LEAN SIX SIGMA (LSS) IMPLEMENTATION IN NAVAL FACILITIES ENGINEERING COMMAND (NAVFAC) CONSTRUCTION PROJECT MANAGEMENT

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This piece of work would not have materialized without the help I have received from the professors I’ve meet during my post-graduate education. Thanks to the Graduate Advisor, Dr. Julio Valdes, to the Head of J.R. Filanc Construction Engineering Program, Dr. Kenneth Walsh and to my advisor Dr. Thais da Costa Lago Alves. The opportunity to take part in the project has been invaluable. I extend the dedication to my family, to my parents who inculcated a spirit of hard work in me from an early age. To my children and husband, for they endured in many ways the time and effort put forth here. Victoria, Jaime Rafael, and Jaime even though I am unable to recapture time away from you, because there is so much I may have missed, you motivate me every evening when I am welcomed with a smile, and the heartfelt embrace of your hug. It is all worth it, since you have been by my side, all along.
ABSTRACT OF THE PROJECT

Lean Six Sigma (LSS) Implementation in Naval Facilities Engineering Command (NAVFAC) Construction Project Management

by
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Six Sigma works towards the precise definition of problems and their root causes with a focus on financial and quality indicators; whereas, Lean Production focuses on the entire value stream to deliver products precisely when they are needed in the amount requested by the client. Lean Six Sigma aims at combining the best of the Lean Production and Six Sigma worlds. In 2006, the United States Secretary of the Navy released a memorandum entitled “Transformation through Lean Six Sigma” (LSS). The document indicated the LSS Program’s mission as the creation of more readiness within the organization’s budget through LSS and indicated a top-down approach for the dissemination and implementation of the program. The implementation of LSS aligned with other practices already used by the Naval Facilities Engineering Command (NAVFAC) in their contracts, i.e., design-build and partnering, have multiple goals and effects on NAVFAC construction projects: reducing litigation and adversarial relationships, reducing costs and delivery time, and improving the buildings and the lives of those who use them. Ultimately, the successful deployment of LSS supports NAVFAC’s mission to “strengthen Navy and Marine Corps combat readiness worldwide through facilities lifecycle support focused on the Fleet, Fighter, and Family” and serves as an example to institutions with similar roles. This study aimed at investigating how LSS has been deployed specifically by the Naval Facilities Engineering Command (NAVFAC) in construction project management. A literature review was carried out on Lean Production, Six Sigma, Lean Six Sigma, and Lean Construction, followed by a review of publicly available online material and NAVFAC’s intranet material regarding the implementation of LSS in the U.S. Navy. Examples of successful process improvements related to LSS implementation were found in several areas of this organization; however, LSS implementation in construction projects has not been fully deployed yet. It is also necessary to mention that even though there are instances of unsuccessful LSS implementation, based on anecdotal evidence, unfortunately these are not documented in the sources reviewed and could not be presented in this research. The paper ends with recommendations regarding LSS training in the construction training school which provides education to officers in charge of construction projects. The training will strengthen the adoption of the LSS culture in construction and disseminate it among the different departments of this global organization.
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Table 1. LSS Training Levels/Belts

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LIST OF ACRONYMS

AEC - Architecture, Engineering and Construction
ASQ - American Society for Quality
CEC - Civil Engineer Corps
CECOS - Civil Engineer Corps Officer School
CPI/LSS - Continuous Process Improvement/Lean Six Sigma
DMAIC - Define, Measure, Analyze, Implement, Control
DMAIC-V - Define, Measure, Analyze, Implement, Control, Validate
DoD – Department of Defense
FacTS - Facilities Team Surveys
FEC - Facilities engineering command
JDIs - Just Do Its
LC - Lean Construction
LCI - Lean Construction Institute
LPS™ - Last Planner System™
LPDS™ - Lean Project Delivery System™
NAVFAC - Naval Facilities Engineering Command
NAVFAC SW - NAVFAC Southwest
PWO - Public Works Officer
ROI - Return on investment
SAP - Simplified Acquisition Procedures
SPC - Statistical Process Control
TQM - Total Quality Management
TPS - Toyota Production System
VSM - Value Stream Map
ACKNOWLEDGEMENTS

I would like to acknowledge Dr. Thais da Costa Lago Alves for her contributions to my work. She believed in me before I did. I would like to express my sincerest appreciation and respect; I regard her input highly for her professionalism, vast knowledge, and experience; her guidance has helped me achieve this venture which simply turned into an achieved milestone.
CHAPTER 1

INTRODUCTION

This document discusses Lean Six Sigma (LSS), as it is currently being applied in the Naval Facilities Engineering Command (NAVFAC). For the most part this document is based on a literature review on Lean Six Sigma and Lean Construction and sources about Navy projects. The research was performed by means of a literature review from previous Lean Construction introductory academic courses, books, credible source articles that set the basis of Lean and Six Sigma theories. Then the document includes Navy publications from publicly accessible internet sources. Also, the author accessed NAVFAC’s intranet, a limited internet website, to look for examples that could illustrate the use of LSS by this organization. Examples from the latter sources were used to represent a measure of LSS implementation in NAVFAC, which to date shows it has not been fully deployed to NAVFAC’s construction areas.

NAVFAC is a Department of the Navy organization with an annual business volume in excess of $8 billion, in charge of managing the planning, design and construction of Navy shore facilities and activities around the world (Global Security, 2010). On May 3, 2006, Secretary of the Navy, H. Donald C. Winter, published a memorandum with the directive to employ a top-down approach to attain LSS integration in management approaches in the Navy. Consequently, NAVFAC has developed a Continuous Process Improvement/Lean Six Sigma (CPI/LSS) program, adopted from the Department of Defense (DoD) guidebook, which has proved to accomplish high productivity, quality delivery cycle time and safety improvements (U.S. Department of Defense, 2008). Following the LSS Memo, the Navy partnered with the American Society for Quality (ASQ), the world's leading authority on quality, to legitimize LSS into the training portfolio and develop a customized certification (U.S. Department of Defense, 2008).

With such top level support and high financial benefits, LSS has demonstrated powerful capabilities improve processes in the Navy. While investigating NAVFAC’s construction efforts, some examples were found in design or acquisition (pre-construction),
but there is no method adapted or developed to improve a construction project’s process performance. Therefore, after having reviewed the current LSS implementation, this document’s main objective is to inquire into How can LSS be implemented in the Navy’s construction project management? Construction projects though complex\(^1\) can benefit from LSS concepts which are aimed to reduce costs, shorten a project’s duration while keeping high quality and increasing customer satisfaction. This document presents the best practices which have been adopted mostly in private industry, and to lesser extent in the public sector, regarding the implementation of Lean and Six Sigma. This document also describes how such work has created the backbone of a system’s structure and enforcement for LSS in construction project management. The systems presented are the Last Planner System\(^{TM}\) (LPS\(^{TM}\)) and Lean Project Delivery System\(^{TM}\) (LPDS\(^{TM}\)) (Abdelhamid, 2003). Provided the Navy has had a successful LSS execution in different areas of the organization, a new venue of deployment is suggested to take advantage of the lessons learned in the field and their dissemination through established training programs which already exist within the Navy.

The basic limitation of this work is the period of research, which was about a year, in which the author has learned of and been involved with Lean concepts and practices. The next limiting factor was time. The author is a Civil Engineer Corp Naval Officer, with only three semesters available to complete the academic course load required by the Master’s Program and to develop the work presented in this project. Finally, procedural constraints were imposed by the Institutional Review Board at San Diego State University. A part of the research method which involved interviews with LSS subject matter experts at NAVFAC could not be carried out because there was not enough time left to obtain approval from the Navy to publish the findings of the interviews. Therefore, the extent of the present research is limited to publicly available online material and NAVFAC’s intranet only.

This report is structured as follows: Chapter 2 provides a Literature Review detailing the main concepts related to Lean theory, followed by several initiatives derived from Lean,

\(^1\) Complex project: A construction project is developed with the intervention of many different hierarchical levels, operational and technological interdependences between them, and specialties that each contribute to form an organization with the end goal of delivering a facility or service (Schramm, Rodrigues, & Formoso, 2006).
such as LSS, LPS™, Lean Construction and LPDS™. Chapter 3 provides an account of the CPI program results on several departments, NAVFAC‘s sister entities and NAVFAC‘s own efforts related to LSS implementation. The CPI program project results clearly exemplify LSS in the Navy. Finally, Chapter 4 presents conclusions and suggestions for future work in this field (See Figure 1).
Research Question: How can LSS be implemented in NAVFAC’s Construction Project Management?

