Applying Lean Manufacturing Initiatives to Naval Ship Repair Centers Implementation and Lessons Learned

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Abstract

The United States Navy is under pressure to reduce the cost of fleet maintenance in order to redirect funds for the construction of new ships and submarines. The Navy looks to private industry for process improvement ideas such as the Theory of Constraints, Six Sigma and Lean Manufacturing Principles.

This thesis examines the Lean Manufacturing movement in the private sector of ship repair and how it eventually came to government owned ship repair operations. Recent National Ship Research Program (NSRP) initiatives provide shipyards a strategy of how to select areas of an operation for Lean improvements. The Norfolk Naval Shipyard method is a combination of the Theory of Constraints, Six Sigma and Lean Principles called Lean Sigma.

The Lean Sigma methodology for planning, executing and sustaining lean improvement and how to measure success with various metrics is presented. Lean Sigma is implemented into the Electric Motor Rewind and Repair Center as a case study. Before and after assessments, lessons learned, and recommendations from the implementation case study are presented. Details of the challenges and pitfalls encountered during the Lean Sigma implementation in the areas of culture, budget, management, metrics and cost benefit measurement, are described throughout the test case. In conclusions key elements for successful Lean transformation and a vision for the future Lean Ship Repair Enterprise are presented.

Thesis Advisor: Henry S. Marcus, Professor of Marine Systems

Author's Biographical Information

LCDR Murphy enlisted in the Navy's Nuclear Power program in his senior year at Kenmore East Senior High School, Tonawanda, NY in 1981. Qualifying in submarines and advancing to Machinist Mate Second Class (MM2 (SS)) aboard the USS *Bremerton* (SSN 698) out of Pearl Harbor, HI, he qualified in all mechanical operator watches up through Engineering Watch Supervisor (EWS) and Leading Engineering Laboratory Technician.

He was released to the NROTC program at Rochester Institute of Technology in NY for undergraduate education, completing bachelor's degrees in Mechanical Engineering and Energy Engineering with honors. He was commissioned as an Ensign in 1989.

LCDR Murphy returned to the submarine force, attending the Nuclear Power and Submarine Officer Training Pipeline, then serving aboard the USS *George C. Marshall* (SSBN 654) as Chemistry and Radiological Controls Assistant and Electrical Division Officer, conducting patrols out of Groton, CT and Holy Loch, Scotland. After conning *Marshall* from Groton through the Panama Canal and north to Puget Sound Naval Shipyard (PSNS) for inactivation and decommissioning, he transferred to the USS *George Washington Carver* (SSBN 656) and served as the Main Propulsion Assistant during operations as an attack submarine out of Bangor, WA. *Carver* was eventually ordered to decommission at PSNS where LCDR Murphy served as Defueling Engineering Officer of the Watch and Ship's Duty Officer, and completed Nuclear Engineer qualification.

LCDR Murphy's next assignment was at the Nuclear Power Training Unit, Ballston Spa, NY, where he served as Operations Officer, Shift Engineer and Instructor at the D1G Prototype Plant. After Instructor Duty, he reported to the Precommissioning Unit *Louisiana* (SSBN 743) serving on as Damage Control Assistant, Quality Assurance Officer, Ship Safety Officer, Initial Criticality Coordinator and Shipyard Liaison Officer at Electric Boat, Groton, CT. The last of the Tridents, USS *Louisiana* (SSBN 743) was commissioned in September 1997.

In May 1997, LCDR Murphy joined the Engineering Duty Officer community and reported to the Massachusetts Institute of Technology's Ocean Engineering Department for graduate studies. He achieved the degrees of Naval Engineer and Masters in Mechanical Engineering in the class of 2000. His thesis topic was "Methodology for Implementation of Automation Systems to Reduce Manning of Ships." Following postgraduate studies, LCDR Murphy reported to Naval Diving and Salvage Training Center for Basic Diving Officer and Salvage Officer Class where he was the class leader and Salvage Officer Honorman.

LCDR Murphy has been assigned to Norfolk Naval Shipyard (NNSY) since March of 2001 serving as an Assistant Project Superintendent on USS *Boise* (SSN 764) and USS *Montpelier* (SSN 765) Docking Selective Restricted Availabilities (SRA), then serving as Project Superintendent for the USS *Hampton* (SSN 767) docking SRA and the USS *Jacksonville* (SSN 699) Interim Dry-docking (IDD). He is currently the NNSY Regional Maintenance Officer responsible for submarine and surface ship depot level maintenance conducted at the Naval Base during restricted, technical and voyage repair availabilities assigned by the Type Commanders and for Regional Repair Center (RRC) operations of the Mid Atlantic Regional Maintenance Center (MARMC)

LCDR Murphy's special qualifications include Submarine Project Superintendent, Diving and Salvage Officer, Nuclear Engineer, Engineering Duty Officer, Submarine Warfare Officer, underway Officer of the Deck, Engineering Officer of the Watch and Submarine Duty Officer. He is a licensed Professional Engineer in the Mechanical Engineering field.

Acknowledgements

This thesis would not have been possible without the support and the *expert* assistance of the Process Improvement Team, Code 2390, at Norfolk Naval Shipyard. They are effecting a lean transformation at the shipyard, one individual at a time. I want to specifically thank the Civilian Managers, Mr. Jim Tice and Mr. Mike Johnson in the Mid Atlantic Regional Repair Centers for encouraging me to pursue this work. Thanks to the men and women who work in the Motor Rewind and Repair shop for sharing their knowledge and opinions and for participating in the lean improvement workshops.

I wish to thank Professor Henry Marcus, for his continuing support as my professor, advisor and mentor in Ocean Systems Management, whenever asked.

And finally it is appropriate to thank the United States Navy for the professionally and personally enriching opportunities given and their support throughout my career.

To The Mid Atlantic Regional Repair Center
of Norfolk, Virginia
Cambridge, Massachusetts, January, 2004

Table of Contents

List of Figures

1 Introduction

1.1 Factors Motivating the US Navy Repair Community to Change

The United States Navy is under pressure to reduce the cost of fleet maintenance in order to make the savings available to fund the construction of new ships and submarines. The current budgeted new ship build rate has not sustained the goal of maintaining a 300-ship navy. As a result of President Reagan's drive toward a 15 carrier, "600 Ship Navy" during the eight years of his administration, by the time he left office in January 1989, the Navy had become a 15-carrier Navy of 594 ships deployed around the world. The total ship count has dipped to 12-carriers in a 295 ship Navy today in spite of government defense reviews that suggest 300 is the minimum to sustain our Navy's mission statement.

