deming, 1982).  He had taken his ideas on management principles to Japan prior to his efforts to revolutionize manufacturing in the U.S.  He developed 14 Points for Management that were adapted by Taiichi Ohno to help improve the Toyota Corporation in Japan.   Deming's 14 points in several ways represented a departure from the traditional American view of assembly line work.  He proposed organizations should "Improve Constantly and forever the system of production and service, to improve quality and productivity, and thus constantly decrease costs," in the fifth of the 14 Points (Deming, 32, 1982).  Ohno was able to build a highly successful corporation even as Japan was emerging from World War II by embracing continuous improvement as a hallmark of his business model.

The Toyota Production system began to gain international notice as Toyota was able to weather the 1970s oil crisis better than other auto manufacturers (Lander & Liker, 2007).  That success spurred the curiosity of firms in the West and led to further examination.   J.P. Womack observed Japanese manufacturing firms and techniques and synthesized the term 'lean' to describe the next evolution of manufacture past mass production  (Womack, Jones, & Roos, 1991).  Womack continues to define lean as elimination of waste and production of value for a customer.  Toyota became the standard for lean production opposed to the mass production mindset.

Toyota was highlighted as a paradigm of lean production as these principles became more widely known.  However, understanding the lean principles really did not describe

HOW to create or sustain lean production. Many firms view the TPS as a set of tools to eliminate waste, but this view is flawed and will likely lead to an unsuccessful lean transformation (Lander & Liker, 2007). More successful transformation takes place when tools are used as part of a larger management system (Suzaki 1987, Shingo and Dillon 1989, Monden 1993). A deeper understanding of the tools and philosophies behind them is necessary to adapt the TPS to new environments. A scientific approach to testing new ideas is behind Toyota's Continuous Improvement activities (Spear & Bowen, Sept-Oct 1999). There is much evidence to suggest that the TPS is larger than the sum of its tools.

Toyota really believes that its true competitive edge lies in its people. Ken Kreafle, senior executive for Toyota Motor Engineering Manufacturing North America Inc., explains, true lean is about "people doing the work, improving their own work through problem solving with support from management and in accordance with company goals and objectives" (Badurdeen & Gregory, 50, 2012). Thus in advanced lean environments, floor level workers are respected enough and trained to make process improvements. A no-blame workplace is one of Toyota's cultural hallmarks and shows respect for workers in a firm. Badureen and Gregory note that "Toyota's human system is the most complicated and the most difficult for others to replicate when pursing true lean; it also is important to understanding the missing but necessary pillar for success in lean transformations" (51).

The hard side (tools and techniques) clearly is central to making continual improvements in quality, cost reduction and delivery times. "But it's clear that a soft side that encourages people involvement is equally, or even more important" (Badurdeen & Gregory, 51, 2012). There is much evidence to suggest that having both a deep understanding of the principles of the TPS and involving the firm's workers in the lean transition is essential to making process improvements. Employing both sides of the TPS is the key to building sustained, incremental process improvements in both military and private sector firms. The root of TPS is about supporting and encouraging people to constantly search for better ways to do their job (Lander & Liker, 2007).

The softer side of lean may be just as important as the harder side to continuous process improvement, but it is more difficult to measure (Badurdeen & Gregory, 2012). A firm can visually see if they have level flow or a pull system in place simply by walking around their production facilities. Large amounts of WIP inventory are cues that the process is not fully leaned out. A repair process in the depot can be broken down in modular workstations in an attempt to level-load the workflow, or achieve the *heijunka* principle of TPS. Simply implementing these tools with a less than full understanding of the consequences can actually slow production and de-motivate employees to try further process improvements in the future due to feelings of reduced cooperation (Deming, 1982). We can assume that even if the firm has a very good understanding of the tools of TPS and their application, they may be lacking in the softer side that is necessary to sustain lasting CPI success and achieve a more advanced Toyota-like system.

The Motawi company's leadership was supportive of the change and employees had the tools necessary to tailor new business practices to their needs. Leadership must be supportive of any lean transition if it is to succeed (Deming, 1982; Liker J. K., 2004; Anderson, Rungtusanatham, & Schroeder, 1994). These sources also stress the importance of leadership's commitment to long-term vision over short-range improvements.

Lander and Liker's model derives its conditions for successful CPI from those of a learning organization (Deming, 1982; Senge, 1990; Imai, 1986) that continually improves its processes. Developing a learning organization is essential for continuous improvements, otherwise a group will stagnate (Senge, 1990). Lander and Liker examined a company that made a successful transition to lean system over a 2.5 year period. They worked with the company to perform a lean transition, and noticed six conditions that necessitated the successful transition to new business practices shown in Figure 2.1. Each condition is grounded in management theory. We used their definitions to define our own independent variables and hypothesized each condition positively influences CPI.

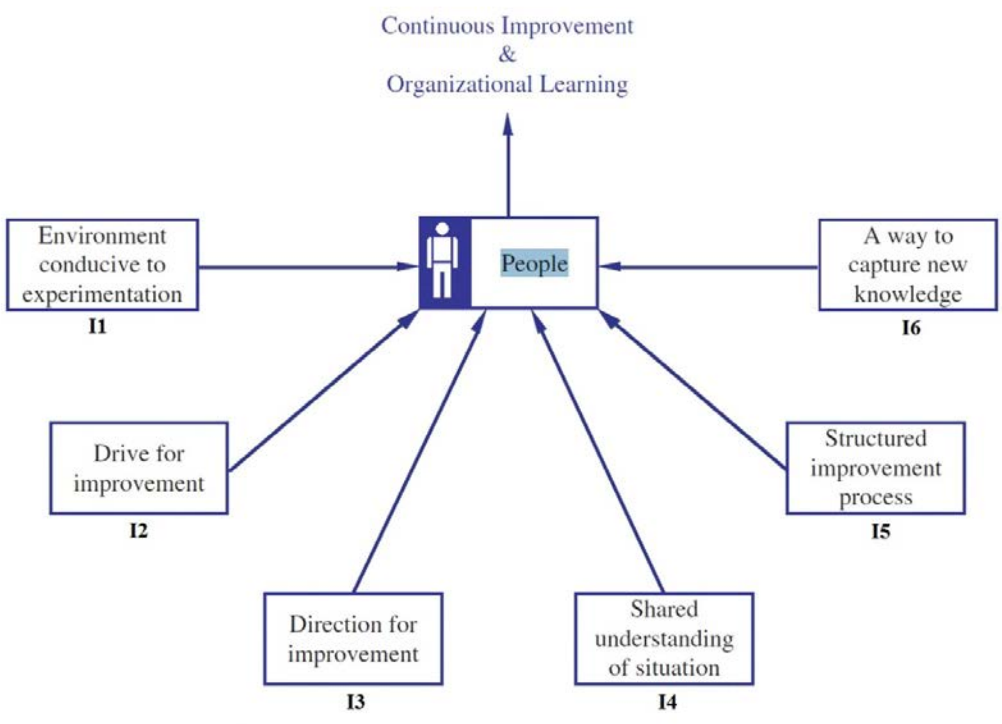


**Figure 2.1 Source Lander and Liker, 2007.**

We reviewed other references to the (Carleysmith, Dufton, Altria, 2009) (Vinodh, Chinthathe, 2011) (Jayaram, Das, Nicolae, 2010) Lander and Liker paper, but none evaluate their conceptual model and the conditions necessary for CPI. References to the paper are limited to successful application of the TPS in a highly variable environment. We did not identify any other studies that evaluated the model's suitability for predicting CPI. Their study provides conditions they found necessary for Continuous Process Improvement in addition to evidence for universal application of the TPS. The proposed conceptual model is ground in generally accepted Quality theories, yet has not been evaluated.

Each condition in the model has an influence on the people in the work environment, although Lander and Liker did not suggest the relative importance in their study. Higher presence of each of these conditions should lead to a higher degree of Continuous Process Improvement. Each condition is rooted in the principles of the Toyota Production System. "By understanding Toyota's system at a principles level we can make the right choices to ensure that the tools implemented fit the organization and support its people while achieving the objectives they were designed for. The principles provide a foundation of understanding and thus should be the guiding force behind every TPS transformation (Lander & Liker, 3696, 2007)." Developing these conditions will help guide a successful lean transition for the 76th Propulsion Maintenance Group and help it sustain process improvements.