Objective: Analyze current areas where LSS has been implemented and research venues to deploy LSS to construction project management

**BACKGROUND**
- Toyota Production System
- Waste/JIT/Autonomation/kanban/internal customer/poka-yoke
- Lean Thinking
  - Identify Value
  - Map Value
  - Create Flow
  - Establish Pull
  - Seek Perfection
- Six Sigma
  - 3.4 defects per million parts produced (TQM)
- DMAIC
- Belts
- Lean Six Sigma
  - Micro & Macro
  - Organization analysis
- Lean Pyramid
- Lean Construction
- LPS™
- LPDS™

**RESEARCH IN THE NAVY**
- CPI/LSS
- Belt Training
- CPI Events / RIE
- NAVAIR Examples:
  - Lean tools used at projects with funding shortfalls
  - Look-ahead Plan (2023)
  - Future: energy savings, transportation cost, facility utilization
- NAVSEA Examples:
  - Accounting streamlining
  - Repair process streamlining
- NAVSUP Examples:
  - Streamlining SAP’s

**NAVFAC**
- NAVFAC Examples:
  - Housekeeping “5S”
  - Streamlining Design Review
  - Streamlining Internal Acquisition Process
  - Dedicated committee
  - High visibility and Supported Portfolio

**RESULTS**
- Top to Bottom Support and Interest
- Well established training

**RECOMMENDATIONS**
- Officer Training School as a diffusion venue
- Further research in the topic:
  - Interviews NAVFAC: PWO, LSS Black Belts, CECOS instructors
  - Case Studies
  - Training Teams
  - Other Interviews:
    - NAVAIR
    - NAVSEA
    - NAVSUP

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**Figure 1. Research model.**
CHAPTER 2

LITERATURE REVIEW

The literature review presents the genesis of Lean manufacturing since the Toyota Production System followed by the beginning of Six Sigma. Both philosophies highlight the benefits of waste elimination and a systematic problem analysis to improve business processes, which results in high value savings. The chapter introduces Lean Six Sigma, along with the process analysis tool known as DMAIC, explained here in detail. The chapter concludes with the description of the Lean Production System™, the Lean Project Delivery System™ and the Lean Construction Industry as Lean efforts have made its way to this industry.

ORIGINS OF LEAN

What we know as Lean today, can be traced back to the Toyota Production System (TPS), developed by Taiichi Ohno in the 1950s in the Toyota Motor Company (Ohno, 1978). TPS highlights the importance of improving operations efficiency through the elimination of seven types of waste: overproduction, time on hand, transportation, processing itself, stock on hand, movement and defective products. To address such waste, Mr. Ohno’s TPS was based on two pillars, Just-In-Time (JIT) and Autonomation. JIT in an assembly line refers to a production state where only the right parts arrive at the time and in the amount needed. In order to create this state, the production assembly line was analyzed in reverse order, treating each step in the process as an internal customer, with the aid of Kanbans. A kanban is usually viewed as a piece of paper that clearly identifies the part needed, amount, location, date and time needed. Therefore, an entire process was analyzed, from the last process step to the first; meeting the needs of each “customer” by fulfilling each kanban. In Toyota, the kanban was the tool that supported the JIT system and contributed to minimizing inventories and avoiding production mistakes (Ohno, 1978).

Autonomation or automation with a human touch refers to the transfer of human logical intelligence to a machine via poka-yoke or a fool-proofing mechanism. An example of
A *poka-yoke* can be a visual or audible signal alerting that an assembled item is unsatisfactory, after a pressure test has detected a leak. These mechanisms assist the operator in identifying defective parts and prompting an action. The employee, as the most valued asset, acquires the power and control to correct the defect, and his action implies taking the responsibility for altering the production and quality of his work. In other words, the opportunity of employee empowerment is presented at the crucial instance when the employee's attention and action is needed, as opposed to wasting his talent if he is tending to a piece of equipment that is working properly (Ohno, 1978).

Thus, JIT and autonomination provide the basis for smooth work production by addressing internal customers, avoiding unnecessarily large inventories and autonomously identifying defects; thus, making the best use of human intervention, reducing waste and increasing productivity and profitability. Following these principles Mr. Ohno’s base concept guideline was stated as: “Improvement is both eternal and infinite,” introducing the concept of *kaizen*, which means small incremental changes at regular intervals. *Kaizen* is key in Lean, as small changes provide positive results, fostering people's trust in the system instead of making radical changes that are often opposed and highly disruptive to any organization (Ohno, 1978).

As Lean became more adept, it evolved into Lean Production, still maintaining its core principles; but more literature emerged to facilitate its applicability in different industries, beyond manufacturing where it originated, such is the appearance of the 5 Lean Thinking Principles, Lean Six Sigma, Last Planner System™, Lean Construction, and Lean Project Delivery System™, all derived from the TPS and applied to this document’s subject of interest, construction. The 5 Lean Thinking Principles are explained here, while the rest are in the following separate sections, detailing how they were adapted to other production and service industries. The 5 Lean Thinking Principles are: (1) Identify value, (2) Map value stream, (3) Create flow, (4) Establish pull, and (5) Seek perfection (Alves, 2009; Womack & Jones, 1996).

The first two of the Lean Thinking principles address the concept of value. In identifying value, the focus is placed on the customer—what the customer values is what the
final product should display to satisfy the customer. Value for a customer is the main factor that will prompt him or her to select a product and should be what drives production as well. Therefore, a product’s production process should be designed with the customer in mind. The second principle, map value stream, introduces the concept of value stream and the tool value stream map (VSM). A VSM is a representation of all activities (value added, non-value added, and waste)\(^2\) currently present in a product process flow from raw materials to completion, or directly to the customer. The third principle, create flow, is related to the analysis of the value stream, keeping the customer’s value in mind in order to promote a continuous generation of value throughout the value stream. Creating flow will be a result of mapping the value stream and dissecting all parts of a process to easily identify value-added actions from the non-value-added actions and waste. The current VSM can then be streamlined to eliminate the above mentioned waste actions and also to identify areas of unnecessary wait, transportation, etc, which prevent the continuous generation of value to the client.

Relating back to one of the pillars of the TPS, i.e., Just in Time production, the fourth principle is to create pull and produce only what is requested by internal and external clients. Ideally, no activity should be initiated without a request from the client (e.g., Kanban) to prevent the generation of unnecessary inventory. The use of pull production, which is based on client’s needs and knowing what the client values, contrasts with the definition of pull production based on forecasts and not necessarily on client’s needs.

Lastly, to maintain the desired constant flow, the fifth principle is presented: seek perfection. Seeking perfection is the infinite loop of improvement continuity; after you have improved a process, analyze it again to find new areas to improve (Alves, 2009).

\(^2\) Value-adding activity: Activity that processes material and/or information into a product as required by the end customer. Non-value-adding activity (contributory) takes up time and resources but does not add value to product. This non-value added activity contributes to the production of the final product because without it the product cannot be produced and delivered to the customer. Waste represents all the activities that could be eliminated without compromising the final product; these activities are not needed.
**LEAN SIX SIGMA**

In the mid-1980s, Mikel Harry along with Bill Smith were employed at Motorola, which was experiencing serious quality issues at the time. They experimented with Statistical Process Control (SPC) and Total Quality Management (TQM) tools to minimize costs due to poor quality throughout the company. This experimentation and the subsequent method that resulted from it became what is currently known as Six Sigma. The creators of the Six Sigma methodology acknowledge its roots from the 1979 book *Quality is Free* by Philip Crosby (Harry & Schroeder, 1999).

The term Six Sigma originated from basic statistical analysis of a normally distributed set of data or normal curve. Sigma (σ) is the Greek letter used in statistics to denote the standard deviation of a set of data. In this regard, the mean and standard deviation are associated with the analysis of the data, providing information on its average value and how the data varies from the average value. Six sigma, as described in process capability studies, illustrates the statistical notion that the data collected about a specific variable (e.g., slab thickness) which falls within six standard deviation (6σ), i.e., +3σ and -3σ, measured from the average of the data sample is considered acceptable and nearly free of defects (Wikipedia, 2010b).