The Navy is also going through a period of significant operational change from a rotationally deployed Navy to a "surge on demand" capable Navy. The surge Navy must be able to deploy forces in different combinations of ships and on different timelines to meet fairly unpredictable threats. This rapid surge was experienced during *Operation Iraqi Freedom* when 70% of all U.S. naval forces were rapidly deployed.

The Naval Sea Systems Command (NAVSEA) is the largest of the Navy's five major acquisition and fleet support organizations, managing nearly one-fifth the service's annual budget, or almost $20 billion annually to fund ship repair, modernization and new construction. NAVSEA is transitioning to a new business model to better serve the rapidly evolving fleet; to strengthen relationships with industry, and to devise improved methods to fund the construction of new ships with a limited budget.

NAVSEA has high expectations that process improvement initiatives within its maintenance organizations will provide for the redirection of maintenance savings into new ship construction, and also provide increased repair capacity to support a surge force for action when called upon. NAVSEA must become more efficient to sustain the fleet for the on-going war on terrorism, and to build and refurbish this force for the future.

NAVSEA looks to private industry for process improvement ideas that have been successfully implemented. This "tool box" contains initiatives such as Vision and Mission Development, Change Management, Assessment Models, Value Stream Analysis, Brainstorming, Win/Win Agreements, Prioritization, the 5 Why's, the Theory of Constraints, Pull Systems, Root Cause Analysis, Supply Chain Management, Critical Chain Project

Management, 7 Management & Planning Tools, Capacity Analysis, Takt Charts, Process and Data Analysis Tools, Six Sigma and Lean Manufacturing Principles.

1.2 The Goal - to Create a Lean Ship Repair Enterprise

The NAVSEA leadership wants to create a Lean Ship Repair Enterprise. Although NAVSEA is a government organization, private industry processes and corporate strategies can provide significant advantages to the government. Instead of a drive to increase profit margin through improvement initiatives, the Navy strives to increase maintenance capacity, and to redirect maintenance savings into new ship construction. The largest sector of the NAVSEA organization is the Naval Shipyards at Pearl Harbor, HI, Puget Sound, WA, Portsmouth, NH, and Norfolk, VA. The leadership wants to effect a lean transformation of our Naval Shipyards, with the desired outcome being a commitment to Lean as a business strategy to improve shipyard performance in both the short and long term view.

Lean history over the past several years has been that each shipyard is learning and doing Lean "proof-of-concept" activities with varying strategies and pace. Resultant improvements have been mostly localized successes.

The Norfolk Naval Shipyard (NNSY), as a unique government facility of NAVSEA, has combined the basic principles of the Theory of Constraints, Lean Manufacturing and Six Sigma into a methodology called "Lean Sigma". Lean Sigma considers the differences in culture and processes between a profit driven private shipyard and a government operated shipyard. This thesis applies the Lean Sigma approach to the Electric Motor Repair Center as a test case and provides an adjusted methodology with the lessons learned and recommendations for applying the technique to other government job shop facilities.

Expectations are that Lean improvements will rapidly improve shipyard performance, promote collaboration, standardization and alignment of other improvement initiatives and eventually provide a comprehensive, long-term, improvement methodology.

1.3 National Shipbuilding Research Program (NSRP) Initiatives

Lean Implementation is ongoing in the Naval Ship Industry to varying degrees at companies like Northrop Grumman Newport News, Avondale, Ingalls, General Dynamics Electric Boat, Bath Iron Works, NASSCO, Todd Pacific, and Atlantic Marine.

The NSRP sponsored a Lean Enterprise Project. The participants (Todd Pacific Shipyards, Atlantic Marine, and Puget Sound Naval Shipyard) have developed models for the application of lean manufacturing concepts to multiple market segments of the U.S. shipbuilding and ship repair industry. In October 2003, the NSRP team presented their experiences in developing an "ideal" model for lean ship repair and some methods or approaches for transition to a lean ship repair environment. NNSY has developed and continues to improve their Lean Sigma implementation method while sharing experiences with the NSRP team.

1.4 Overview of the Approach Used in this Thesis

This thesis describes a methodology for implementing a lean transformation.
This thesis highlights a specific implementation, the methodology used and the key aspects of the improvements that are applicable to other job shop environments. The research for this thesis was completed at Regional Repair Centers (RRC) of the Mid-Atlantic Regional Maintenance Center, a US Atlantic Fleet maintenance consortium. The RRCs are job shop type facilities handling low volumes of varied components. The strategic goal of the project was to improve ship repair operations by focusing on more throughput and shorter cycle time while minimizing cost.

Chapter 1 of this thesis presents the motivation and history behind the US Navy's entry into the Lean Ship Repair enterprise.

Chapter 2 of this thesis describes the background of the Motor Rewind and Repair shop and the specific nature of the shop that lends itself to an implementation of Lean.

Chapter 3 provides background discussion on the Theory of Constraints, lean manufacturing and six sigma and provides a framework for utilizing a combination of them (called Lean Sigma) in a job shop repair setting.

Chapter 4 of this thesis describes the methodology for implementing Lean Sigma in a job shop repair environment.

Chapter 5 of this thesis describes Measures of Effectiveness and other metrics and their relative importance to the success of Lean improvement.

Chapter 6 describes the test case implementation and results in the Motor Repair Center; and some of the barriers to implementing Lean Sigma in a traditional ship repair environment, including technical, cultural and organizational issues. The specific issues confronted in this implementation are detailed and suggestions on dealing with these issues are presented.

Chapter 7 evaluates the Lean Sigma process and summarizes the lessons learned. The recommendations for successful implementation of future Lean Sigma workshops are presented. Many acronyms are used in this thesis and are described in detail in the text. If used more than once the acronyms are also included in a glossary at the end of the thesis.

2 Naval Ship Regional Repair Centers (RRC) Background

The RRCs of the Mid-Atlantic Regional Maintenance Center (MA-RMC) are consolidated job shops. They were created in 1999, by combining redundant U.S. Navy repair capabilities in the region, from multiple locations into a single shop. The RRCs were designed to eliminate redundancy of capability and capacity. By reducing excess infrastructure, integrating military and civilian personnel, and streamlining the administrative processes, a greater percentage of each maintenance dollar can be used to accomplish productive maintenance. Evaluating the RRCs for lean process improvements is essential in today's geopolitical environment.

2.1 Planning

RRC work does not normally allow for advanced planning. As a result, authorization to perform work and required funding must be in place prior to knowing what work is to be performed. This allows production to start work upon the customer's request without administrative delays. The automated issuance of a job order to the Production Manager is authorization by the RRC Business Operations Office to perform work.