The first condition, an environment conducive to experimentation where employees can try new ideas, is essential to improving business practices (Deming, 1982; Garvin, 1993). Lander and Liker define this construct as "a no blame environment where problems are seen as opportunities for improvement is necessary to ensure that people can experiment and make mistakes as they learn (Lander & Liker, 2007, 3694)." Employees cannot make beneficial improvements if management does not support some level of risk-taking. Incentive systems that reward trying new things help develop an environment where new ideas grow (Garvin, 1993; Choo, Linderman, & Schroeder, 2007). Likewise building a feeling of trust highlights Toyota's principle of resepect for people (Liker, 2004). An key we used to evaluate H1 was: Leadership is o.k. with risk taking. Other keys used to measure this condtion are shown in Table 1.

**H1: Environment conducive to experimentation is positively correlated with successful CPI.**

Employees must also be motivated to change, as measured by the Drive for Improvement construct. "They must be willing and feel the urgency to make things better…(Lander & Liker, 2007, 3694). Motivation is equally as critical as teamwork, the basis of truth and rationality in the organization, and several other conditions (Anderson, Rungtusanatham, & Schroeder, 1994) to implementing the proper process changes in an organization. Employees who are not motivated to change or are afraid to change hamper the progression of CPI. Conversely, empowered and motivated employees will think outside of current known constraints to solve their problems (Spear & Bowen, Sept-Oct 1999). An element we used to measure H2 was: Workers feel like there is a good reason to improve their process. The other keys used are listed in Table 1.

**H2: Drive for Improvement is positively correlated with succesful CPI.**

Likewise employees need to know the direction of their efforts "to achieve and overall objective they support (Lander & Liker, 3694, 2007)." The direction of improvement can be linked to setting goals for the improvement effort. Goal theory suggests having a specific direction to improve produces greater successes than less defined strategies (Latham & Locke, 1979). Additionally, employees that have challenging goals are more motivated to achieve than easier more attainable goals. Developing the goal with employees often generates understanding of the direction of the improvement and a shared understanding of the current situation in the same effort (Likert, 1961). A key we used to measure H3 was: a team develops a consensus of what the improvement should be**.** Other keys are shown in Table 1.

**H3: Direction for Improvement is positively correlated with successful CPI.**

Quality management theories place emphasis on cooperation believing that collaboration yields better decision, higher quality, and better morale (Detert, Schroeder, & Mauriel, 2000; Senge 1990). Lander and Liker stated, "Visual systems and standards are needed to highlight problems and promote a shared understanding of the current situation (Lander & Liker, 3695, 2007)." Thus management developing an understanding of the desired outcomes with workers should yield better improvement efforts. A key used to measure H4 was: The team seems to agree on their current performance status. Other keys are shown in Table 1.

**H4: Shared Understanding of the Situation is positively correlated with successful CPI.**

Structured improvement processes lead to more successful improvement efforts. Toyota is known for their scientific problem solving approach (Liker, 2004; Spear & Bowen, Sept-Oct 1999). Lander and Liker said, "A structured process must be used to ensure that improvements happen continuously and that results are consistently good (Lander and Liker, 3695, 2007)." Haphazard problem solving methods are no better than random trial and error. Any improvement is made in accordance with the scientific method eliminating guesswork (Spear & Bowen, Sept-Oct 1999) It is this formulaic approach that maximizes employee efforts and ensures the process is repeatable. Similarly other quality management proponents stress the use of thorough planning, structured change, and reevaluation of the situation to produce continuous improvement (Deming, 1982; Imai, 1986). A key used to measure H5 was: the team used some series of steps to achieve a goal. Other keys are shown in Table 1.

**H5: Structured Improvement Process is positively correlated with successful CPI.**

Lander and Liker propose, "Finally, there must be a way to capture knowledge to ensure that individual learning results in organizational learning (Lander and Liker, 3695, 2007)." New work standards need to be created from improvement efforts if they are to be translated into accepted business practices (Liker & Meier, 2006). Toyota values standard work as a way to reduce quality defects and implement best practices (Liker J. K., 2004). The change must be internalized by workers and work routines updated if the change is to be considered truly institutionalized (Fujimoto, 1999). Improvment efforts begin again once changes are institutionalized (Deming, 1982; Imai, 1986; Senge, 1990). A key used to to measure H6 was: new performance standards were created. Other keys are shown in Table 1.

**H6: Way to Capture New Knowledge is positively correlated with successful CPI.**

We developed the definition of the Dependent Variable successful Continuous Process Improvement by reviewing the Motawi Case study to align our measured condition with that proposed by Lander and Liker. Liker suggested following the Plan Do Check Act (PDCA) cycle (Deming, 1982), to create standards capturing new knowledge ensures that the organization learns as well (Liker J. K., 2004). We needed to establish consensus on the concept of successful CPI with Squadron Directors as they scored the dependent variable. Their definition was not drastically different than that proposed in the study, or other impressions of a learning organization (Liker, 2004; Deming, 1982; Imai, 1986; Senge, 1990). We wanted to meld the definition of success proposed in the study with the Squadron Director's to provide meaningful results to the ALCs. Conversation with a Squadron Director stressed retention of the improvement. He stated, "Sustainment is the hard part. We can get people to make improvements, but keeping them going is the challenge (Arnold, 2012)." Thus we defined the dependent variable:

**(D1) Successful CPI is making an improvement, sustaining that improvement, and continuing to improve over time.**

Lander and Liker developed the conceptual model while observing the lean transition of Motawi Tile Company. Motawi had sales near $2 million per year producing a variety of parts in generally low volumes including a catalogue of 6400 different end items ranging from standard products to completely customized based on customer inputs (Lander & Liker, 2007). The production setting of Tinker Air Logistics Complex is somewhat similar to that of Motawi Tile in Lander and Liker's study. Thus we found it a sufficient area to evaluate the model.

## III. Methodology

We collected primary data by interviewing two people from 19 job-shop level groups. Participants and groups were somewhat randomly selected by Squadron Directors at our request. We asked for a cross section of both successful and unsuccessful teams. The authors developed definitions of the dependent and independent variables based on review of literature. Interviews were digitally recorded and each group was scored on a 1-5 scale measuring the presence of each independent variable. The first author and a research assistant scored the interviews measuring independent variables. The dependent variable was scored 1-5 by the Squadron Directors, who were the third line supervisors of participant groups. We conducted correlation and regression analysis on the collected interview data to evaluate the model.

We selected the 76th Propulsion Maintenance Group (76 PMXG) at Oklahoma City Air Logistics Complex as our study population. The 76 PMXG is comprised of approximately 1,600 military and unionized civilian personnel at the Air Force's only engine maintenance facility. The workforce is approximately 90% Department of Defense employed civilian workers and 10% uniformed service members. The PMXG is run to a $1 billion budget, and performs repair, modifications, test and reclamation of whole engines and engine items subject to repair on 14 aircraft engine types. The Air Logistics Center is a large production facility comprised of many job shops. The job shops perform work for all engine types (U.S. Air Force). We found the similarities between Motawi and the 76$^{th}$ Propulsion Maintenance Group sufficient to test this model over other alternatives. Additionally, this model explained why some work cells were more advanced in improving their processes and business rules than others.  The model proposed in Figure 2.1 suggests causal reasons for the difference between groups.

Our research used the proposed model as a measurement of the less tangible principles of TPS as the Air Force seeks to become leaner in its production facilities.  We noticed  shop-floor level workers often understand the details of what is causing production slowdowns or missed delivery dates that are discussed in Squadron and Group level production meetings, and often have ideas an ways to make process improvements.  If the lowest level employee is able to understand the principles of TPS, then continuous improvement is certainly possible in the Air Logistics Centers.

***We hypothesized (D1) Continuous Process Improvement is positively correlated with each of the following conditions listed in H1-H6.***

1. ***(H1) Environment conducive to experimentation***
2. ***(H2) Drive for Improvement***
3. ***(H3) Direction for Improvement***
4. ***(H4) Shared Understanding of situation***
5. ***(H5) Structured improvement process***
6. ***(H6) A way to capture new knowledge***

$\mathbf{H_o}$**:** $r \leq 0$

$\mathbf{H_a}$**:** $r > 0$

We defined variables to test our hypotheses based on the 14 principles of the TPS described in The Toyota Way and other quality management principles discussed in the literature review.  Variable definitions are listed in the “Independent variable and definition” column of Table 1. The keys in column 2 were used to score the independent variables. For example, a team that scored highly on I1 showed nearly all elements like "Leadership is ok with risk-taking," and "Workers are not chastised for ideas that do not fully succeed." . A team that showed more keys was given a higher score.