To translate statistics to its application at a company's production, a three sigma production specification represents that 99.73% of the production parts fall within the three sigma limits. The remainder, 0.27%, is therefore defective and when it is converted to parts per million, a three sigma specification represents 2700 defective parts. Similarly, a six sigma production specification represents 99.99966% production within specification limits, and 0.00034% defective, or 3.4 defects per million parts produced (Breyfogle, 2003). With this basis, the Six Sigma process was created and trademarked by Motorola (Harry & Schroeder, 1999).

In business practice, the Six Sigma process is characterized by dramatically achieving streamlined operations, quality improvement and a reduction in defect error that yields increased profits. While Six Sigma can be used in detecting and eliminating variation (reactive approach), a production process can be designed from the start so it produces near
perfection (proactive approach). Motorola’s Six Sigma projects documented results of a 58 percent cost reduction and 40 percent error reduction, and 60 percent time reduction to design new projects. Later, General Electric CEO, Jack Welch, popularized a Six Sigma initiative when his company reduced total costs by 10 percent, with a record one billion dollar savings in only two years (Harry & Schroeder, 1999).

Six Sigma’s methodology is adopted from the Plan-Do-Check-Act Cycle\(^3\) into DMAIC, an acronym used in projects aimed at improving existing business processes. Its five phases are described below (Alves, 2009; U.S. Department of Defense, 2008):

- **Define** the problem and provide specifics representing the voice of the customer and project goals.
- **Measure** key aspects of the current process and collect data.
- **Analyze** the data to investigate and verify cause-and-effect relationships. Seek root cause.
- ** Improve** the current process based on data analysis: techniques like design of experiments, *poka-yoke*, standard work, etc., to create a future state.
- **Control** the future state process to ensure performance, implement control systems like reiterative process control, improvement publication and continuously monitor the process.

Six Sigma implementation requires adherence to measurable and quantifiable financial returns from the Six Sigma project; it establishes an hierarchical training infrastructure from the macro level "Champions," to more detailed Six Sigma methods training "Master Black Belts," down to "Black Belts," and "Green Belts." In addition, Six Sigma calls for a commitment to base decision making on verifiable data, discarding any assumptions and guesswork (U.S. Department of Defense, 2008).

Recently, the Six Sigma philosophy merged with Lean manufacturing in what is known as Lean Six Sigma. Selecting the best of these two philosophies, Six Sigma targets identification of problems and their root causes with a focus on creating a positive impact on quality and, therefore, on the financial aspect. On the other hand, Lean Production covers the

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\(^3\) PDCA - iterative four-step problem-solving process typically used in business process improvement, also known as the Deming cycle, named after its creator Dr. W. Edwards Deming, who is considered to be the father of modern quality control.
product’s value stream as a whole in order to deliver what the customer needs, when needed and in the correct amount. Or plainly expressed, Six Sigma provides tools for problems that are hard to find but can be easily improved, while Lean presents tools that analyze easy to find problems but entail a larger effort to fix, as is the case of the systems presented in the following sections of this document (Abdelhamid, 2003).

**THE LAST PLANNER SYSTEM™**

Along the same lines of Lean Production and Lean Six Sigma, an attempt to improve construction projects with a focus on improving reliability and stability of plans, and ultimately of projects, was developed by Ballard (2000a).

The Last Planner System™ (LPS™) presents a systematic production planning and control approach which will, in its core concept, promote project stability through the definition of reliable assignments that can be carried out as planned. Planning according to the LPS™ considers a proactive approach in which tasks are continuously reviewed so that potential constraints that may prevent their execution are removed before tasks are scheduled. The goal is to prevent “defective” assignments from being released, and the way the LPS™ achieves that is by continuously screening tasks before they are released to production trades. This control system is opposite to the traditional project control system where action is taken after-the-fact; that is, a defect or cause of failure is detected first, which prompts an action in order to control it (Ballard, 2000a).

The LPS™ highlights the importance of planning the project in different hierarchical levels which are dependent on the level of information available when plans are prepared. The hierarchical or vertical dimension of planning implies the utilization of long term or master planning, mid-term or look-ahead planning and short-term or commitment planning on a project (Formoso, Bernardes, & Oliveira, 1998). Each planning level must contain key information and the involvement of the appropriate players for effective results. Such is the case of the master plan which identifies and manages long lead items, and requires the

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4 The Last Planner System has been trade marked by developer Dr. Ballard, for use and reference.
involvement of major stakeholders at the earliest possible stage of the project. The look-ahead plan requires proper identification, addressing and resolving constraints, situations that may hinder production, by the project managers, suppliers and contractors. While undertaking the commitment plan, as constraints have already been taken care of, the supervisors and project managers oversee the labor, tools, machinery or equipment utilization in place. Thus, ownership, responsibility and decision-making capability is spread throughout the organization as opposed to centralized in management. The developer of LPS™ goes further by providing the levels of control that can be translated to any industry, emphasizing their importance; he recognizes control at the company level, at the factory level and at the production level (Ballard, 2000a).

In order to achieve the above-detailed state, LPS™ prompts the employment of Horizontal Planning at each level of the vertical planning. Horizontal Planning is based on the application of the following six steps: (1) planning the planning process, (2) gathering information, (3) preparation of plans, (4) diffusion of information, (5) action, and (6) evaluation of the planning process. Each of the steps requires project preparations even before the project has begun. Planning the planning process requires gathering all interested parties to initiate efforts before any deadlines or workload is imposed and designed, to mirror their vision of the project’s development. This serves as relationship building amongst the players and common ground for setting rules that all will commit to follow. Gathering information gives the team a space and time where all pertinent research will be performed, from design criteria, standards, to materials, to labor, and other resource information gathering. Preparation of the plan is materializing commitments, requirements and goals, putting them all in a written format. Diffusion of information enforces transparency of the entire plan for review and general knowledge of the same. Action refers to the actual start of the tasks in a project, and evaluation of the planning process introduces a continuous monitoring element that will undertake the task of adjusting and changing the plan as needed to maintain a desired performance level in the project (Laufer & Tucker, 1987).

Lastly, task assignments should adhere to the following criteria: they should be clear, sound, in proper sequence and size and reviewed against lessons learned. Additional action
items include: ensuring tasks assigned are specific and in constructability order, with design and prerequisite work complete, having materials available, within a skilled crew’s capacity, coordinating work with other trades, checking for completion and/or tracking non-completion with its reason. In other words, by ensuring that management removes constraints before work starts, the work flow is enhanced, plan reliability is enforced and higher productivity is achieved (Ballard & Howell, 1997).

The LPS™ methodology follows a typical analysis of activities in construction projects addressing methods, resources, labor, sequence and timing. LPS™ offers a systematic approach of separating plans into three hierarchal levels to shield production against uncertainty and variability; further planning within each level is introduced, enforcing communication across all levels, ensuring sound assignments, and spreading decision making power, thus eliminating waste and increasing productivity. The LPS™ system has proven to be effective as it has previously been applied by production and service companies, but it has been limited to production management, as opposed to applying it globally in the factory (Ballard, 2000a).

**LEAN CONSTRUCTION**

As the origins of Lean Thinking continued to grow and evolve from its start in Toyota, Koskela (1992) noted that new methodologies, techniques and tools were developed and were successfully applied in manufacturing, but little had been done in the construction industry. Koskela (1992) carried out a review of important concepts, principles and tools related to theories of production and summarized his findings in a report about a new production philosophy, which was presented to the construction management community as an alternative to traditional forms of management used in the construction industry. This new production philosophy, as discussed by Koskela, provided the construction industry with an alternative interpretation of how construction processes should be understood and managed while it recognized its implementation challenges, triggering what is recognized today as Lean Construction (Koskela, 1992).

The main premise of the new production philosophy is for construction to be viewed as a combination of conversion (transformation) and flow (transportation, inspection, and
waiting) activities, and not just a conversion process (i.e., conversion of inputs into outputs).