2.2 Assist Shops

Each RRC has a specified production focus. To complete a repair from cradle to grave, other RRCs must be utilized for processes outside of the shop floor. The term "assist shop" is used to describe this arrangement. The senior Production Manager, or designated representative, is the single point of contact for execution of work and is responsible to identify the need and request all assist shops required. The funded job order will normally acknowledge all potential assist shops necessary to receive temporary funding. Assist shops include, but are not limited to, other production, quality assurance, and engineering. In addition, the Production Manager is responsible to obtain all assist shop estimates and provide funding once the decision is made by the manager that the estimated hours are acceptable.

2.3 RRC Process Outline

The RRCs introduce functional and technical complexity into the implementation. The RRCs are a joint line of business between the Ship Intermediate Maintenance Activity (SIMA), and Norfolk Naval Shipyard (NNSY). They couple the knowledge and experience of the long standing civilian shipyard tradesman and the SIMA sailors by working side by side. The RRCs being of the Shipyard have the authority to work depot level repairs for the items they are designated. Being of SIMA, the sailors gain experience and knowledge by working a larger depth and breadth of repairs not normally conducted at the Intermediate level.

2.4 Work Ordering and Execution Processes

The RRCs receive work requests from three different sources. Work is sent to them via SIMA Norfolk like any other SIMA Work Center. The RRCs also receive work from the Shipyard for work that is for a ship in a Chief of Naval Operations (CNO) availability, at Norfolk Naval Shipyard. The remainder of work is given to them from the Naval Inventory Control Point (NAVICP), to refurbish material to be put back in inventory in the Naval Supply System. Business processes exist at these activities for: brokering, planning, scheduling, execution of work, accumulation of equipment history, inspections, status accounting, progressing, Human Resources, material procurement and handling. Functionally this means that for work identified from the ship an RRC will be notified that this work has been assigned to them. All of the planning for the maintenance order will occur in detailing the tasks and operations to be performed. There are thirteen RRCs located at both Norfolk Naval Shipyard and the Norfolk Naval Base 12 miles to the north. Figure 1 describes their functions, and Figure 2 describes their manpower. The first four are at the Naval Station, Norfolk waterfront, and the rest are within the industrial boundaries of Norfolk Naval Shipyard. The combined monetary resources expended per year are $58.8 Million, to provide service to a large customer base.

Repair Center	*Functional Description*
Calibration	Calibration of electronic test equipment through the Navy's MET/CAL program.
Corrosion Control	Processes for the prevention of corrosion and deterioration of ship and aircraft components by means of surface preparation, painting, and other preventive measures.
Diesel Engine	Overhaul and repair of diesel engines
Diving Services	Underwater maintenance and repairs.
Fleet Support Equipment	Overhaul and repair of fleet support equipment, which is non-avionics support equipment assigned to any carrier or amphibious type ship to support aircraft flight deck operations.
Flight-Deck Operations Equipment	Maintenance, repair and testing of flight deck equipment in the categories of arresting gear and JP-5 fuel hose reels, fuel detectors, transfer/defuel/spill carts.
Life Rafts	Repair and certification of inflatable life rafts.
Material Testing	Primarily the testing of oil samples through the Navy's JOAP program.
Motor Rewind	Overhaul and repair of electrical motors including AC & DC general purpose motors, AC & DC noise critical motors, motor and turbine generators.
Pump	Overhaul and repair of close-coupled pumps, split casing pumps.
RAST	Overhaul, repair and testing of Recovery, Assist, Secure, and Transit (RAST) aircraft handling system components.
Rigging	Provides weight handling services, weight testing services, nylon net manufacturing.
Small Boat	Manufacture and repair of equipment and furnishings for small boats. Also performs general fiberglass work and general woodwork.

Figure 1 Repair Centers Functional Description

2.5 Current Business Challenges of the RRCs

There are currently 2 major categories of work being accomplished in the RRCs. The RRCs work on equipment that is dismantled from a ship and is to be reinstalled, and they refurbish material either for Rotatable Pool capabilities or Refurbish Material to be placed back into an inventory such as NAVICP or specialized inventories such as Carper assets.

Most shops, as in SIMA, have a small inventory of Rotatable Pool assets or ready for issue materials they have refurbished. These are items that have been pulled from Decommissioned ships or OEM supplied inventories as part of the procurement process. The rotatable pool process is a critical success factor in being able to turn high priority work around in a timely manor. The rotatable pool process relies on refurbishment orders to correctly identify the object of the order.

The object of a refurbishment order is a material that arrives in inventory in a less than optimal condition and is returned to inventory in a rotatable or ready for issue valuation. These rotatable assets are then held in inventory waiting for the next time critical job needing that item. Flight Deck Operations RRC is a prime example of this type of process.

Regional Repair Center-Employee Count		Civilian	Military	Customer Self Help in Shop	Contractor
(CC)	Corrossion Control	0	30	0	0
(DE)	Diesel Engine Repair	10	38	0	0
(DV)	Diving	25	76	0	0
(FOE)	Flight Deck Ops. Equip.(fuel handling)	0	7	0	0
(FSE)	Fleet Support Equip.	0	5	110	70
(LR)	Liferafts	8	1	0	0
(MR)	Motor Repair	28		0	0
(PUP)	Pump Repair (ship to shop)	43	26	0	0
(PUG)	Pump Repair (water front)	19		0	0
(RA)	Rast	1	28	0	0
(RS)	Rigging Services	14		0	0
(SB)	Small Boat Repair, Wood Working, Fiberglass	6	82	20	0
	Totals	154	293	130	70
	Total Labor Force	647			

Figure 2 Repair Center Manning Table

Another flavor of refurbishment is where NAVICP feeds items to be refurbished to the shops to be accomplished as time permits. This work is reimbursable, much like the repair of a non-navy ship would be.

The Pump shop in particular is problematic in the nature of their work. They are the third work center to get the pump after it has been dismantled and rigged off the ship. They have to disassemble the pump to assess root cause of problems. At this point, shop reports are filed to order additional parts, and a true assessment as to the nature of the repair is made. This leaves little time for parts to be bought and shipped, the repair to be made, and the pump and motor to be reassembled, balanced, and reinstalled for testing. This process also does not lend to ordering the parts ahead of time efficiently or projecting an accurate planned cost of the work. Rules of thumb need to be developed for average costs to be budgeted by type of pump to estimate the costs that will be incurred because little material can be planned in a task list for this type of work. The pump and the motor RRCs are the largest work centers and have large volumes of work at any one period of time. Being that the work is already time critical, any process delays such as funding or material routing mistakes are amplified.