Interview with our participant groups' senior leaders showed a high understanding of lean concepts and commitment to achieving long term improvements. Leadership and support for change were consistent across all of our participant groups, and we held this condition constant during our study and did not evaluate them as part of the study. Some other condition or combination of conditions must drive successful CPI if leadership is fairly constant (Anderson, Rungtusanatham, & Schroeder, 1994). Thus we evaluated the six other conditions in the Lander and Liker model.

Two squadrons had many shop-level units (>20), and those units were identified as having varying degrees of success with CPI by the squadron directors. Each squadron had at least 25 job shop level units. One squadron provided 9 participant groups and another squadron provided 10. We collected data through face-to-face personal interviews where at least two shop-floor workers were present. Two participants were interviewed at one time in an attempt to gain a better consensus of the group as a whole and limit the influence of one outlying participant. The interview groups were assembled and scheduled by the squadron directors so as minimize interference with the normal duty day. It was important for the directors to know which groups were participating in the study, so they could accurately score them on the dependent variable D1 at the conclusion of data collection. The group order and participants chosen were assembled at random in an attempt to control selection bias from the viewpoint of the researcher.  Additionally, squadron leaders were asked to provide a full range of groups from the most successful to the least according to their perception of group success.  A pseudo-random cross-section of participants aided in controlling selection bias from the directors and allowed fuller evaluation of the model.

Interview methodology was chosen because a relatively small group was investigated. The study required high participation rates and accurate measurement.  We were able to answer participant questions and direct conversations towards measurement of independent variables using interview as the data collection method.  Asking similar questions of different participant groups allowed for a targeted range of responses and aided evaluation of the constructs in question.   The first author steered conversation towards identifying the nature of the variables in the study due the flexible interview structure.  Some interviews would not have produced useable data if participants were allowed to speak without some guidance.

We piloted our structured interview design with two peers approximately four days prior to the first investigative interview.  The pilot interview used pre-defined questions that would have been asked to every participant group. They commented that the style was too rigid and made them feel uncomfortable.  We decided data collection interviews should be more free-flowing based on the outcome of the pilot interview.

Every participant group was scored on a 1-5 scale.  A score of 1-2 generally showed little or no presence of the condition and a score of 3 showed some presence of the condition. Scores of 4-5 were assigned to groups with high and very high levels of the conditions respectively.  The two respondents' comments were considered together to produce a total group score.  Participants were guaranteed anonymity to encourage honest interview responses. A scoring matrix for all variables is listed in Appendix A. This matrix was used to assign scores by the first author and a research assistant. The first author listened to all recordings in their entirety except for Group 6. An incomplete recording of Group 6 was captured, so an assessment was made on that group immediately following the interview. Approximately three weeks passed between collection and evaluation of the interviews. A score was assigned to each group on each variable and recorded in an Excel spreadsheet.

The director of one squadron and the deputy director of the other scored the dependent variable. The directors had no knowledge of the independent variables or model we were testing. Hence they based their scores solely on the definition of successful CPI, and not how well the participants groups were accomplishing I1-I6. The researcher had a brief discussion with both prior to their scoring of the groups to ensure that all understood and agreed on the definition of success. The directors were encouraged to make comments on each group that might help the authors better understand their assessment. We did not view dependent variable scores until scoring of the independent variables was completed.

We hired a research assistant to independently score the independent variables (Lincoln & Guba, 1985) and eliminate any bias the first author developed while scoring. We first conducted an hour long discussion with our assistant to detail what a score of 1 through a score of 5 should be based on the definitions and elements listed in Table 1. We also provided her the Variable Scoring Matrix listed in Appendix A to reduce subjectivity while developing scores.

We reconciled differences in scores when our assistant finished listening to the recordings. We gave special attention to major differences in interpretation of scores. We considered a major difference anything greater than or equal to 2. We used a subjective averaging method to reconcile differences in scores. For example, if the first author scored a group "3" and the assistant "4" they discussed if the group was a high/low 3 or a high/low 4. A high 3 and high 4 were scored a 4, but a high 3 and low 4 were scored as 3.5. Major differences (i.e. 2 and 4) were generally averaged as a 3. Both the first author and assistant provided justification for their rankings to reach a consensus. Descriptive statistics for Rater 1 (the first author), Rater 2 (the research assistant), and reconciled scores are listed in Appendix B. Reconciled scores were used for the data analysis portion of the study.

## V. Analysis and Findings

*Variable Descriptive Statistics and Inter-Rater Agreement*:

Review of the descriptive statistics (Table B5) of the independent variables I1-I6 shows the means for all variables are between 3 and 4 with a standard deviation less than 1. This shows limited variability in the measurement scale. Examination of dependent variable scores (n =19, mean = 3.86, s.d. = .89) revealed similar outcomes.

Rater 1 (first author) and Rater 2 (research assistant) individually scored 18 participant teams. Rater 2 was unable to score group 6 due to an incomplete recording so only rater 1's score was used for that group. In order to test inter-rater agreement we used the Related-Samples Wilcoxon Signed Ranks test. We used this test because the two groups cannot be considered independent of each other and no assumption of normality could be made for the underlying distribution of the ranks. Assumptions of this test were violated, as the underlying data were not truly continuous (McClave, Benson, & Sincich, 2011), but we considered the results valid for the context of this study. Examining the scores as a whole did not suggest significant differences between Rater 1 and Rater 2 (n=133, α=.05, T=.379) as indicated in Table B1. However, examining the scores categorically indicated some differences in rater opinion on the Environment Conducive to Experimentation variable (n=18, α=.05, T=.031) as indicated in Table B2. We resolved this difference through the score reconciliation process. There were no significant differences between the other variables when tested categorically, hence there was no evidence to suggest that Rater 1 and Rater 2's scores drastically differed from each other. We considered the reconciled scores the most accurate, and they were used for further analysis.

*Correlation analysis*:

We normalized the dependent variable (D1) as one squadron director appeared to rank his groups consistently higher than the other. An arbitrary value (2) was added to the z-scores to continue analysis with positive numbers. The inter-variable correlation matrix (Table B6) shows most of the variables are highly related to each other. The degree of inter-variable correlation ranged from .89 to .15. I4, Shared Understanding of the Situation, showed the least correlation with the other variables, ranging from .60 to .15.

The only significant positive correlation ($r$ =.53, p < .01) between I1-16 and D1 was I5, Structured Improvement Process. All correlations are shown in Table B6. The other variables were weakly positively correlated with success .24-.40, but some coefficients were close to being statistically different than zero (see table B7). The closest significant positive relationships were Way to Capture New Knowledge ($r$ =.40, p <.05) and Drive for Improvement ($r$=.37, p =.12). Even the highest p-value at .36 suggests that the positive relationship between Shared Understanding of the Situation and Successful CPI is only 36%

due to chance. These findings do not support hypotheses H1, H2, H3, H4 and H6 are significantly positively related to Successful CPI. Further examination of the inter-item correlation matrix suggests some interesting relationships that occur between the predictor variables. Those relationships are covered in the Discussion section of the paper.

*Regression analysis*:

The full model included all six predictor variables and suggested the following relationship using standardized Beta coefficients:

**Successful CPI (normalized mean 2, s.d.1) =**

**-.114 + .206(I1) + .206(I2) - .304(I3) + .073(I4) + .973(I5) -.510(I6)**

The model's F-statistic was 1.095, $p = .419$ and adjusted $R^2 = .031$. None of these standardized coefficients were significant at $\alpha = .05$. The closest significant relationship was H5 ($p = .125$). Variance Inflation Factors ranged from 3.4 to 8.2. Eigenvalues were all less than 0.1. The full model summary is shown in Table B8.