Koskela (1992) criticized the traditional conceptualization of construction activities because of its focus on the management of transformation activities, i.e., activities that transform the shape, form or substance of materials into new products. For instance, based on the traditional management view, a task such as placing concrete into a formwork has the management focused on “placing of concrete” and overlooks other activities such as how the material will be transported to the point of use, how it will be inspected or how much time it may wait before it is placed. By overlooking these activities, management misses the opportunity for improving the flow activities, and much of the waste found in the construction industry has been ignored because not all parts of a value stream are managed.

The new production philosophy’s application in construction, as suggested by Koskela (1992), brought to light the following 11 principles which must be implemented in order to design, control and improve the construction projects:

1. Reduce the share of non-value-adding activities.
2. Increase output value through systematic consideration of customer requirements.
3. Reduce variability.
4. Reduce the cycle time.
5. Simplify by minimizing the number of steps, parts and linkages.
6. Increase output flexibility.
7. Increase process transparency.
8. Focus control on the complete process.
9. Build continuous improvement.
10. Balance flow improvement with conversion improvement.

The first four principles, as they relate to construction, can be undertaken by (principle 1) mapping the value stream, which identifies the value-added, non-value-added, and wasteful activities, (principle 2) alongside the consideration of the customer's
requirements,\(^5\) (principle 3) identifies variability's root cause and seeks to eliminate it, and (principle 4) actions which in turn contribute in cycle time reduction. Examples of cycle time reduction include addressing waste in production due to inventory, work-in-progress, large batch sizes, layout to minimize transportation or introducing parallel activities, etc.

Principles 5, 6 and 7 provide guidance on actual processing practices, on site improvements and controls that aid the employees as much as they aid in increased productivity. The transparency principle suggests the use of means and methods that allow a production system to communicate with those who are part of it through the use of indicators and the display of information throughout production areas. Modularization (principle 5) and standardization are strategies that, in addition to increasing process transparency through the use of standards, would result in productivity improvements and serve as a basis for increasing flexibility (e.g., different combinations of modules would allow products with different configurations without compromising productivity and ultimately the time and cost to provide a product). Flexibility (principle 6), depends on small batch sizes to allow for quick response to change, providing product customization late in the process, and forming a multi-skilled workforce. Lastly, (principle 7) transparency introduces visual controls to promote communication at all levels, enhances work areas via layout and signage, enforces benefits of diffusion of information, standards, and organization, orderliness, cleanliness, personal cleanliness and discipline (last five also known as housekeeping’s “5S”) (Koskela, 1992).

Starting from principle 8, the focus is shifted to a global and inclusion aspect. The entire project is viewed as a whole. For example, focusing on the complete process can highlight how the entire project benefits from external players like suppliers. Supplier inclusion can benefit the complete process by ensuring the in-time delivery of the required amount of correct materials to the work site, promoting the continuous flow of work and avoiding a delay in the start of work. Principle 9 poses the need for continuity, referring back

\(^5\) Key concept is recognizing two types of customers, the end customer, and the internal customers represented by each activity in the process.
to *kaizen*, i.e., small incremental changes, by setting attainable targets that can be measured and monitored, delegating responsibility for improvement to all employees, rewarding improvement and advocating a challenge for better solutions. Principle 10 is a reminder of thorough process flow (flow activities) improvement, before introducing a new technology which is the most costly solution to any problem. The last principle (11) introduces the concept of benchmarking which encourages research and adaptation of best practices from leaders in other industries to the construction industry (Koskela, 1992).

The connection between LPS™ and Koskela’s 11 principles lies not only in core Lean values and their own interpretation in different industry settings, but both address the work at micro and macro levels, all encompassing. Moreover, both systems assert that, regardless of work position, the distribution and ownership of improvements is equal throughout the organization and must be equally embraced and carried forward as well. Both systems have displayed actual results which support their existence in many business practices to date. Shortly after Koskela’s new production philosophy was presented, with its clear application in the construction industry, the Lean Construction Institute (LCI) was founded in 1997 by partners, Gregory A. Howell and Glenn Ballard. LCI is dedicated to research, training and consulting in construction industry production management (Ballard, 2000b)

The LCI focuses on the premise that construction is the final output of management, a management based on making good decisions. These decisions cannot be based on productivity and progress data alone, but on a consciousness of change that must be accepted, learned, adopted and periodically updated. Lean Thinking has come a long way from its beginnings and has spelled change all along. However, just as traditional practices have been criticized, it has also been argued that for this change to endure it will have to be based on a broad spectrum of concept learning, followed by the concept’s adaptation to principles that can be applied to construction, and lastly by the direct hands-on employment of the many tools developed thus far, see Figure 2 (Alves, 2009).
The implication derived from Figure 2 is that without a strong conceptual basis and a consistent deployment of concepts into principles and tools, the theory applied to the construction field may have minimal, if any, effects in terms of changing the management practices and culture of the construction industry. As this culture change continues to take force, based on the many interlinked sets of theory discussed, a further effort is made into crafting a system’s design, presented in the next section (Alves, 2009; Ballard, 2000b; Ballard, Howell, & Casten, 1996).

**LEAN PROJECT DELIVERY SYSTEM™**

One of LCI’s goals is to develop new methods to design, manage, and build construction projects. This alternative has to prove efficiency and cost saving tendencies if it is to be used by companies in the Architecture, Engineering and Construction (AEC)
industry. The Lean Project Delivery System™s (LPDS™)⁶ definition of a project is a process that aligns ends, means, and constraints, starting with the customer’s accomplishment goals and its constraints (Ballard, 2000b). Lastly, LPDS™ performs under the assumption that the project delivery team is “not only to provide what the customer wants, but . . . help[s] the customer decide what they want.” LPDS™ captures the conception, design, supply and assembly phases in the project, extending to post-occupancy, founded on production control and work structuring (Ballard, 2008). Figure 3 illustrates the relationship between different parts of the LPDS™.

There are a few driving guidelines to LPDS™ that have to be discussed as an introduction. As a straight application to construction and construction design, LPDS™ relies

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⁶ The Lean Project Delivery System has been trademarked by developer Mr. Ballard, for use and reference.
on the creation of a work environment of teamwork and cooperation. This environment compares to construction’s design-build contract efforts, where the alliance between the builder and the designer, yielded valuable gains, in productivity, financial and delivery time savings. LPDS™ evokes a team where builder, designer, construction specialists and suppliers are equal partners. The system’s premise is the use of pre-established relationships of trust and commitment amongst all players. LPDS™ calls for the creation of true commitments, where the different entities strip down from their own productivity and profit to take on and support actions for the benefit of the entire project (Ballard, 2000b).

The LC1 emphasizes team commitment by introducing reliable promises evoking ownership, pride and ethics. The following question and assertions exemplify how reliable promises are build based on one’s effort to consciously commit to acts s/he can deliver (Lean Construction Institute, 2001):

1. I am competent to perform, or do I have access to competence?
2. I estimate it will take some amount of time (hands-on).
3. I have the capacity and I’ll allocate it.
4. I am not having a private unspoken conversation in conflict with my promise.
5. I will be responsible.

The Last Planner System™ supports the LPDS™ as it promotes controls production through the definition of reliable commitments as part of a systematic process that defines: (1) the amount of work assigned to each construction specialist (subcontractor), (2) the sequence of the assignments, (3) the “handoff” size between the construction specialists, and (4) available capacity and buffer inventories to absorb variability. The concept of production control permeates all the pieces of the LPDS™ and their linkages as shown in Figure 3.

Another important core concept of the LPDS™ is that of work structuring. The term work structuring is introduced as it reflects the efforts to design products and processes in an integrated fashion. In other words, “work structuring” tasks means product characteristics (what will be built) as well as process characteristics (how it will be built) are considered during the design and planning stages.

Description of the LPDS™ model is provided as follows (Ballard 2000b): The Project definition phase aligns the customer’s needs to the appropriate design criteria to create the
project’s conceptual design. Not a simple task, this entails materializing the customer’s vision into requirements that receive input from several entities, such as stakeholders, architects, and construction specialists in order to fulfill pertinent design criteria and present the customer with several concept designs. The Lean Design phase then, takes on the conceptual design the customer selected to define the desired outcome and design the process to achieve it. The process design aims to simplify on-site work procedures in terms of constructability, sequence and installation. With this goal in mind, LPDS™ encourages the use of 3D/4D modeling by specialty contractors to mutually benefit theirs and the designer’s interests by providing input in the design process, recommending component and equipment selection, etc. (Ballard, 2000b).