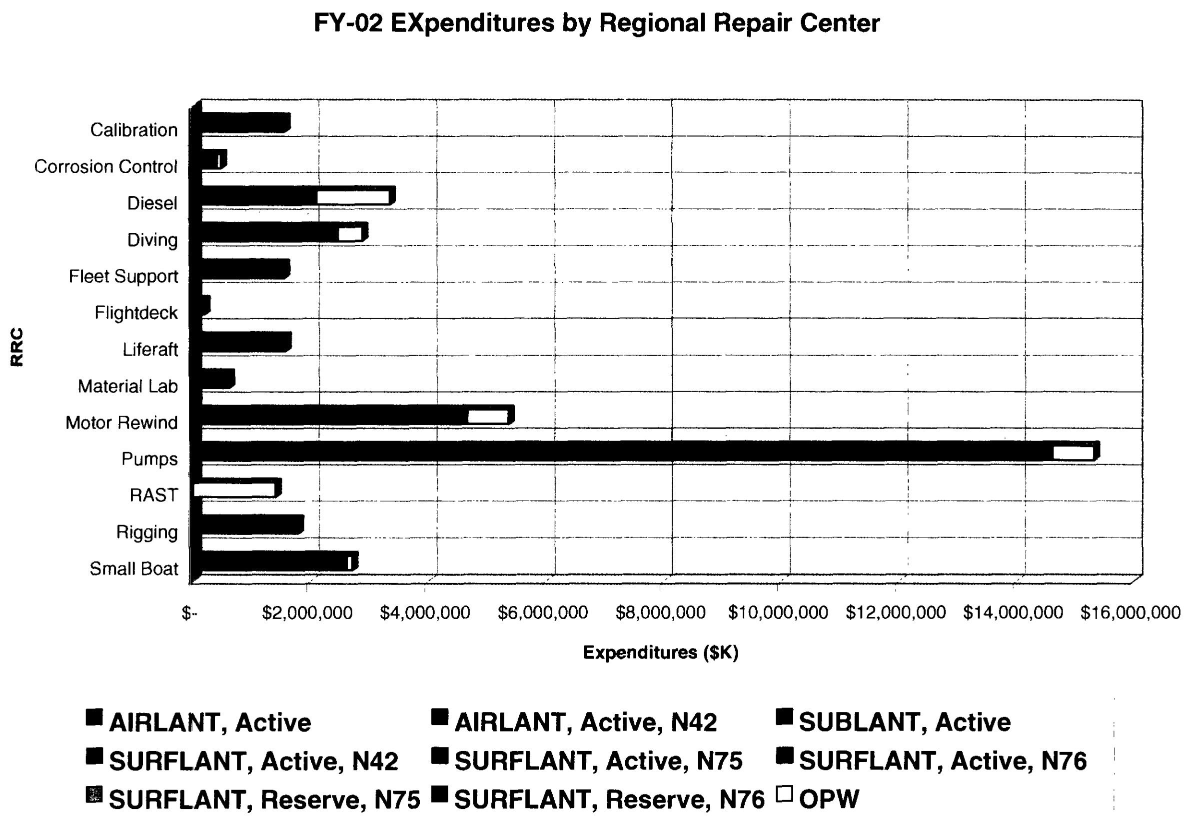


Figure 3 Fiscal Year 2002 Expenditures by Repair Center

There are thirteen repair centers in all, and the goal is to implement Lean Sigma in all of them. The motor repair center was chosen as a good test case due to the manageable scope of a lean analysis of its reasonable shop flow. Strategically, its relative importance as the shop with the second largest volume of work could result in a visible victory, to get organizational buy-in and momentum to carry on future Lean Sigma work in the other twelve shops.

3 Background Theory

Increased competition between various types of manufacturing companies in the last few decades has brought about several manufacturing concepts including, Theory of Constraints (TOC), Lean Manufacturing, and Six Sigma. The overall goal of these production systems is to increase organizational effectiveness through cost efficiency and increased profits. Although these systems differ on the approach, the underlying concept remains the same: Produce the necessary product when customers need it without unnecessary investments in capital, people or inventory. These concepts are all based on fundamental operations management science.

Naval ship repair facilities that are owned and operated by the government are obviously not operating with profit as a goal. The motivation is to get more maintenance accomplished for the same budget. Efficiencies are expected to reduce cycle time so naval units receive an overhauled motor quicker with a resultant benefit of more ship operational time available. This means an increased throughput or capacity to meet emergent work demands. To recap, the government owned and operated repair center goals are reduced maintenance time resulting in additional operational time for ships, increased capacity for additional maintenance that may be necessary in times of conflict, as well as maintenance savings that can be redirected to building new ships.

Other Benefits of Efficiency gains are improved customer satisfaction, improved safety, increased capacity, shortened cycle time, improved flexibility, reduced cost, and improved space utilization.

3.1 Theory of Constraints (TOC)

Theory of Constraints is a proven management philosophy for project management, manufacturing or integrating both together with a focus of increasing throughput of an organization. Traditional project management concepts have been around for over thirty years. Early studies noted that for Department of Defense projects, cost and schedule overruns were often two to three times the initial estimates and that project durations were frequently 40 to 50 percent greater than the original estimates. The manufacturing as well as repair and overhaul business has stimulated introduction of many management philosophies that have attempted to provide managers the ability to look at the right information at the right time to make the best decisions. All try to maximize shop performance, to meet schedule, quality and cost goals.

Critical Path Method (CPM) –based project management was introduced as a solution for performance problems with a goal of delivering projects within the original cost and time estimates. CPM fails to provide the improved performance partially because of the way the performance of projects and managers are measured. In today's Project Management environment, the Critical Path (longest series of dependent tasks to achieve the shortest duration) does not take into consideration resources and the continuous conflict for those resources. At the same time, management measures concurrent and dependent projects and commodities, which should be integrated, as discreet parts each striving to meet established individual performance measures leading to significant sub-optimization of production capabilities.

TOC emerged from the shop floor. The Drum-Buffer-Rope Methodology is a shop floor planning algorithm that plans and schedules, focusing on maximizing the performance of the constrained resource, using buffer management to ensure effective control to achieve maximum throughput. The basis for the concept lies in normal statistical variation, or an acceptance and accommodation that "Murphy" will strike. If the planning and execution processes do not properly allow for Murphy along with a measurement system, which allows local decisions to be measured against the global goal, then sub-optimization will be the norm.

In 1997, Dr. Eliyahu Goldratt introduced the first significant new approach to project management that addresses both the human side and the algorithmic methodology side of project management in a unified discipline called Critical Chain. Using Critical Chain Project Management projects are completed in significantly shorter time than traditional CPM techniques. Of significance is that Critical Chain project management is also simpler to use and requires less work for the project team in both the planning and tracking phases of projects.