Step-wise regression analysis removed all variables except I5, Structured Improvement Process (Criteria for Entry, F = .05, Criteria for Removal, F = .10). The y-intercept, .31, was not found to be statistically different than 0, ($n = 19$, $t = .462$, $p = .650$). However, there was no evidence to suggest the intercept should be removed from the model. Table B9 highlights regression statistics where the following relationship was suggested:

**Successful CPI (normalized mean 2, s.d.1) = .31 + .49(Structured Improvement Process)**

The F-statistic was 6.77 ($p < .05$) and adjusted $R^2$ value was .243. This level of explained variation may be sufficient for real world use (Pearson, 2010). The standardized $\beta$ coefficient of Structured Improvement Process was significant at $p < .05$. Examination of the reduced model in conjunction with inter-item correlation matrix and anecdotal data collected during the interview process may provide practically significant data for Air Force managers. These relationships are discussed in section VI.

## VI. Discussion

The intent of this study was to provide Air Force managers with focus areas that might aid in continually improving over time. We selected a model rooted in the principles of the Toyota Production System that was developed during the lean transformation of a private sector company. The data support hypotheses 1-6 are positively correlated with successful CPI. The full model did not produce any predictive capability. However, the reduced model suggests H5 Structured Improvement Process can be used to predict the success of CPI efforts. H5 represented the "hardest" condition we measured with focus on eliminating waste from existing processes. This finding surprised us as we thought one or more of the "softer" elements would show more influence on CPI. Further evaluation was limited due to low variability in both the independent and dependent variables and small sample size.

**Examination of Inter-Item Correlations**:

The one significant variable, I5, was very highly correlated with I6, Way to Capture New Knowledge (.89, p = .01). This makes practical sense based on interview data collected. Highly structured improvement processes usually ended with a goal or defined improvement metric in place; reducing cycle time by 10 days for example. The group worked towards achieving that goal, and if it was successful, it was generally accompanied by a change in business rules to ensure the new standard was institutionalized and did not backslide to the previous acceptable standard. Actually incorporating the new standard into technical data, or updating a technical order (T.O.) was less frequent than a de facto change in business rules. Writing a change into tech data can sometimes take over a year, but temporary measures are put in place to institutionalize the change. The high correlation suggests that the Structured Improvement Process variable might capture the explanatory power of Way to Capture New Knowledge. Perhaps Structured Improvement Processes lead to capture of knowledge because the structure is a flag for leadership support. Leadership's notice of the change may drive change institutionalization.

All of the variables displayed a high level of correlation with themselves (>.50) except I4, Shared Understanding of the Situation. This high correlation between variables suggests one of three underlying causes. First, the six constructs we considered independent might represent a single construct. However, we do not feel this is the case as I4 was much less correlated to the other variables. This provides evidence that the model is indeed measuring six different constructs. Second, bias in independent variable scores caused the correlation. Again, we do not feel this was the case as both scorers ranked the groups similarly. Finally, an underlying construct not measured by this study is driving the correlation. We think this is the most likely outcome. Perhaps team dynamics significantly influence CPI. For instance, a team that works well together will score highly on all six constructs. Further research to explore the singular underlying driver for successful CPI may produce interesting results.

**Model Selection:**

The full model did not suggest inclusion of all variables provides any more explanatory power than random noise based on the low adjusted $R^2$ value and high multicolinearity diagnostics. Stepwise removal of all variables other than H5 showed a Structured Improvement Process significantly impacts Continuous Process Improvement. The reduced model was used for further analysis and we considered the relationship it suggested significant for managerial recommendations. Discussion of our impression of a highly structured improvement process follows in the next section.

**Focus areas for Managers:**

*Structured Improvement Process*

This study's data suggest that having a Structured Improvement Process significantly impacts the success of CPI. It was moderately correlated, but was able to explain some of the variance present in the dependent variable. Most highly structured improvement processes were the same as a Rapid Improvement Event (RIE) at Tinker Air Logistics Complex. The term RIE, should be recognizable by Air Force personnel that participated in an AFSO21 event. The groups ranked as most successful by Squadron directors had gone through an RIE in the last 24 months. We did not intend the variable to be synonymous with RIE, but there was an unmistakable relationship between what this variable was measuring and RIEs in the observed groups.

Groups that underwent an RIE sometimes started the event with a predetermined goal (i.e. reduce flow time by 20 days), but others simply set out to improve their business process. The groups were sometimes cross-functional including members from outside the focal shop, but most often, they only involved members within the focal shop. RIEs in both squadrons began with value-stream mapping that followed part movements as they flowed within the shop according to required work. The shop workers themselves captured distance measurements using a surveyor's wheel. Those distances were transposed to "spaghetti-map" usually with the help of a process engineer, or "lean expert." Workers became more familiar with their work processes and were able to identify non-value added steps. They developed a better understanding of their current situation and constraints as measured by I4 through process mapping. The groups ranked as "5" by squadron directors were able to remove non-value added steps from their processes. Removal of steps was vetted through materials engineers prior to implementation to ensure that removal of steps did not affect product quality.

Another factor that contributed to the success of RIEs was the level of attention given by Squadron level and Group level leadership. An improvement effort termed "RIE" was given approval by flight level and Squadron level managers. Not all ideas or efforts were given RIE status. Some ideas were implemented below flight level without performing detailed planning or leadership approval, but were seldom institutionalized. RIEs were given support by leadership and participants were often given time away from primary duties to plan and implement RIE requirements. There appeared to be a significant link between Squadron and Group level event tracking and RIE success. One participant noted, "Once the boss gets ahold of these things, they usually turn out pretty good."

Also linked with RIE success was the involvement of a "lean expert." The Maintenance Group that was studied at Tinker ALC employed a Six Sigma black belt that had participated in many improvement efforts. The black belt was present at RIE meetings and was responsible for steering the direction of team.  Several participants highlighted the black belt did not dictate the direction or the specifics of the improvement, but did provide tools to help examine processes.  Those tools were reading materials describing the basics of lean concepts like elimination of waste and level loading flow, Excel based tools to help them identify how long it took to achieve tasks, and guidance when the team hit roadblocks or could not agree on the direction for improvement.  Several shop floor level participants made comments like, "The lean concepts and math behind them were really difficult to understand.  But when we put them in place and started moving stuff around, it started to make more sense."  One participant was particularly happy with the Excel tools.  He commented:

> "The lean expert explained how to use the spreadsheet.  He made it really simple to use so we just plugged times into cells, and it did all the calculations for us.  Now that we have the math to back up our changes, management is much more willing to let us do what we want to change the process.  Before, we knew that making the same change would help, but we couldn't prove it, so we couldn't make the change.  Now, we can communicate with numbers, the way management wants to hear it.  We get stuff done a lot faster now that we can communicate our ideas with numbers."

The same spreadsheet tools were provided to all RIE participants to help them provide data-driven decisions to managers.  Several participants made comments that it was helpful to have the lean expert to guide them through the process the first time, but after completing one successful RIE, they could do it again without as much guidance.  The researcher also observed that RIEs were more successful when the lean expert provided guidance. The expert answered directly to Squadron and Group leadership and had vested interest in seeing the projects succeed.

It was possible that having an RIE captured most of the elements that the other independent variables were attempting to measure. RIE participants seemed to develop a better understanding of their current constraints, reach a consensus of how to break those constraints, were motivated to break constraints, and the outcomes were more often institutionalized. We were surprised to find that the most tangible and structured construct had the most influence on success. This finding adds evidence to the argument that an understanding of the TPS principles such as flow and elimination of non-value added steps is necessary to implement lean transformations.