The LPDS™ model continues by addressing the project from its supply side, Lean Supply. The product design element is developed thoroughly by a detailed engineering effort, delineating the fabrication or purchasing of components and materials, and triggering the establishment of a logistics management for delivery and inventory control. Lean Assembly follows, encompasses all actions performed once construction breaks ground and until the finished facility is turned over to the end customer. It is at this phase that the LPDS™ model proposes a change in the field supervisor's role, where instead of passing on orders and tracking action on the same, the supervisor will take on a coaching role while managing assignments to promote every opportunity for improvement. Additionally, the supervisor will be open to crew communication to support previous or future crews, combination of similar operations or common trade tasks under a single umbrella, or the advocate of a multi-skilled workforce, to further continuous flow processes (Alves, 2009; Ballard, 2000b).

LPDS™ provides a project guide to a detail level that prompts thought for design addressing the proper operation and maintenance the facility will need even while the project is still forming in the mind of the customer or at the core group’s white board, before its clear definition. Lastly, the model encourages crafting of the alteration alternatives or eventual disposal plan of the building. An all inclusive system, LPDS™ encompass the facility’s life cycle from definition, to design, supply, installation and use. The entire system relies on a culture change which supports a collaborative approach to create value, reduce waste, and
requiring a close coordination among all stakeholders, suppliers, construction specialists, etc., to meet the customer's needs in a specific timeframe (Ballard, 2000b).

Successful employment of Lean Project Delivery principles is evidenced by the case study of the St. Olaf College Fieldhouse Project (Ballard & Reiser, 2004), a widely-cited study in Lean Construction, with hard factual results which substantiate the project's success. This case study used Lean Project Delivery alongside target costing. Target costing limits design alternatives to those that are within a given cost; thus, cost becomes a design criterion. While the team has to keep options under a certain cost cap, all involved with the design are challenged to meet the target without sacrificing customer's requirements or even exceed the customer's needs. Major players contributed from the beginning as scope was adjusted to the money allocated to the project. The team was kept informed of the design development and an agreement was made to share contingency (available resources that could be used anywhere in the design) among all players. The result innovated current practices, where value engineering was performed since the start of the project and produced an integrated and useful facility. Noteworthy is the idea of defining a target cost and what value meant for the customer from the start; this allowed the creation of value propositions (design alternatives) to be analyzed by the team and the client during the entire design process. This process contrasts with the traditional use of value engineering which alters a project's design and specifications after they were finalized, thus generating rework and potentially loss of value for the client. The process design was kept clear, while target costing was taken to subsystem levels which included suppliers and installers. The hard evidence revealed a project that compared to previous similar efforts displayed project duration reduction by fifty percent, and cost reduction of over thirty percent (Ballard & Reiser, 2004).

**SUMMARY**

This chapter presented the literature review carried out to develop the conceptual basis for this project. Concepts, principles, and tools related to the Toyota Production System (TPS), whose basis formed what is currently known as Lean Production, and the combination of Lean and Six Sigma were presented. Literature pieces regarding the use of Lean concepts
in construction, which represent the field of study known as Lean Construction (LC), were also presented alongside examples of how LC has been implemented in construction projects.
CHAPTER 3

LSS IMPLEMENTATION IN THE NAVY

This chapter presents a discussion about the Lean Six Sigma (LSS) within the Navy. The author has searched for evidence about LSS implementation in the Navy mainly from open sources available on the internet, e.g., website articles, publications from the Naval Postgraduate School (NPS), and newsletters. The chapter starts with a discussion about the Continuous Process Improvement (CPI) method used to deploy LSS in the Navy followed by the presentation of examples that attest how LSS has been implemented by this organization so far.

CONTINUOUS PROCESS IMPROVEMENT

Policy governing the guidance of Lean Six Sigma (LSS) use through Continuous Process Improvement (CPI) was the outcome of the United States Secretary of the Navy memorandum entitled, “Transformation through Lean Six Sigma,” 2006. Two subsequent policy documents were instituted. The first one entitled: Validating and Leveraging Financial Benefits Associated with Lean Six Sigma for Continuous Process Improvement, provides guidance to consistently capture, report and generate sound financial decisions. The second one: Continuous Process Improvement (CPI), officially institutionalizes CPI as the primary enabler to manage effectiveness and efficiency of the department (Winter, 2007). To this effect, DoD published a Continuous Process Improvement, Lean Six Sigma Guidebook where it delineates the Navy's implementation plan (Winter, 2009).

The CPI framework originates from various performance improvement philosophies (e.g. Lean Thinking, Six Sigma, Theory of Constraints), noting the adaptation of Lean which focuses on work flow, customer value, and eliminating process waste; Six Sigma focuses on satisfying customer requirements while minimizing waste by reducing and controlling variation; and Theory of constraints focuses on systems thinking and improved throughput by addressing system constraints (U.S. Department of Defense, 2008). These fostered the following CPI goals in the Navy: (1) increase the speed of operational responsiveness; (2)
reduce operation costs; (3) improve quality of work life; and (4) improve safety of working the environment. Dictated by Navy experience, the list below describes four „musts‘ as pre-requisite requirements to ensure an effective CPI implementation (U.S. Department of Defense, 2008):

1. The establishment of an infrastructure to support implementation. The infrastructure consists of a set of different organizational levels, champion, steering committee, support team, and work groups, as appropriate. It is noted that this document presents the implementation team at the work group level (belts), as it represents how people are allocated within the LSS hierarchy to manage the field work (see Table 1 for Belts’ role description).

2. The strategic alignment of outcome-focused goals based on the voice of the customer. This is described in the Strategic Deployment plan which conceptualizes a strategic vision by establishing 3-5 year goals, running annual priorities of the same, deploying the priorities to sub-organizations for operational plans development, then returning to update and run annual priorities again.

3. The use of problem solving structures and tools, such as Definition, Measurement, Analysis, Improvement, and Control (DMAIC), 5 Whys, Histograms, Pareto charts, cause and effect diagrams, control charts, cost benefit analysis, root cause analysis, design of experiments, etc., as related to organizational objectives and priorities.

4. The existence of top-to-bottom support, by the strong and continuously visible leadership commitment and involvement from the top of the organization to stress and support a CPI culture of innovation and teamwork.

Table 1 provides a concise list of the well-defined training structure as adopted from LSS principles. The table lists the different certification or belt levels, the training requirements for each level, describes the team member’s roles, and for some, lists member’s desired qualities expected of individuals that will fill these positions (U.S. Department of Defense, 2008).

The following section describes LSS principles and tools used in CPI implementation, including Rapid Improvement Events (RIEs) and Event Analysis and Results Report.

**CPI TOOLS**

Lean Six Sigma has been endorsed by DoD leadership as the primary means to build efficiency in its operations as it implements its continuous task to support the warfighter. CPI suggests that every part of one’s work should employ the CPI deployment cycle. The deployment cycle is driven by customer value; it includes planning, value stream analysis, structure development, and deployment which is based on meeting one’s commitments, self-
Table 1. LSS Training Levels/Belts