The Theory of Constraints is a holistic management philosophy that applies to running and improving organizations. It views every organization with three fundamental assumptions: that every system has a goal and a necessary set of conditions. That every system is more that the sum of its parts. That very few variables limit the performance of the system at any given time. TOC is most appropriate to the Regional Maintenance environment because it supports NAVSEA requirement to ***significantly*** improve on:

1. Throughput of commodities and end items
2. Net Operating Revenue
3. Reduce Cycle Time
4. Reduce Inventory and increase inventory turns
5. Due Date Performance (Schedules)

6. Better meet and respond to customer's needs

TOC uses five (5)-focusing steps:

1. Identify the Constraint ... the single weak link ...be it a machine, labor, supplier, market or policy/procedure.
2. Exploit the Constraint ...never let the constraint be idle ...ensure maximum production through the constrained resource.
3. Subordinate to the Constraint ...ensures flow of all other resources is based on the constraint.
4. Elevate the Constraint ...if additional capacity is required to meet the goal ...elevate the need of the constraint.
5. Return to step 1 ...don't let inertia take over ...continue to review and find the new constraint.

Theory of Constraints addresses "exploitation of constraints" and "subordination to constraints" as necessary elements for properly managing daily activities of the organization. Exploitation means ensuring the weakest links in the organization are fully utilized and meet the goal of the organization as a whole. Subordination means to design the processes throughout the organization so every process supports the exploitation in the best way possible. Under Subordination every process has a clear objective that can be translated into measurements and support the exploitation.

Theory of Constraints is a powerful management philosophy that has been utilized by the private sectors for years and only recently it has been incorporated into Navy activities. A great example is at the Naval Aviation Depot Cherry Point, NC. The results have been realized quickly and they are impressive. The successful training and lean implementation last year on the H-46 helicopter rework line has resulted in the recent improvements on the H-53 helicopter line. Today, the Fleet Commanders are having their aircraft, which undergo intensive and individually developed rework and modification, returned to service 30% faster with extremely few quality defects, in addition to the fact they have about half as many out of service at any given time. The net result is faster, better, cheaper and increased availability of assets.

3.3 Lean Manufacturing

The Lean Manufacturing system that was developed by Taiichi Ono at Toyota has come to be understood as a combination of production methods that improve competitiveness through reduced manufacturing costs. "The main purpose of the system is to eliminate through improvement activities various kinds of waste lying concealed within a company" (Monden, 1997). Eliminating waste in manufacturing processes translates into reduced costs, and thus increasing profits. Several techniques have been used to manage the elimination of waste.

The theory behind *just in time production* is to produce only what is needed when it is needed in the quantities needed. The Toyota Production System achieves just in time production through eliminating excessive production resources, overproduction, excessive inventory and unnecessary capital investment. (Monden, 1997)

Heijunka (Production Leveling) implies that eliminating inter-process variability smoothes the production demands, and the amount of inventory and excess capacity necessary to sustain the desired service levels will be reduced. The concept of smoothed production requires that each type of product be produced at the average demand rate. To achieve this, flexible types of machinery with optimized setup times must be in place. This will result in the ability to shift to changes in the market demands, a balance between processes and increased ability to introduce new products.

The Japanese term *kaizen* literally means, "change for the better." By continuously examining the current production methods and eliminating waste, "the levels of quality, lead time and cost reduction can be improved" (Monden, 1997). A continuous cleanup activity within an organization with strong management support can be an extremely powerful tool both for improving operations and increasing the effectiveness of the employees. By capturing every employee's creativity and knowledge, an organization can target waste in the business processes and eliminate them on a continuous basis.

Lean manufacturing is the elimination of excess productive capacity. In a high volume production environment, it is possible to balance the production tasks of line employees to minimize the idle time. Where each task is timed and matched to the cycle time of the process to enable a level production schedule. Achieving balanced flow requires the elimination of inter-process variability to ensure constant production rates. Large fluctuations in processing times create excessive disturbances in the production schedules. Lean manufacturing suggests that variability must be eliminated from the process and the process steps must be balanced. Once the factory reduces the variability significantly, a lean manufacturing based approach to managing operations can be utilized. Balanced flow lines and single order flow can then be implemented.

The Mid-Atlantic Regional Maintenance Center (MA-RMC) has taken an initiative to integrate Lean Manufacturing techniques into its production system primarily through Kaizen events, which MA-RMC calls Lean Improvements Workshops (LIW's). The MA-RMC has run several LIW's in the traditional Lean Manufacturing approach.

One of the weaknesses of the LIW approach at the MA-RMC is that the repair centers are continually under significant schedule pressures and are not willing to limit production for an entire week to conduct the kaizen event to try to gain long-term improvements.

This can drive the selection of areas for improvement to be focused on areas that are not critical to near term production. Therefore, even if the LIW is a success and improves the efficiency of the area, it may not have a significant impact on the organization as a whole. A high number of LIW's results in many small incremental improvements in the organization, but the focus must shift to more detailed value stream mapping and constraint analysis. The other difficulty lies in obtaining tangible results. This a challenge to the management team in documenting Lean Sigma improvement success and progress.

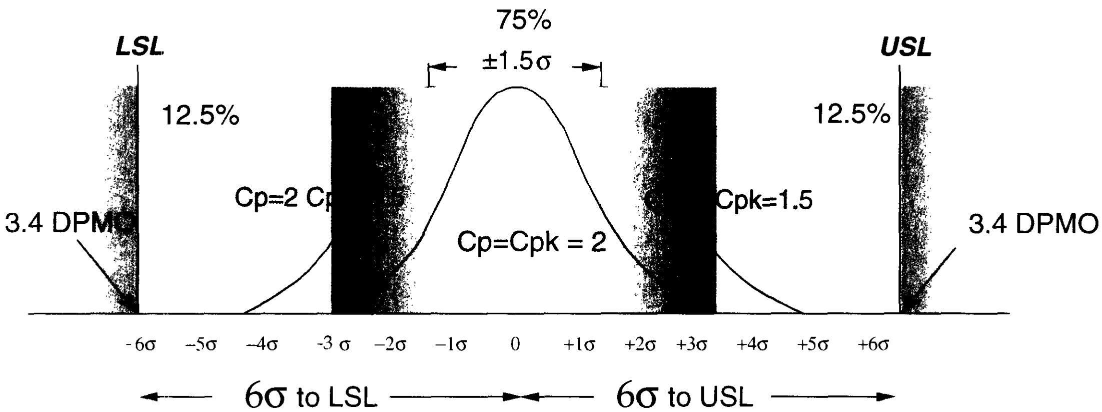
3.4 Six Sigma Background

"Six Sigma" is an optimized performance level; approaching zero defects in any process whether it produces a product, a service or a transaction. Six Sigma seeks near-zero defects and variability. This requires having a common focus on excellence throughout the organization. The objective of a successful "six sigma" program is that all processes (manufacturing, service or administration) are predictable and capable. A predictable process has virtually no out of control points due to special causes. A capable process has a Process Capability Index or Cpk > 1.5 so it will always be within specifications.