We segregated all participant groups by those that underwent a RIE (Group 1) in the last 24 months, and those that had not (Group 2). Wilcoxon Rank Sum tests add evidence that RIEs influence development of other conditions in the model. Groups that experienced an RIE scored higher on independent variables shown by the Wilcoxon test. These tests are summarized in Table 2 where $H_o$ was identical distributions. An RIE encourages drive for improvement, direction for improvement, structured improvement process and capture of new knowledge. However, RIEs did not show an increase in environment conducive to experimentation or shared understanding of the situation. We did not expect RIEs to increase experimentation, but were surprised they did not help understanding of the situation. We think further evaluation would show that RIEs do in fact develop higher understanding of the situation. Or perhaps RIEs are not needed to understand the situation, but they do help to communicate the situation better.

| Condition | Rejection Bound | test statistic | p-value-1 tail | Reject Null? |
|---|---|---|---|---|
| **Dependent Variable** | 46 | 60 | 0.22 | no |
| **I1** | 46 | 48.50 | 0.030 | no |
| **I2** | 46 | 46.00 | 0.025 | yes |
| **I3** | 46 | 42.5 | 0.001 | yes |
| **I4** | 46 | 73.50 | 0.400 | no |
| **I5** | 46 | 38.50 | 0.003 | yes |
| **I6** | 46 | 38.00 | 0.003 | yes |

Table 2. Wilcoxon difference of means tests for RIE participants

A similar evaluation of the dependent variable showed RIE groups did not score higher than non-RIE groups. This finding adds evidence that the squadron directors ranked groups based on long-term success as we intended. The data would have been skewed if the dependent variable was only scored on success or failure of RIEs.

*Drive for Improvement*

The observed data do not support the conclusion that I2, Drive for Improvement, was strongly correlated with successful CPI. However, the primary researcher made observations that link the two conditions. Shop floor workers tended to make changes if they really believed it would make a significant improvement. Sometimes, the improvement was made without vetting it through management and the workers took it on themselves to ensure that quality defects were not caused by the change. However, the unvetted improvements did have a higher potential for creating a local optimum at the individual shop level.

For example, a seasoned machinist with over 10 years' experience kept having downtime due to materials catching fire in a lathing process. He had worked in the private sector performing the same type task on the same machine. Their solution was to place a simple steel bar into the machine that prevented the lathing material from catching fire, but his Tinker Air Logistics Complex leadership did not support using the same type device, thinking that an adverse reaction might take place between the steel and lathing material. An excerpt from his anecdote follows:

> "I knew putting the bar in there would work, because I'd done it before. I know it makes the process faster, and you have less fires so why wouldn't you do it? I even knew that we had some (bars) around here, but they didn't quite fit my machine. They were ordered over a year ago, but were sitting in a warehouse because they didn't fit right. But I knew a guy in a different shop that could cut and mill it to fit my machine. So, I got one, took it to the guy, and he milled it and I put it in my machine. Before I used it, I got the engineer down here to see if there was going to be anything bad happening between the two metals. He didn't find anything in the data to suggest that it would, so I tried it out…and suddenly I have less fires and less downtime. I easily outpace my demand now."

He said the idea had been taken to management, but they did not act on it. There were several more machines like his in use at the Air Logistics Complex, and bars that could be put in them at a minimal cost. He was unsure why leadership wouldn't make the investment to install bars in all the machines.

*Workers Generally Supportive of Change*

Another finding was that a majority of participants interviewed were not really averse to changing their business processes, especially if they had a say in how the change was implemented. Most would support change if they thought it would be a better way of doing business. However, the majority was also opposed to frequent changes in business rules.

Frequent changes seemed to cause on the workers who noted frequent management turnovers hampered process improvement. Several participants commented that management did not seem to give process changes time to fully develop without reverting back to the old way. Additionally, most participants when questioned, seemed to think that they could eliminate waste in their processes and perform their job better. This study did not examine how or why shop floor workers were motivated to implement change, but it seemed that they would make changes if they were driven enough, regardless of management approval.

*Direction for Improvement*

Another somewhat surprising observation was the source of the improvement idea did not seem to be linked to successful CPI. The researchers believed at the onset of this study that ideas generated by shop floor workers themselves would be more successful than those suggested by management or someone outside of the workgroup. However, there did not seem to be a real difference between who suggested the idea or mandated that change in business processes take place. Employees appeared to be more willing to implement and take ownership of the change the more they were included in the process, as noted earlier. They also seemed more willing to accept change if management took time to explain the rationale behind the decision. Data driven decisions helped develop improvement ideas, and using projected time savings or potential WIP reductions helped workers develop a better understanding of the direction of the improvement. The more successful groups made comments about management helping them to understand why they were changing and the desired end state of the change. This observation, suggests understanding the direction for improvement as measured by I3 may indeed be positively linked to successful CPI.

## Limitations and Further Research

A limitation and threat to validity of this study was the researcher's interpretation in scoring the independent variables. This limitation stemmed from the non-quantitative nature of the data. Measurement of our seven constructs was subject to researcher bias as are all attempts to quantify subjective constructs. Hence, this investigation was inherently prone to human bias and difference of opinion. Two people with similar understanding of the constructs may score interviews differently based on their impression of how to score the construct and what the construct means to them. It is possible the constructs' underlying conditions were different than we measured.

Future researchers might evaluate this model with a larger, more diverse sample size. Application of this study's findings is limited due to the small population that was sampled. Managers in the two squadrons that were investigated might be able to apply our suggestions to aid in future Continuous Improvement projects. However, focusing on Structured Improvement Processes in a different Group at Tinker Air Logistics Complex, or a different Complex altogether might not produce the desired outcomes. It is possible that focusing on a different independent variable of the model is more beneficial in different units. Thus, evaluating this model across a few units from all three Air Logistics Complexes might help develop more global findings, or even refute the model all together.

This research effort attempted to develop and define seven constructs in Table 1. Those constructs were measured in a single variable that summed the desired characteristics into a singular score. Simply scoring "Environment Conducive to Experimentation" with a single value failed to capture the variability necessary to adequately evaluate the underlying nature of the condition. It is possible to develop a richer data collection instrument using the conditions listed in Table 1 and Appendix 1 to develop at least five underlying constructs that sum the independent variables. For example, develop five conditions that can be scored on a 1-5 scale that measure “Environment Conducive to Experimentation.” Instead of having 6 conditions to measure CPI success, the researcher would have 30. Taking a sum of those scores across all participant groups will introduce more explanatory variability in each of the independent variables.

Likewise, our dependent variable measured on a single 1-5 scale lacked variability as the squadron directors rated on a 3-5 scale due to the way we defined the dependent variable. Our definition of “Successful Continuous Process Improvement” included three elements: an improvement was made, the improvement was sustained, and the group continued to improve over time. Our approach to measure all three at once limited the underlying variability in our dependent variable. Like the independent variable, development of at least 5 constructs to measure each of the three conditions suggested by the dependent variable would produce a total of 15 quantifiable constructs. Introduction of more variability in both independent and dependent variables may highlight the true predictive capability of this model.

Additionally, further research can be conducted to find out what Successful Continuous Process Improvement really is in the Air Force context. Perhaps Air Force leadership values attributes different from what we tested. A Delphi study surveying Air Force leaders across all three ALCs will help shape and more fully develop the construct of successful CPI. The conditions identified from that research can be used to develop a different dependent variable and evaluate the model in a way that is more meaningful across all three ALCs.

Also, development of a survey instrument to evaluate the model across a larger sample size will likely generate more substantial findings. Our research suffered from a narrow scope with a sample size of 19. A survey instrument can be easily distributed across a much larger, more random sample that includes participants from Warner Robins and Ogden. Evidence gathered from these depots might identify more global conditions that will help Air Force managers continually improve their processes.

Finally, exploring the underlying cause of independent variable correlation may produce interesting findings. Researching this construct may identify an even better focus area for managers. Taking our findings in combination with the new construct may help develop teams better suited to lean transitions. Perhaps managers need to ensure certain skill sets or personalities are on an improvement team prior to launching a structured improvement process. Exploration of these interactions might reveal an even more powerful approach to creating CPI.

**Conclusion**

The purpose of this study was to provide Air Force managers, and specifically those at Air Logistics Centers with focus areas to aid Continuous Process Improvement Efforts. The Toyota Production System provides a principle based approach to developing CPI. We evaluated a conceptual model based on observational evidence collected while observing the transition of the Motawi Corporation to a Toyota-like manufacturing system. Our research did not support H1, H2, H3, H4, and H6 because these correlation coefficients were not significantly different than zero at the $\alpha = .05$ level. Despite lack of significance, the coefficients were positive as we proposed.

Our data suggest that focusing on Structured Improvement Processes has the most impact on successful CPI. However, our limited sample size and low level of data variability limit extrapolating this finding outside of the two Squadron level units where the study took place. Anecdotal evidence collected while interviewing participants provides some further focus areas. Our interview data supports the conclusion that having Structured Improvement Processes, usually in the form of Rapid Improvement Events, positively affects CPI. RIEs seemed to encourage drive for improvement, direction for improvement, structured improvement process and capture of new knowledge. There was also anecdotal evidence to support Drive for Improvement, and Direction for Improvement also positively affect successful CPI.