<table>
<thead>
<tr>
<th>Training Level (Belts)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Champions</td>
<td>Executives trained to help break down barriers.</td>
</tr>
<tr>
<td>Master Black Belts</td>
<td>Serve as trainers and may oversee enterprise initiatives. Extensive training consisting of a five week course that is conducted over a period of five months. Each Black Belt candidate must attend the training with a project in hand and must work on that project as the course moves through each of the five phases. After certification, the member occupies a full-time position, in the facilitation of corporate DMAIC projects. Mentor Green Belts, provide training to Yellow Belts, etc. Advancement to this position is based, among an array of qualifications, on their years of experience at NAVFAC as well as their leadership qualities.</td>
</tr>
<tr>
<td>Black Belts</td>
<td>Substantial training, one to two weeks, focused on introduction of tools typically used in Rapid Improvement Events (RIEs, definition on next section). Certification at this level warrant a part-time position (~25%) working as project facilitators conducting RIE’s or small DMAIC projects. Mentored by Black Belts these members are expected to have a strong understanding of the NAVFAC organization and is usually at this position due to higher leadership support.</td>
</tr>
<tr>
<td>Green Belts</td>
<td>One to two days of training specifically targeted for DMAIC-V where method is presented for practical application. Post training, these members can actively participate as subject matter experts, providing assistance to improve the process being studied.</td>
</tr>
<tr>
<td>Yellow Belts</td>
<td>One to two days of training specifically targeted for DMAIC-V where method is presented for practical application. Post training, these members can actively participate as subject matter experts, providing assistance to improve the process being studied.</td>
</tr>
<tr>
<td>White Belts</td>
<td>Basic understanding of LSS theory via an online tutorial on LSS. This individual is any member of NAVFAC who has a desire to learn about this new management concept.</td>
</tr>
</tbody>
</table>


progress monitoring and a non-stop process improvement mentality. LSS is an integral part of progress monitoring. LSS guides and provides the framework methodology that yields data, and determines how the work is proceeding. The tracking of such progress can be used to evaluate set goals. In addition to LSS implementation at the project or office level, LSS across the enterprise provides a common communications ground, i.e., knowledge basis, set goal attainment and enforcement, a true cross-functional team (U.S. Department of Defense, 2008).
A widely-used tool in the CPI improvement is a Rapid Improvement Event (RIE), a short-term, high-intensity effort to address a specific problem. RIE is the term of choice, though such events are also identified by other names in the Navy, including rapid improvement workshop, *kaizen* event, *kaizen* blitz, and accelerated improvement workshop. It closely relates to *kaizen* because it meets the following points: Events are solved by developing actions that create small incremental change for the better; the change produces process improvements where the capital or effort investment is minimal. In addition, affected stakeholders must buy-in on the change, and the change should be focused and identify its limits, or characterize measurable goals and targets as they contribute to quick improvement completion. RIEs are typically structured as 3-5 days in duration, consisting of cross functional teams and an improvement cycle made up of a three-week preparation period, one execution week and a three-week follow up (U.S. Department of Defense, 2008).

A CPI Event Analysis and Results Report is a document modeled after an A3 report, which was pioneered by Toyota to identify a problem, document its analysis, present potential solutions and expected results (targets), and present a plan to implement solutions (Shook, 2008). Thus, the CPI Event Analysis and Results Report provides key information, like project and event description, goals/deliverables, estimated event date, process owner, team members, implementation costs and savings. All information is formatted (within an A3-sized paper), so that a single piece of paper provides the problem statement, analysis and proposed solution. Also, the use of the adopted A3 report enforces priority in the information gathered; that is, the outcome of the CPI Event Analysis and Results Report is to the point, clear and easy to interpret and it further represents the Plan phase of the PDCA cycle (Alves, 2009; U.S. Department of Defense, 2008).

**NAVY’S ADOPTION OF LSS THROUGH CPI EVENTS**

This section begins by introducing the Navy’s organizational structure, called the Navy’s Shore Establishment, see Figure 4. The arrows identify the divisions where the author encountered LSS implementation efforts, namely NAVSEA, NAVAIR, NAVSUP, and this paper’s subject of interest, NAVFAC.

The Navy’s shore establishment structure is made up of the department branches that provide the necessary support to the "the fleet." Such support can be exemplified in the
construction of facilities for ship and aircraft maintenance and repair; communications centers; training areas; intelligence and meteorological support; storage areas for repair parts, fuel, and munitions; medical, dental, lodging and recreational facilities (NAVY.mil, 2010).

The following subsections describe the four divisions previously mentioned (NAVSEA, NAVAIR, NAVSUP, NAVFAC) by presenting their mission statement followed by the account of a few projects, if available, to illustrate the division’s LSS knowledge, acceptance, implementation, results and future goals.

**NAVSEA**

The mission of Naval Sea Systems Command (NAVSEA) is “to develop, deliver and maintain ships and its systems on time and under cost” (NAVSEA, 2010a). Noteworthy undertakings that illustrate the LSS journey the Navy have been adopted. A NAVSEA’s site manager states that after having successfully transitioned implementation from external consultants to internal certified Green Belts, Black Belts, and Champions, they have
aggressively embraced Lean which has developed their confidence in setting ambitious goals and consistently achieving them. Their experience with the use of Lean tools has led the way in resolving repair funding shortfalls that affected the quality-of-life issues for the workforce. The teams have focused on specifically identified opportunities to reduce waste and cycle time and create increased process efficiency. NAVSEA’s future goals include the application of value stream analysis or RIE employment in program management initiatives like energy savings, transportation cost control, and facility utilization (NAVSEA, 2010b).

Another site is commended for the development of a look ahead port plan into the year 2023. The plan incorporated various Lean Six Sigma initiatives where the port would save in excess of $26 million. The site’s port is distinguished as “the fleet’s sentinel and indispensable warfare systems support at the waterfront” (NAVSEA, 2008).

**NAVAIR**

The mission of Naval Air Systems Command (NAVAIR) is “to provide full life-cycle support of naval aviation aircraft, weapons and systems operated by Sailors and Marines” (NAVAIR, 2010a). This department houses fleet readiness centers who pride themselves in promoting their motto “to provide top quality products and services at the best value in the fastest time.” Their motto itself carries the key elements of LSS definition: quality, cost and time. NAVAIR has become an entity that on a daily basis employs management systems, and they named the following: Lean, Theory of Constraints, Six Sigma and best business practices. As well, this department holds certifications in ISO 9000, 9001 and 14001 (NAVAIR, 2010b).

NAVAIR has experienced palpable benefits, like the creation of the AIRSpeed program, which is a result of straight implementation of Lean Six Sigma. AIRSpeed reports on two success stories. One relates to the streamlining\(^7\) of accounting practices that yielded annual savings of $176.9K and projected savings of $146.3K in waste elimination. The second one comes from a maintenance facility that observed repair cycle time, inventory and man-hour reduction, which accounted for a 10% cost reduction, and employees’ reallocation for

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\(^7\)Streamlining refers to process optimization where a process is adjusted to optimize a specified set of parameters. Its goals are minimizing cost, maximizing throughput, and/or efficiency.
optimal resource utilization. These stories exemplify LSS in NAVAIR as they stand by the core of its mission, professionally supporting the fleet” (Apte & Kang, 2006).

**NAVSUP**

For the Naval Supply Systems Command (NAVSUP), “Our Mission…Supporting the Warfighter” is not taken lightly. NAVSUP’s mission seeks to provide combat capability through logistics. This department manages supply chains that provide material for Navy aircraft, surface ships, submarines and their associated weapons systems. Dealing with areas that support daily base operating and waterfront logistics support services, NAVSUP also coordinates material deliveries, contracts for supplies and services, and provides material management and warehousing services. Additionally, NAVSUP is responsible for many of the Quality of Life programs that directly touch the lives of Sailors and their families, like Navy Exchanges, Navy Postal System, Navy Food Service Program, lodges, relocation services (NAVSUP, 2010).

An example that demonstrates NAVSUP’s new management systems application is illustrated by an RIE project in which NAVSUP tackled its Simplified Acquisition Procedures (SAP). An appointed team reviewed the SAP and the SAP’s modification process to identify a method to reduce cycle time and facilitate workload shifting. The existing procedures were broken down step-by-step, eliminating six steps and reducing the average cycle time per action to 1.8 days. As a result, a new standard was created, increasing the employees’ average annual productivity. This relatively simple analysis computed an expected 10% annual productivity increase per employee which generates annual cost avoidance in excess of $377,000. This project’s team leader, a certified Black Belt, expressed his satisfaction by venturing off the well-beaten path of doing things the ‘old way’ and engaging the principles of Lean Six Sigma” (NAVSUP NEWS, 2010).

**NAVFAC**

The Naval Facilities Engineering Command (NAVFAC) manages planning, design, construction, contingency engineering, real estate, environmental, and public works support
for U.S. Navy shore facilities all over the world, since 1842. NAVFAC can enter into contracts with commercially-owned companies in order to deliver construction for the military, such as housing, piers, airfields and hospitals. As LSS became Navy policy, immediate actions included surveys to obtain client’s project feedback, encouraging active employee engagement to solicit ideas for improvements, and enforcing the use of the organization’s management system to document current processes; then, after the application of LSS tools, maintain the management system update for future reference. NAVFAC’s LSS subject matter experts embrace LSS implementation, knowing that use of LSS tools in continuous process improvement involves a cultural change (NAVFAC, 2007).