Why is 99% success not good enough? Because 99% can mean 20,000 lost postal mail items per hour, 15 minutes of unsafe drinking water per day, 2 bad landings per day at a major airport, 5000 incorrect surgical operations per week, 7 hours of lost electricity per month, or 20,000 incorrect prescriptions per month. The Six Sigma process theory is illustrated graphically in Figure 4.

Statistical Definition of Six Sigma

Statistical Definition



Evolution to:

A Management driven, scientific methodology for product and process improvement which creates breakthroughs in financial performance and Customer satisfaction

Figure 4 Six Sigma Graphical Representation

The levels of six sigma as spelling errors would be equivalent to: 1σ=170 misspelled words per page of a typical book, 2σ=25 misspelled words per page of a typical book, 3σ=1.5 misspelled words per page of a typical book, 4σ=1 misspelled word in 30 pages of text, 5σ=1 misspelled word in a set of encyclopedias and 6σ=1 misspelled word in all books of a small library.

The characteristics of living the government paradigm of "just meeting spec" are: large independent inspection groups; frequent bad parts either reworked or scrapped; no constancy of purpose; external forces driving change only when costs or scrap levels are quite high; and a belief that processes are "just not reliable, never have been and never will be".

4 The "Lean Sigma" Methodology – A combination of techniques

The basic elements of lean are the elimination of waste, workplace organization (5s), value stream mapping and Lean Improvement Workshops

Lean Sigma is a combination of techniques devised for Naval Shipyard personnel to continually improve their work processes. Improvements are based on appropriate customer value data, in order to deliver the best possible products and service to the customer. Lean Sigma is targeted towards shipyard maintenance activities more than manufacturing, but the Process, Principles, and various methods can apply to a wide range of activities: Engineering and design, Production, refit, conversions, Overhauls, maintenance and repair, Logistical support, Administrative systems, Supply management.

Key Lean Sigma Tactics are to Focus on the total system. Do only what is needed, when needed, as dictated by your customers needs. Use existing assets to accomplish the change to avoid adding unnecessary sophistication. Eliminate anything that does not add value as waste. Continuous improvement is through the elimination of variations. Give everyone ownership in the change process so that continuous improvement becomes a way of life. The underlying principles of Lean Sigma are:

1) Know what is "value" to the customer.
2) Make the Value Stream flow by the elimination of variation and waste.
3) Focus on the constraints to deliver value to the customer.
4) Get buy-in and commitment to improvement at all levels of the organization.
5) Use the right improvement tools at the right time.
6) Continuously improve processes and products.

Start by evaluating the value stream. It is that sequence of value added (VA) activities that directly contributes to providing customer value

The Lean Sigma method is outlined as a sequence of stages called Define, Commit, Characterize, Improve, Implement, and Closure. Each stage is outlined in the next sections.

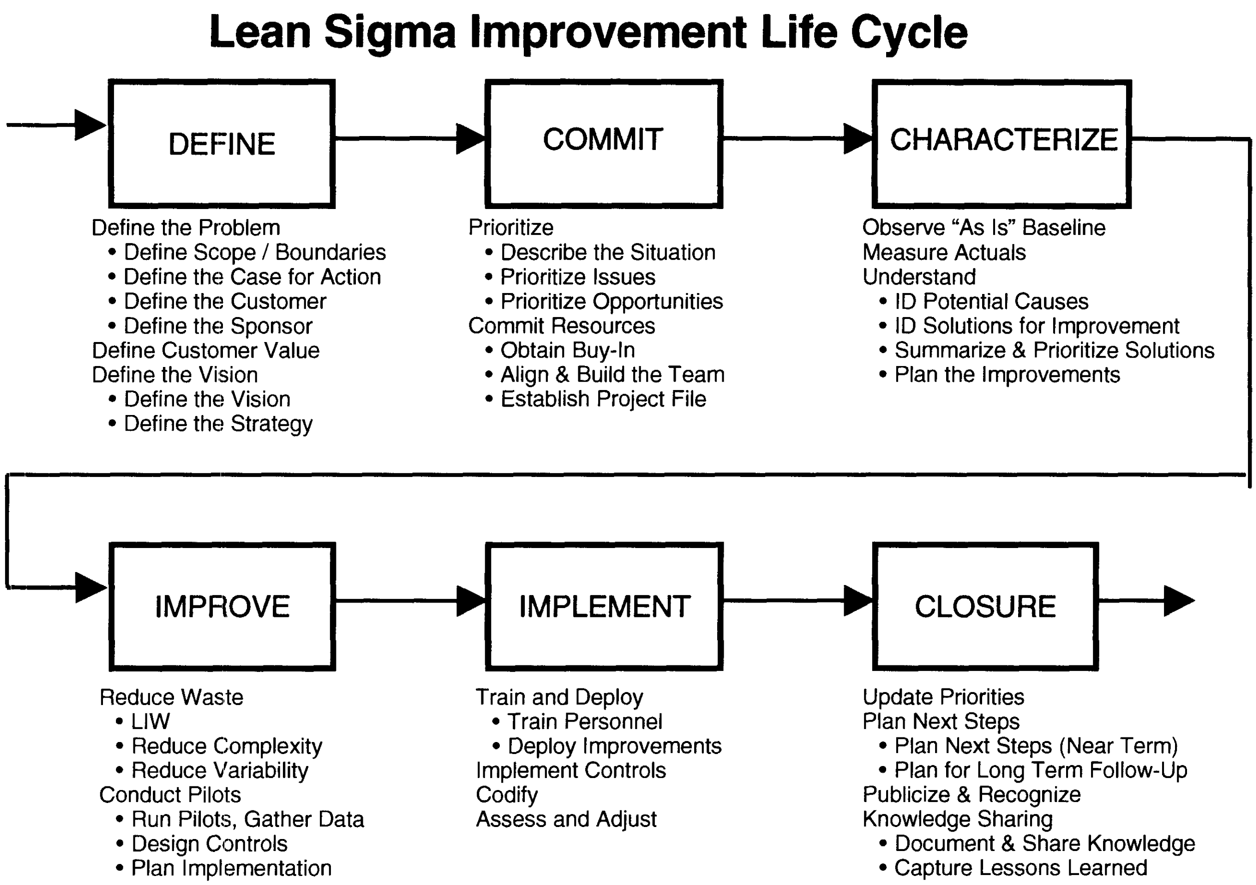


Figure 5 Block Diagram of the Lean Sigma Method

4.1 Define

Begin by defining the problems within the process through observations and discussion, and by defining the current state of the process. Then build the future state of how the process is desired. The challenge is to establish a sense of urgency in the organization and convince them that continuing "business as usual" is more dangerous than jumping into the unknown of process improvements.