It was possible that the influence of the independent variables was truly explained by Structured Improvement Process, however, we think that further examination of the model will highlight other significant relationships. We suggest that managers at Tinker ALC focus on these three conditions to help meet their production targets in a fiscally constrained environment. This suggestion is by no means exhaustive and other conditions in the model may be more applicable in certain situations. Earlier efforts to “lean out” the ALCs have provided guidance for how to structure “lean events” to eliminate waste. This research may provide additional insights into making those events more successful and provide a starting point for future Process Improvements.

Table 1. Independent Variable Definitions

| Independent variable and definition | Keys used to evaluate variables |
|---|---|
| **1. Environment Conducive to Experimentation:**<br><br>**A no-blame workplace where problems are seen as opportunities for improvement where people can experiment and make mistakes as they learn.** | **Looking for evidence of:**<br>**- Leadership that is ok with risk-taking**<br>**- Workers are not chastised for ideas that do not fully succeed**<br>**- Problems are viewed as challenges that can be overcome instead of insurmountable barriers**<br>**- Leadership provides enough work-time for improvements to be made**<br>**- Workers learn from their mistakes and failures**<br>**- Workers are encouraged to come up with their own ideas for improvement**<br>**- Management supports justifiable improvement ideas**<br>**-Management lets the "change" happen and doesn't revert to the old way** |
| **2. Drive for Improvement:**<br><br>**Employees are willing and feel the urgency to make things better.** | **Looking for evidence of:**<br>**- Workers want to improve**<br>**- Workers are rewarded for coming up with ideas and ways to improve**<br>**- Workers feel like there is a good reason to improve their process**<br>**- Workers are not stagnated in their day to day task performance**<br>**- Employees feel good when they attempt a process improvement**<br>**- Has their feeling about improvement changed from start to finish?** |
| **3. Direction for Improvement:**<br><br>**Employees know the direction of their efforts to achieve and overall objective they support.** | **Looking for evidence of:**<br>**- A clear definition of what "better" is.**<br>**- A consensus of what the improvement should be**<br>**- The team considers all ideas before deciding on the best one**<br>**- Specific, measurable, attainable, challenging goals**<br>**-Team members focus on process flow rather than having piles of work in front of them**<br>**- Simply working on something isn't necessarily good, employees are working on the "right" thing** |

| | |
|---|---|
| **4. Shared Understanding of the Situation:**<br><br>**Visual systems and standards are needed to highlight problems and promote a shared understanding of the current situation** | **Looking for evidence of:**<br>**- The current process is, for the most part, under control**<br>**- Team understands its current performance metrics**<br>**- Team seems to agree on their current performance status (good, ok, needs improvement)**<br>**-Agreement/Disagreement on if I do "X" then "Y" is the outcome**<br>**-Visual Cues to prevent batching** |
| **5. Structured Improvement Process:**<br><br>**A structured process must be used to ensure that improvements happen continuously and that results are consistently good.** | **Looking for evidence of:**<br>**-Team used some series of steps to achieve a goal**<br>**- Deliberate planning took place prior to implementation**<br>**- Team members understood the steps**<br>**- Value stream mapping**<br>**- Diagrams of current work flow**<br>**- Identification of waste in processes** |
| **6. A way to capture new knowledge:**<br><br>**Beneficial process improvements produced a tangible result that can be institutionalized.** | **Looking for evidence of:**<br>**-New performance standards were created**<br>**-The results of the improvement were measurable**<br>**-The team is sustaining the changes they made**<br>**-Team members were involved in creation of new metrics** |

## Appendix A.  Variable Scoring Matrix

**1. Environment Conducive to Experimentation**

1. **Employees make suggestions to management but management completely ignores**
2. **Employees make suggestions, management "considers under advisement", but doesn't get back to employee**
3. **Employees make suggestions, management passes the idea on up the chain, management allows trial of the idea**
4. **Management says try the idea and gives support of the change**
5. **Management says try the idea, and encourages multiple iterations of the change if the first is not successful**

**2. Drive for Improvement**

1. **Workers have bad attitude and do not want to change at all**
2. **Somewhat negative attitude; workers will change if management makes them**
3. **Workers have neutral feelings about change and change if management leads the change**
4. **Workers believe that changing their process will help them do their jobs better**
5. **Workers lead the change for improvement without management influence**

**3. Direction for Improvement**

1. **No ideas for improvement**
2. **Limited ideas for improvement**

3. **Employees have general ideas for improvement, management may or may not agree**
4. **Employees have specific ideas, management may or may not agree**
5. **Employees have specific ideas, management agrees**

**4. Shared Understanding of Situation**

1. **Employees work on easiest parts, or do little work.  No understanding of job.**
2. **Works on easiest parts, have minimal understand of what their job is and why they do it.**
3. **Understanding of tasks, why they do it, but limited understanding of current system.**
4. **Understanding of tasks and big picture understanding of current system**
5. **Explicity knows work processes, and can thoroughly identify upstream and downstream customer.**

**5. Structured Improvement Process**

1. **Haphazard trial of ideas.  No defined process.**
2. **Some evidence of planning prior to implementation of improvement idea**
3. **Generally structured planning process**
4. **Defined series of steps used prior to implementation of idea; some process mapping**
5. **Very defined series of steps used in planning process.  Defined implementation, process mapping used.**

**6. Way to Capture New Knowledge**

1. **Process change made, but management quickly reverted back to old way of doing business**
2. **Process change made, did things the new way for longer than 1, but still reverted to old way.**
3. **Still doing business the new way, but not written down or formalized.**
4. **Change is institutionalized, all employees are doing it this way, but not captured in business rules or technical instructions.**
5. **Same as 4, but technical instructions, work control document or Technical Order has been changed.**

**Dependent Variable – Measure of Successful Continuous Process Improvement**

**The most successful teams made improvements, sustained those improvements, and continued to improve over time.**

**Team has:**

1. **Shown no improvement**
2. **Made improvements in events only but improvements lost over time**
3. **Made and sustained improvements**
4. **Made self-initiated incremental Improvements**
5. **Made self-initiated, self-sustained, continuous process improvements**

## Appendix B. Statistical Evaluation

Table B1. Overall Wilcoxon Signed Ranks Difference

**Hypothesis Test Summary**

| | Null Hypothesis | Test | Sig. | Decision |
|---|---|---|---|---|
| 1 | The median of differences between Rater_1 and Rater_2 equals 0. | Related-Samples Wilcoxon Signed Ranks Test | .379 | Retain the null hypothesis. |

Asymptotic significances are displayed. The significance level is .05.

Table B2. Wilcoxon Signed Ranks Difference between Environment Conducive to Experimentation

**Hypothesis Test Summary**

| | Null Hypothesis | Test | Sig. | Decision |
|---|---|---|---|---|
| 1 | The median of differences between Environment and Environment 2 equals 0. | Related-Samples Wilcoxon Signed Ranks Test | .031 | Reject the null hypothesis. |

Asymptotic significances are displayed. The significance level is .05.