It has become common to associate time extensions when a construction contract modification arises. Such time extensions generate the term time growth in construction, which may result in delayed construction start and completion, and cost increase, ultimately impacting the facility’s end user. NAVFAC addressed this issue by focusing on design review time, as one of the reasons, within its control, that contributed to a project’s time growth. The following describes a NAVFAC’s initiative whose goal was reviewing the current process and providing a design review time limit. An RIE team was set up to reduce the average number of calendar days for design reviews, which were taking an average of 30 calendar days at that time. The tools utilized included a root cause analysis, and a current value stream analysis, both of which produced a future value stream which eliminated process waste (e.g. redundant reviews, enforced dual submittal to contract and design manager, etc). Therefore, the team devised an implementation plan: (1) to increase the review workforce, (2) create a logbook, (3) use existing electronic system for project tracking purposes, (4) create standard submittal forms, and (5) allow concurrent review submittal, on a standard form, to appropriate personnel for visibility, tracking and follow-up. The RIE team’s implementation plan reduced design review time to only 10 calendar days from the average 30 calendar day review. Needless to say, the customer’s satisfaction is incalculable; and the time reduction to one third of its original duration immediately yields time savings which may affect the project’s schedule (NAVFAC, 2010a).

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8 Establishment of the Bureau of Navy Yards and Docks (BuDocks), forerunner to the Naval Facilities Engineering Command.
Another RIE took on the examination of the upkeep of a storage area in a contracting office. The problem arose as an area used for supplies and closed-out contract files storage grew cluttered and unorganized. This problem impacted its users’ ability to quickly obtain desired supplies or files. The RIE team incorporated and applied the housekeeping –5S9–, a Lean technique, in order to improve the physical organization of the storage space, to reduce redundant supplies and apply visual aids to promote easy identification of supplies and file locations.

RIE team also helped in an updated supply inventory and inventory management to control contents, reordering and orderly storage. With the RIE team and end users’ coordinated effort a functional supply closet and contract storage area was created, and eliminated the necessity for personnel to keep closed contract files within their office spaces. Finally, the entire office voted to establish a semi-annual cleaning of the office as their way to support the essence of this event and maintain organized spaces (NAVFAC, 2010b).

A different event targeted the value stream analysis on NAVFAC’s internal acquisition processes. The event was an item of interest as it had been previously identified by a high level executive committee as having a potentially significant return on investment (ROI). The output of the event crafted a rapid improvement plan which listed several LSS Just Do Its10 (JDIs), RIEs, and one large Project. The RIE team accomplished several goals; for instance, a documented Current State Map and development of a Future State Map, and an Improvement Plan. In conjunction, the outputs were focused on reducing redundant reviews and rework, improving communication, encouraging knowledge sharing, promoting technical competency and improving flow through constraint removal. By streamlining the current state process, establishing and following the new state map, the potential quality improvement was estimated to increase by 27%, and the throughput yield was expected to increase from 33% in the current state to 60% in the Future State (NAVFAC, 2010c).

9 5S methodology term used in the workplace that uses a list of five Japanese words: seiri, seiton, seiso, seiketsu and shitsuke. Translated into English they are: sorting, setting in order, sweeping or cleanliness, standardizing and self-discipline. One of the 5S goals is to build a clear understanding among employees of how work should be done, and also instill ownership of the process (Wikipedia, 2010a).

10 Just Do Its – Point improvements.
Finally, the same executive committee mentioned above continues to participate in providing input to the CPI/LSS Portfolio, demonstrating the importance of groups dedicated to CPI/LSS initiatives. These individuals assist NAVFAC in identifying the objectives and opportunities for action where strategic issues can be addressed and provide a significant return on investment while remaining focused on improving readiness, performance and sustainability. This is NAVFAC’s systematic process to better align its efforts with the needs of the supported customers (NAVFAC, 2010d).

As commended by Donald Winter, Secretary of the Navy, in a memorandum in May 2006, “Lean Six Sigma (LSS) is a proven business process that several elements of the Navy and Marine Corps have initiated including training over 500 Black Belts and 1500 Green Belts who have facilitated 2800 events and projects. These activities have averaged a 4:1 return on investment” (Winter, 2006). Much has been done, and even more is expected in return. It is fair to state that the seed is planted, but the road to take is still long.

**SUMMARY**

This chapter presented a series of examples that illustrate LSS implementation in different divisions of the Navy. The chapter initially introduced the Continuous Process Improvement (CPI) process defined by the Navy and further presented examples on how the program has been implemented in NAVSEA, NAVSUP, NAVAIR, and NAVFAC. The CPI process embraces concepts related to Lean, Six Sigma, and the Theory of Constraints and proposes the use of methods and tools based on these concepts to improve the Navy’s ability to efficiently reach its goals as an organization. The research carried out about LSS implementation in Navy divisions has shown that different processes (e.g., accounting, contract documentation and processing, and maintenance to name a few) have achieved tangible benefits that not only justify the use of LSS but encourages its implementation in other projects and initiatives deemed important by the Navy.

The last chapter of this document presents the conclusions of this research and provides a recommendation on a LSS training deployment venue to aid in the diffusion of LSS to NAVFAC’s construction undertakings.
CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

From austere beginnings in the manufacturing industry at Toyota, “do more with less,” to the grasping of Lean in the “production of value” and the strategic problem or root cause elimination with strong financial impact of Six Sigma, Lean Six Sigma has evolved and transformed in order to be adapted to different enterprises. NAVFAC has embarked on its own Continuous Process Improvement / Lean Six Sigma program to achieve increased effectiveness in everyday dealings. According to the literature and the sources reviewed for this project, the CPI/LSS program has already established a solid training basis which enforces the rationale presented in Chapter 2, Figure 2. Figure 2 represents a culture change paradigm built on the solid conceptual understanding which supports the higher levels of principle adaptation and application to ultimately make use of the developed tools. Figure 2 displays the structure of learning that goes from the broad to the specific. So far, in NAVFAC the CPI/LSS program has been used mainly to streamline processes currently in place in areas like acquisition and design with noteworthy results as discussed in chapter 3.

In addition to addressing the state-of-the-art of LSS implementation at NAVFAC, under the institution of its CPI/LSS program, this project looks back at the research question posed at the beginning of this document, How can LSS be implemented in Navy’s construction project management? In order to answer the research question, the logical sequence of events for LSS implementation will be followed, and that the next step is for NAVFAC to expand CPI/LSS to its construction area. As stated by Ballard (2000b) while addressing his work on LPDS™, he expressed interest in observing “the dynamics of organizational change provoked by initiating change in a single element … [Ballard’s] experience has been that all other organizational elements eventually have to be brought into alignment.” This statement holds true when the LPDS™ model is superimposed on NAVFAC’s organization, inevitably, all other elements become aware of LSS effects. This
document exhorts the NAVFAC enterprise to reach out to the Civil Engineer Corps (CEC) community by making use of the Civil Engineer Corps Officer School\textsuperscript{11} (CECOS) as a deployment venue for LSS. This action will align the CEC (construction) community with the already implemented LSS efforts within the enterprise.

A useful exercise to aid in LSS deployment to the CEC community is to engage CEC officers to initiate direct contact with NAVFAC’s subject matter experts on LSS implementation by conducting interviews (see Appendix for Sample Interview Guides). The prospective interviewees would include NAVFAC’s LSS Black Belts and other LSS certified personnel, in order to assess LSS acceptance and deployment at the working (project) level. Interviews would also be carried out with construction heads who would provide feedback on actual construction projects where LSS has been implemented. They would also provide input on their experience with LSS as a global paradigm shift in the Navy (i.e., NAVFAC use only suppliers and vendors recommended from NAVSUP). Furthering the results of such exercise, as CEC personnel receive LSS training, a group could be integrated to merge training with interview results in order to develop a specific CEC/LSS training program and apply what they learned to pilot construction projects.