A. Define the Scope and Boundaries of the problem to address what areas are included and what is not. Address customer value in detail (breadth of focus) and determine what areas may be ripe for lasting change (depth of focus).
   Define the Case for Action - why tackle this problem?
   Define the Customer – how will it benefit the customer?
   Define the Sponsor - who will provide resources?

The sponsor's role is to authorize activities, commit resources, lead the initiatives, and own the problems and their solutions. Ensure the right sponsor for the desired change is chosen (go only high as needed). Skipping a level can create a gap between. The champion is the lean enthusiast who wants this improvement initiative to work. The champion can serve as sponsor

B. Define Customer Value - what matters to the customer and their priorities. Ultimately the customer is the Navy's ship and submarine crews and their supporting organizations. They want their ships returned at full operational capability, with continually improving cost, schedule and quality performance. They also want agile and flexible shipyards to meet changing operational demands.

C. Define the Vision - what is the desired End State?

D. Define the Strategy - layout how to reach the End State; what are the major tasks to pursue, and who must participate to effect these changes?

E. Outputs From The Define Part of Lean Sigma

    Problem Statement
    Defined Work Scope
    Defined Work Boundaries
    A Case for Action
    Identified Customer
    Identified Sponsor
    List of Stakeholders in the organization
    Customer Value Statement
    Vision Statement
    Strategy (Top Level Plan)

4.2 Commit

Commit resources critical to getting the job done because "without commitment to action its all been just talk up to this point".

A. Prioritize - what is most important?

Describe the Situation - list all of the issues and opportunities-brainstorm with appropriate representation of all levels in the organization. Choose individuals who have experience and interest in change.

Prioritize Issues and Opportunities – ask what needs to be solved first, and where can we make gains; always be looking for "long poles" (hardest issue to solve) and "low hanging fruit" (easily implemented improvements).

B. Commit Resources - who will participate and support?

Obtain Management Buy-In - ensure all parties commit to the Vision and resources needed to get there.

Align and Build the Team -carefully involving the right people and the right skills; begin team-building. Create a list of opportunities for change. Get buy-in from the team, the organization, the department, and the affected workers. Choose to work on initiatives that are good for both the department and the customer.

Establish Project File – this addresses the administrative aspects at the start, and will aid in tracking progress, and determining results to be presented to management.

C. Outputs From Commit

- Description of Current Situation
- Prioritized List of Issues
- Prioritized List of Opportunities
- Buy-In from Stakeholders
- Win-Win Contract
- Committed Funding
- Assigned Resources (People)
- Established Team
- Team Charter
- Initial Project File

4.3 Characterize

A. Observe "As Is" Baseline – determine what is reality (vs "on paper"), and conduct in-depth observation and analysis.

B. Measure Actuals - how well are we really doing, in detail?

C. Understand - develop a common picture get team together daily or as necessary to share findings and ensure management is engaged and endorses the action items.

Identify Potential Causes - what are the root causes?

Identify Solutions for Improvement - what should be done to eliminate the root causes?

Summarize and Prioritize Solutions - how might we tackle things, which can we do, and which should we do first?

Plan the Improvements - schedule time and resources to pursue the prioritized solutions

Successful change requires that each action item be assigned someone responsible with estimated completion and start date. Smaller groups can meet and better define the plan.

D. Outputs From Characterize

List of Observations

Baseline Process-current state

Measurements-metrics, times, distances

Summary Observations-spaghetti diagram

List of Potential and Root Causes

List of Potential Solutions

Summarized and Prioritized Solutions

Improvement Plan of Action

4.4 Improve

Go to work on the problems.

Develop the improvements; create the path to success.

A. Reduce Waste - eliminate complexity and variability.

LIW - Focused Lean Improvement Workshops-conduct a LIW.

Reduce Complexity - simplify and streamline- through value stream mapping of current and future state.

Reduce Variability - standardize on best practices; eliminate variation.

B. Conduct Pilots - test out improvements and evaluate results.

Run Pilots, Gather Data - test out, confirm data.

Design Controls - procedures to keep the improvements working as intended.

Plan Implementation – determine how to roll out the improvements to the workforce; communications, timing of changes, and training.

C. Leadership

Champion of transformation vs. defend status quo- do politicking to convince the naysayers.

Demonstrate the vision in action- nurture successes.

Ask questions, rather than give answers – to energize and empower the workers.

D. Outputs From Improve

LIW Results

Process Improvements

Pilot Results

Control System Design(s)

Implementation Plan

4.5 Implement

Implement and embed the improvements as much as possible. Keep a plan of action to accomplish the more difficult improvements.

A. Train and Deploy - ensure everyone knows what the new processes are and what to do.

Train Personnel - formal or OJT – involve the second and third shifts so it is not seen as a dayshift only and so things don't go back the way they were overnight!

Deploy Improvements - establish new processes.

B. Implement Controls – establish procedures to keep things going.

C. Codify – document the changes in shop manuals or doctrine, putting it down preserves it so as personnel come and go the process will continue.

D. Assess and Adjust - make refinements to accommodate differences from pilots. The refinements require periodic meetings to achieve consensus on the solution.

E. Outputs From Implement

Trained Personnel

Deployed Improvements

Implemented Controls

Codified Improvements

Assessment Results

Documented Adjustments

4.6 Closure

The shop must sustain the gains that have been made. Sustainment is the most difficult part of transformation by Lean Sigma. Follow up is the key to sustainment, therefore develop a 30, 60, and 90-day plan. Ensure that the sponsor in management owns the plan and that every action has its own line item with an "owner" and estimated completion dates.

A. Update Priorities - update the "to do" list.

B. Plan Next Steps - the next long pole or low hanging fruit.

Plan Next Steps (Near Term) - next project(s) to pursue.

Plan for Long Term Follow-up - 3 months, 6 months, 1 year, etc., to ensure process discipline.

C. Publicize and Recognize - COMMUNICATE! Tell management of your successes. Try to show improvements to the "bottom line" with metrics.

D. Knowledge Sharing - "sharpen the saw" and tell others about it.

Document & Share Knowledge – maintain project notebooks.

Capture Lessons - what worked well, what didn't work well, and root causes? Thank the persons who emerged as lean champions.