Table B3. Descriptives for Rater 1 Scores

**Descriptive Statistics**

| | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Environment | 19 | 2.0 | 5.0 | 3.711 | 1.0969 |
| Drive for improvement | 19 | 2.0 | 5.0 | 3.368 | .9105 |
| Direction for improvement | 19 | 2.0 | 5.0 | 3.368 | .9978 |
| Shared Understanding | 19 | 2.0 | 5.0 | 3.553 | .8959 |
| Structured Improvement Process | 19 | 1.0 | 5.0 | 3.421 | 1.1816 |
| Way to capture knowledge | 19 | 2 | 5 | 3.42 | 1.017 |
| Valid N (listwise) | 19 | | | | |

Table B4. Descriptives for Rater 2 Scores

**Descriptive Statistics**

| | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Environment 2 | 18 | 2.0 | 5.0 | 3.250 | .9432 |
| Drive for improvement 2 | 18 | 2.0 | 5.0 | 3.278 | .8948 |
| Direction for improvement 2 | 18 | 2.0 | 5.0 | 3.333 | .9393 |
| Shared Understanding 2 | 18 | 3.0 | 5.0 | 3.944 | .4501 |
| Structured Improvement Process 2 | 18 | 2.0 | 4.5 | 3.417 | .8952 |
| Way to capture knowledge 2 | 18 | 2.0 | 4.5 | 3.417 | .7326 |
| Valid N (listwise) | 18 | | | | |

Table B5. Descriptives for Reconciled Scores

| | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Environment | 19 | 2.00 | 5.00 | 3.6053 | .96579 |
| Drive for improvement | 19 | 2.00 | 5.00 | 3.5526 | .79747 |
| Direction for improvement | 19 | 2.00 | 5.00 | 3.5789 | .82096 |
| Shared Understanding | 19 | 3.00 | 5.00 | 3.7632 | .58615 |
| Structured Improvement Process | 19 | 1.50 | 5.00 | 3.4737 | 1.09891 |
| Way to capture knowledge | 19 | 2.00 | 5.00 | 3.5000 | 1.09291 |
| Valid N (listwise) | 19 | | | | |

Table B6

*Inter-Correlations Between Dependent and Independent Variables*[a,b]

| Variables | Mean | *sd* | Scale Range | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.61 | 0.97 | 1-5 | 1 | | | | | | |
| 2 | 3.55 | 0.80 | 1-5 | .61** | 1 | | | | | |
| 3 | 3.58 | 0.82 | 1-5 | .76** | .74** | 1 | | | | |
| 4 | 3.76 | 0.59 | 1-5 | 0.27 | .62** | .50* | 1 | | | |
| 5 | 3.47 | 1.10 | 1-5 | .50* | .59** | .66** | 0.23 | 1 | | |
| 6 | 3.50 | 1.09 | 1-5 | .67** | .60** | .68** | 0.15 | .89** | 1 | |
| 7[c] | 2 | 1 | 1-5 | 0.24 | 0.38 | 0.30 | 0.22 | .53** | 0.40* | 1 |

[a]n was 19 for all Columns,
intercept included
[b]Pearson two-tailed coefficients
[c]Pearson one-tailed coefficients
*Correlation is significant at the .05 level
**Correlation is significant at the .01
level

1. Environment Conducive to Experimentation
2. Drive for Improvement
3. Direction for Improvement
4. Shared Understanding of Situation
5. Structured Improvement Process
6. Way to capture new knowledge
7. Normalized Measure of Success

Table B7

*Dependent by Independent Variable Correlation, Confidence Intervals and Significance*

| Variable | By Variable | Correlation | Count | Lower 95% | Upper 95% | Signif Prob |
|---|---|---|---|---|---|---|
| Normalized Measure of Success | Environment | 0.24 | 19.00 | -0.24 | 0.62 | 0.33 |
| Normalized Measure of Success | Drive for improvement | 0.37 | 19.00 | -0.11 | 0.70 | 0.12 |
| Normalized Measure of Success | Direction for improvement | 0.30 | 19.00 | -0.17 | 0.67 | 0.21 |
| Normalized Measure of Success | Shared Understanding | 0.22 | 19.00 | -0.26 | 0.61 | 0.36 |
| Normalized Measure of Success | Structured Improvement Process | 0.53 | 19.00 | 0.10 | 0.80 | 0.02 |
| Normalized Measure of Success | Way to capture knowledge | 0.40 | 19.00 | -0.06 | 0.72 | 0.09 |

*Table B8 Full Model Summary*

**Model Summary[b]**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | Change Statistics | | | | | Durbin-Watson |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | R Square Change | F Change | df1 | df2 | Sig. F Change | |
| 1 | .595[a] | .354 | .031 | .98460 | .354 | 1.095 | 6 | 12 | .419 | 2.082 |

a. Predictors: (Constant), Way to capture knowledge, Shared Understanding, Environment, Drive for improvement, Direction for improvement, Structured Improvement Process

b. Dependent Variable: Normalized Measure of Success

**ANOVA[b]**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 6.367 | 6 | 1.061 | 1.095 | .419[a] |
| | Residual | 11.633 | 12 | .969 | | |
| | Total | 18.000 | 18 | | | |

a. Predictors: (Constant), Way to capture knowledge, Shared Understanding, Environment, Drive for improvement, Direction for improvement, Structured Improvement Process

b. Dependent Variable: Normalized Measure of Success

*Table B8 cont'd. Full Model Coefficient Matrix*

**Coefficients[a]**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. | 95.0% Confidence Interval for B | | Collinearity Statistics | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | | Lower Bound | Upper Bound | Tolerance | VIF |
| 1 | (Constant) | -.114 | 1.638 | | -.070 | .946 | -3.684 | 3.455 | | |
| | Environment | .213 | .445 | .206 | .478 | .641 | -.757 | 1.183 | .291 | 3.431 |
| | Drive for improvement | .259 | .511 | .206 | .506 | .622 | -.855 | 1.372 | .324 | 3.085 |
| | Direction for improvement | -.414 | .592 | -.340 | -.699 | .498 | -1.704 | .876 | .228 | 4.388 |
| | Shared Understanding | .124 | .560 | .073 | .222 | .828 | -1.096 | 1.344 | .500 | 2.000 |
| | Structured Improvement Process | .885 | .537 | .973 | 1.649 | .125 | -.284 | 2.055 | .155 | 6.461 |
| | Way to capture knowledge | -.467 | .609 | -.510 | -.767 | .458 | -1.794 | .860 | .122 | 8.227 |

a. Dependent Variable: Normalized Measure of Success

Table B9

*Reduced Model Summary and Coefficient Matrix*

**Model Summary[b]**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | Change Statistics | | | | | Durbin-Watson |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | R Square Change | F Change | df1 | df2 | Sig. F Change | |
| 1 | .534[a] | .285 | .243 | .87030 | .285 | 6.765 | 1 | 17 | .019 | 1.998 |

a. Predictors: (Constant), Structured Improvement Process

b. Dependent Variable: Normalized Measure of Success

**ANOVA[b]**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 5.124 | 1 | 5.124 | 6.765 | .019[a] |
| | Residual | 12.876 | 17 | .757 | | |
| | Total | 18.000 | 18 | | | |

a. Predictors: (Constant), Structured Improvement Process

b. Dependent Variable: Normalized Measure of Success

**Coefficients[a]**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. | 95.0% Confidence Interval for B | | Collinearity Statistics | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | | Lower Bound | Upper Bound | Tolerance | VIF |
| 1 | (Constant) | .314 | .678 | | .462 | .650 | -1.118 | 1.745 | | |
| | Structured Improvement Process | .486 | .187 | .534 | 2.601 | .019 | .092 | .879 | 1.000 | 1.000 |

a. Dependent Variable: Normalized Measure of Success

# Bibliography

Anderson, J. C., Rungtusanatham, M., & Schroeder, R. G. (1994). A Theory of Quality Management underlying the Deming Mangement Method. *Academy of Management Review* , 472-509.

Badurdeen, F., & Gregory, B. (2012). The Softer Side of Lean: Analyzing corporate culture can point the way to necessary changes. *Industrial Engineer* , 49-53.

Bowerman, B. L., O'Connell, R. T., & Koehler, A. B. (2005). *Forecasting, Time Series, and Regression; An Applied Approach.* Belmont: Thompson Brooks/Cole.

Choi, T., & Liker, J. K. (1995). Bringing Japanese Continuous Improvement Approaches to the U.S. Manufacturing: The Roles of Process Orientation and Communications. *Decision Sciences* , 589-620.

Choo, A. S., Linderman, K. W., & Schroeder, R. G. (2007). Method and context perspectives on learning and knowledge creation in quality management. *Journal of Operations Management* , 918-931.

Deming, W. E. (1982). *Out of the Crisis.* Cambridge: Massachusetts Institute of Technology.

Detert, J. R., Schroeder, R. G., & Mauriel, J. J. (2000). A framework for linking culture and improvement initiatives in organizations. *Academy of Management Review* , 850-863.

Fujimoto, T. (1999). *The evolution of a Manufacturing System at Toyota.* New York: Oxford University Press.

Garvin, D. A. (Jul-Aug 1993). Building a Learning Organization. *Harvard Business Review* , 78-91.