At this point, the project has identified several areas from the literature review where NAVFAC’s CEC community would greatly benefit, and these are:

- LPDS$^{TM}$ model
- LPS$^{TM}$ implementation

The LPS$^{TM}$ and the LPDS$^{TM}$ could be used in NAVFAC as the basis to introduce a mentality change where cross-functional teams working collaboratively seek improvement opportunities for the benefit of the project. The expected effects are of utmost importance including an overarching reward system; much needed development policies that include its employees, and the focus on top level business strategies (Ballard, 2000b).

To continue the research on this topic, the following are a few suggestions for future work in NAVFAC:

\textsuperscript{11} Civil Engineer Corps Officer School (CECOS) - the construction training school which provides education to officers in charge of construction projects.
- Conduct a case study to investigate and document the implementation results, successful or unsuccessful, of LSS in one NAVFAC sub-division.
- To develop a benchmarking plan to translate how the improvements could be implemented in NAVFAC.
- Form a team to develop a list of training topics which can enhance construction management within NAVFAC.
- Form a team that cross-trains with other Navy divisions (i.e. NAVAIR, NAVSEA, NAVSUP, etc.).
REFERENCES

WORKS CITED


WORKS CONSULTED


APPENDIX

SAMPLE INTERVIEW GUIDES
Interview Guide for NAVFAC Black Belt

Main Question: How has LSS been translated to and used in design, construction, and project management in NAVFAC projects?

- researcher seeks to gather perceptions of processes and accounts on how processes unfold
- during the interviews, the researcher will investigate how NAVFAC professionals understand concepts and practices related to LSS
- and document specific instances where LSS has been implemented in their projects

1. How long have you been in NAVFAC?
   a. Education, origins in NAVFAC, experience, GS level when attained Black Belt certification, etc.

2. What personal trait, project, action, do you consider was a contributor to your selection as a black belt selection? or what situation triggered your interest in LSS?

3. Is there a predominant type of projects where LSS been implemented? Internal Process Streamlining (document processing), Internal Servicing (maintenance work), Design (from conceptual idea, before project is awarded), construction (hands on, ongoing project), etc.

4. Has there been any reach out to the CEC community to implement LSS in construction project management? (both from CEC to CPI/LSS and from CPI/LSS to CEC community)

5. The Civil Engineer Corps Officer School (CECOS) currently offers courses for officers going into Public Works (PW) and Field Engineering and Acquisition Departments (FEAD).
   a. Has there been any thought of using this venue to continue the dissemination of LSS.
   b. All Ensigns (O1’s) go through CECOS. That said, has there been any discussion about introducing LSS to the brand new officers? (e.g., requiring white belt certification (via NKO), as part of introduction to the Corps as a minimum, will stimulate these fresh minds to be open to new ideas and the change process necessary to implement LSS.)

6. Are there any other forums currently being looked at in order to serve as a diffusion platform for LSS?

7. I have encountered several videos depicting success stories under the NAVSUP web portal (e.g., aviation packages, processes like SOP’s). Unfortunately, I have not found those under NAVFAC, if they exist, where can I find them?
8. To date what is your perception of LSS implementation in NAVFAC? What is your perception of LSS implementation’s acceptance in NAVFAC?
   a. What level of leadership has LSS training/hands on implementation reached?
   b. On your latest project, what was the general knowledge of the project participants regarding LSS?
   c. What certification level did they hold if any?
   d. If not certified, what was their willingness to learn at a quick pace? (trust in the method, DMAIC)
   e. What has been the success rate of Rapid Improvement Events (RIEs) that you have headed?

9. How does the region measure implementation? Command personnel quota, project quota, command’s personnel certification, overall region certification, overall training metrics, etc. This question is related to the training quote from SECNAV INST 5220.14: “The Department of the Navy shall invest in the workforce by training, educating, and certifying employees on CPI methodologies and tools.”

10. What are the types of Lean events that NAVFAC SW has developed or participated in? As stated on OSD Lean report 2004: “The Assistant Secretary of the Navy, Research Development and Acquisition (ASN (RDA), has set forth a policy entitled ‘Acquisition Source Document’… it requires each program to conduct at least three Lean events and seek to apply Six Sigma and Theory of Constraints (TOC) tools, as appropriate.”

11. What incentives have been established in NAVFAC as stated on SECNAV INST 5220.14? (i.e., “achievements of teams and/or individuals shall be recognized in personnel award, compensation and promotion processes, as appropriate.”)

12. What action/step is taken after a sufficient collection of the Facilities Team Survey (FacTS)? And after collection of employee improvement ideas?

13. What is the most recent action/change that is a direct outcome of the feedback from FacTS and employee improvement ideas?
Interview Guide for NAVFAC Lean Construction Leader

1. How long have you been in NAVFAC?
   a. Education, origins in NAVFAC, experience, GS level, etc.

2. Literature from Lean Construction (LC) pioneers, G. Ballard (2000b), state the urgency of a true change on traditional construction methods, from your experience, how can this statement be supported in the Navy? (provide examples, tools, innovations in place, etc.)

3. Has LC in the Navy reached a point that supports a Production System Design as introduced by Ballard (2000b)?

4. To date what is your perception of overall diffusion of Lean Construction in NAVFAC? What is your perception of Lean Construction acceptance in NAVFAC?
   a. What level of leadership has Lean Construction training or hands-on practices reached?
   b. On your latest project, what was the general knowledge of the project participants?
   c. Name the most common tools currently used and enforced in NAVFAC as supporters of Lean Construction in the design, planning, contracting and management of construction projects?

   Tools like: Work Packaging and creation of work cells, Line Of Balance. LPS™: Short, mid and long term planning, production shielding, eliminate problems related to waste and low productivity, increase process transparency, improve communication between different managerial levels, analysis of activities, method, sequence and timing. Percent Plan Complete (PPC - rate of completed assignments of total assignments per week). Sound and Clear Assignments, Sequence of assignments, Size of assignments. LPDS™: Introduces DMAIC in fabrication, installation, commissioning, maintenance, etc.

5. What has been your experience with CPI/LSS implementation in NAVFAC?

6. Are you involved in CPI/LSS implementation?
   a. If yes, what type of input do you provide?
   b. Are you an active member in training, or actual project/program implementation?
   c. If not, have you heard of CPI/LSS successes/failures?

7. Are you certified in the different belt levels?
8. What is your role in CPI/LSS as a Lean Construction leader in NAVFAC?

9. From LC perspective, what is the interaction between your department and CPI/LSS, or its projects?

10. Has there been any reach out to the CEC community to implement lean construction concepts/practices in project management? (both from CEC to lean construction and from lean construction to CEC community)

11. Civil Engineer Corps Officer School (CECOS) currently offers courses for officers going into Public Works (PW) and Field Engineering and Acquisition Departments (FEAD).
   a. Has there been any thought of using this venue to continue the promulgation of Lean Construction?
   b. All Ensigns (O1's) go through CECOS. That said, has there been any discussion about introducing LSS to the brand new officers? (e.g., requiring white belt certification (via NKO), as part of introduction to the Corps as a minimum, will stimulate these fresh minds to be open to new ideas and the change process necessary to implement LSS.)

12. Have you heard about the Lean Construction Institute (LCI)? or the International Group for Lean Construction (IGLC)?
Interview Guide for Instructor, Civil Engineer Corps Officer School

1. How long have you been in the Navy?
   a. Education, jobs in NAVFAC, experience with NAVFAC, experience prior to NAVFAC, Rank, etc

2. As a CEC officer have you learned of LSS and different training belt levels?

3. Do you hold a LSS belt level (the highest)?

4. In CECOS training has Lean and/or Six Sigma been discussed during the classes?

5. With class diversity, would it be worthwhile to assess new CEC officers on Lean or Six Sigma or LSS knowledge, prior to CEC? (Some have had work experience before joining the CEC, some may be transfers from other community, etc.)
Interview Guide for Public Works Officer, CEC Officer

1. How long have you been in the Navy?
   a. Education, jobs in NAVFAC, experience with NAVFAC, experience prior to NAVFAC, Rank, etc.

2. As a CEC officer when did you learn of LSS and different training belt levels?

3. Do you hold a LSS belt level (the highest)?

4. In CECOS training has Lean and/or Six Sigma been discussed during the classes?

5. In your experience with NAVFAC projects, has there been occasion for construction industry, contractors on base, to provide Lean, Six Sigma or LSS insight?

6. Have you/your office participated in a LSS project?