Hallam, C., Muesel, J., & Flannery, W. (2010). Analysis of the Toyota Production System and the Genesis of Six Sigma Programs: An Imperative for Understanding Failures in Technology Management Culture Transformation in Traditional Manufacturing Companies. *Technology Management for Global Economic Growth (PICMET), 2010 Proceedings of PICMET '10* (pp. 1-11). IEEE.

Hammer, M., & Champy, J. (2001). *Reengineering the Corporation: A Manifesto for Business Revolution.* New York: HarperCollins.

Hinkle, D., Wiersma, W., & Jurs, S. (1982). *Basic behavioral statistics.* Boston: Houghton-Mifflin.

Imai, M. (1986). *Kaizen: The key to Japan's competitive success.* New York: Random House.

Lander, E., & Liker, J. (2007). The Toyota Production System and art: making highly customized and creative products the Toyota way. *International Journal of Production Research* , 3681-2698.

Latham, G. P., & Locke, E. A. (1979). Goal Setting: A motivational theory that works. *Organizational Dynamics* , 68-80.

Leedy, P. D., & Ormrond, J. E. (2010). *Practical Research: Planning and Design.* Upper Saddle River: Pearson.

Liker, J. K. (2004). *The Toyota Way: 14 Management principles from the world's greatest manufacturer.* New York: McGraw-Hill.

Liker, J., & Meier, D. (2006). *The Toyota Way Fieldbook: A practical guide for implementing Toyota's 4-Ps.* New York: McGraw-Hill.

Likert, R. (1961). *New Patterns of Management.* New York: McGraw-Hill.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic Inquiry.* Sage Publications.

McClave, J. T., Benson, P. G., & Sincich, T. (2011). *Statistics for Business and Economics.* Boston: Pearson.

Mishina, K., & Takeda, K. (1995). Toyota Motor Manufactuing, USA, Inc. *Harvard Business School Case Study #9-693-019* .

Monden, Y. (1993). *The Toyota Mangement System: Linking the Seven key Functional Areas.* Cambridge, MA: Productivity Press.

Pearson, R. (2010). *Statistical Persuasion.* Los Angeles: Sage Publications.

Senge, P. (1990). *The Fifth Discipline: The Art and Practice of a Learning Organization.* New York: Doubleday/Currency.

Shingo, S., & Dillon, A. (1989). *A Study of the Toyota Production System from an Industrial Engeneering Viewpoint.* Cambridge, MA: Productivity Press.

Spear, S., & Bowen, H. K. (Sept-Oct 1999). Decoding the DNA of the Toyota Production System. *Harvard Business Review* , 96-106.

Suzaki, K. (1987). *The New Manufacturing Challenge: Techniques for Continuous Improvement.* New York, NY: Free Press.

US Air Force. (2008). *Air Force Smart Ops for the 21st Century*. Retrieved January 7, 2013, from http://www.au.af.mil/au/awc/awcgate/af/afd-090327-040_afso21-playbook.pdf

Womack, J. P., & Jones, D. T. (1996). *Lean Thinking: Banish waste and create wealth in your corporation.* New York: Free Press.

Womack, J., Jones, D., & Roos, D. (1991). *The Machine That Changed the World: How Japan's Secrect Weapon in the Global Auto Wars Will Revolusionize Western Industry*. New York: Harper Perennial.

## Vita

Captain Robert S. (Bob) Rabon graduated from Gilbert High School in Gilbert, South Carolina. He accepted an appointment to the United States Air Force Academy, where he graduated with a Bachelor of Science degree in Biology in 2004. His first assignment was at Andrews AFB where he underwent training to become a multi-functional logistician. In April 2008, he was assigned to the 49$^{th}$ Logistics Readiness Squadron Training and worked as the Fuels Management Flight Commander and Materiel Management Flight Commander. While stationed at Holloman, he deployed to Iraq and served with the 49$^{th}$ Transportation Battalion as commander of the 37$^{th}$ Movement Control Team, CSC Scania. Additionally, he deployed as a regional logistics specialist supporting Special Operations Command Central from Al Udeid Air Base, Qatar in 2010. In August 2012, he entered the Graduate School of Engineering and Management, Air Force Institute of Technology. Upon graduation, he will be assigned to the Air Combat Command/A4 at Langley AFB.

| **REPORT DOCUMENTATION PAGE** | *Form Approved* *OMB No. 074-0188* |
|---|---|

The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of the collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to an penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.
**PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**

| **1. REPORT DATE** *(DD-MM-YYYY)* | **2. REPORT TYPE** | **3. DATES COVERED** *(From – To)* |
|---|---|---|
| 21-03-2013 | **Master's Thesis** | Sep 2012 – Mar 2013 |

**4. TITLE AND SUBTITLE**
Continuous Process Improvement at Tinker Air Logistics Complex

**5a. CONTRACT NUMBER**

**5b. GRANT NUMBER**

**5c. PROGRAM ELEMENT NUMBER**

**6. AUTHOR(S)**

Rabon, Robert, S., Captain, USAF

**5d. PROJECT NUMBER**

**5e. TASK NUMBER**

**5f. WORK UNIT NUMBER**

**7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S)**

Air Force Institute of Technology
Graduate School of Engineering and Management (AFIT/EN)
2950 Hobson Street
WPAFB OH 45433-7765

**8. PERFORMING ORGANIZATION REPORT NUMBER**
AFIT-ENS-13-M-16

**9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)**
AFMC A4/D
Attn: Mr. Donald L. Lucht
4375 Chidlaw Rd., Suite 6 Comm: 312-787-4760
WPAFB OH 45433-7765 e-mail: Donald.lucht@wpafb.af.mil

**10. SPONSOR/MONITOR'S ACRONYM(S)**
A4/D

**11. SPONSOR/MONITOR'S REPORT NUMBER(S)**

**12. DISTRIBUTION/AVAILABILITY STATEMENT**
APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

**13. SUPPLEMENTARY NOTES**
This material is declared a work of the U.S. Government and is not subject to copyright protection in the United States.

**14. ABSTRACT**
The Air Logistics Centers (ALC) represent the Air Force's largest Maintenance, Repair, and Overhaul (MRO) Operations. The ALCs strive to become leaner by reducing Work In Progress (WIP) inventory, reducing flow times, and increasing product quality to meet aircraft and engine demand levels. The Toyota Production System (TPS) is considered the best example of lean manufacturing by many. TPS utilizes the ingenuity of Toyota employees to generate Continuous Process Improvement (CPI). Achieving CPI can aid the ALCs in reducing operating capital while providing increased levels of service.

The Air Force as a whole has made several attempts to "get lean." Implementing lean tools without fully understanding their underlying philosophy has made it difficult to sustain process improvements. This thesis explores the softer, less tangible conditions that predicate successful CPI. A theoretical model was tested at Tinker ALC to identify focus areas for management. The researcher hypothesized that increased levels of the seven conditions tested would be positively correlated with successful CPI. Focusing on creating these conditions may aid in sustaining improvements.

There was no evidence to suggest that any of the seven conditions are not positively correlated with CPI, although the degree of that relationship is very low. The data suggest that having Structured Improvement Processes most significantly impacts successful CPI. Anecdotal evidence also suggest that Drive for Improvement and Direction for Improvement also support CPI, although these conclusions were not supported by the data. Air Logistics Center managers should focus on those three conditions to aid successful CPI efforts in the future.

**15. SUBJECT TERMS**
Continuous Process Improvement; CPI; AFSO21; lean transition; Air Logistics Center; Toyota Production System; TPS; Rapid Improvement Event (RIE)

| **16. SECURITY CLASSIFICATION OF:** | | | **17. LIMITATION OF ABSTRACT** | **18. NUMBER OF PAGES** | **19a. NAME OF RESPONSIBLE PERSON** |
|---|---|---|---|---|---|
| **a. REPORT** | **b. ABSTRACT** | **c. THIS PAGE** | | | Kenneth Schultz, Ph.D., (ENS) |
| | | | | | **19b. TELEPHONE NUMBER** *(Include area code)* |
| **U** | **U** | **U** | **UU** | 87 | (937) 255-6565, ext 4725; e-mail: Kenneth.schultz@afit.edu |

**Standard Form 298 (Rev. 8-98)**
Prescribed by ANSI Std. Z39-18