E. Outputs From Closure

Updated Priorities

List of Next Steps

Long Term Follow-up Plan of Action

Publication Materials

Completed Recognition Events

Published Project Notes

Documented Lessons Learned

The progression of process improvement works best in sustaining the gains if the trend is to steadily improve, rather than a series of reactionary improvements.

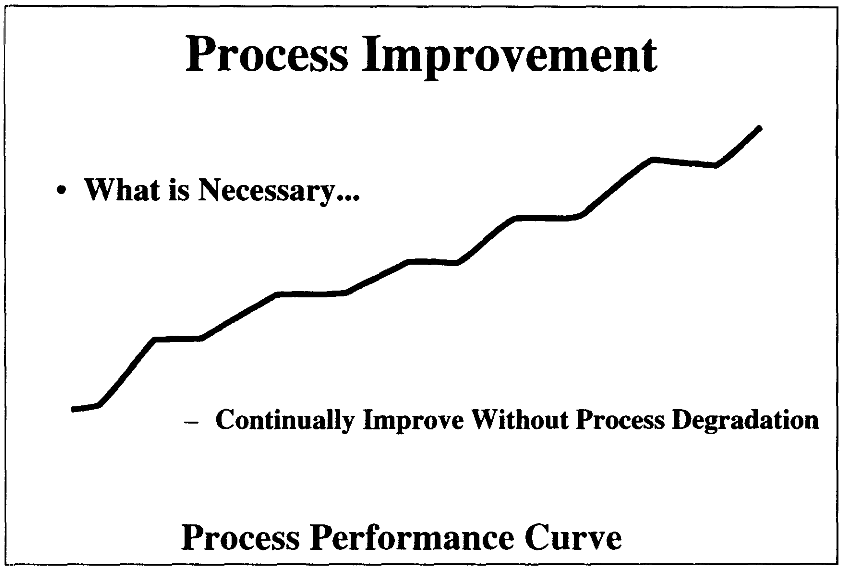


Figure 6 Continuous Process Improvement

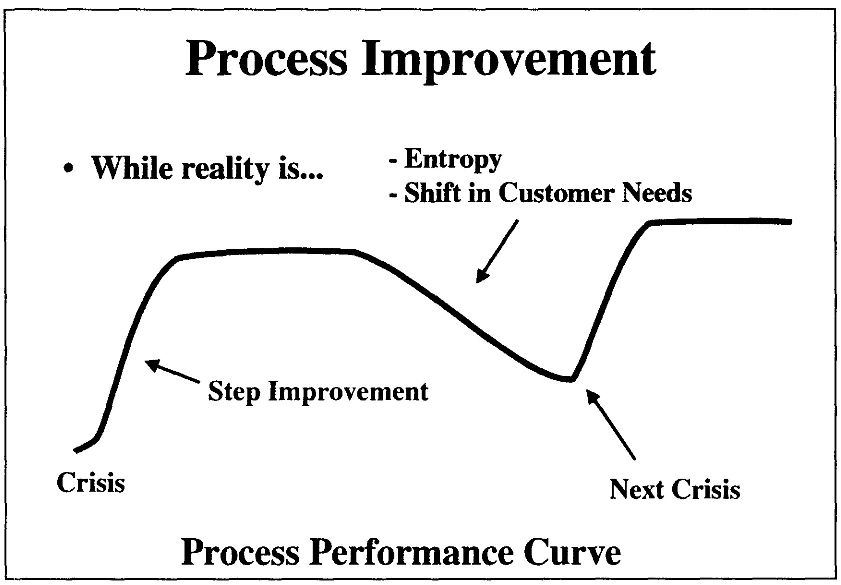


Figure 7 Reactionary Process Improvement

5 Measures of Effectiveness (MOEs) and other Metrics

5.1 Importance of Metrics

The importance of metrics cannot be overstated. They are used for making a case to management that the resources spent on Lean Sigma improvement are well worth it. Conversely, management can use the metrics to kill a project if the metrics do not support continuing the effort. As such the indicators used must be able to show measurable improvement, measure important aspects of the business (customer value), and be specific and accurate. Metrics (measurements) allow comparisons among current performance, past performance, and standards. The metrics chosen will communicate priorities. Behaviors and actions are driven by what is measured. When metrics are not aligned with goals, then the goals may not be met.

Measurements should encourage the "parts" to do what is good for the "whole". That is to encourage the desired behavior and discourage sub-optimization of sectors within the organization. Good metrics are meaningful at each level and related among the levels of the organization. Measurements should direct focus to those areas that need attention or improvement. By identifying the "vital few" constraints or bottlenecks we can drive continuous improvement through smart measurement to allow smart choices based on qualitative, financial, and technical data.

The challenge to the Naval Repair Centers is in calculating a Return on Investment (ROI) in a non-profit organization. The Navy gains for the same budget are increased capacity (surge), increased throughput (more maintenance completed), and more rapid turn around time. The increased capacity should also eliminate the need for contracting additional work to the private sector, saving the customer additional expense. The Military Industrial interdependence and politics will dictate that we continue to contract some work to the private sector to maintain that capability outside of the Navy. Standard measures for facility cost/square feet are $13 per square foot per quarter. This figure will be used in calculating facility cost savings from space reductions. Labor reduction savings are based on an annual labor cost/person of $50,000 for military personnel and $75,000 for civilian personnel. As efficiency goes up the capacity goes up. Obvious savings could be in manpower reduction if the new capacity exceeds demand. This would be a tangible ROI, however it impacts people's lives and is currently the greatest concern of the labor union in regard to lean initiatives.

At NAVSEA Headquarters, the motivation behind process improvement is to save money on maintenance to redirect the funds for new ship construction. As in all organizations, there is a fierce competition for funding among the improvement projects. Therefore the projects that get the highest level buy-in will be funded and survive. These are projects that can deliver or are predicted to deliver tangible monetary results. The CEO and upper management want to have tangible results to the organization's bottom line. Even excellent projects can be cancelled if the ROI or cost avoidance cannot be shown.

The Fleet business office monitors the RRC work by tracking MOEs. MOEs are designed to give managers a tool in the decision making process. They provide a meaningful benchmark, create a sound basis for manning and facilities decisions and monitor the impact of these decisions. Desirable attributes for all MOEs are that they should be simple and few, relevant to decisions, credible, universal, and automated.

5.2 Mid-Atlantic Regional Maintenance MOEs

The Navy selected MOEs on a national, regional, and self-determined basis for monitoring the repair center performance back in 1999, when the RRCs were established. A business case analysis (BCA) was performed and the metrics were baselined at RRC inception.

National MOEs measure total cost, space, and personnel in a designated geographic location (Region). The metrics are collected annually and measured against the regional baseline footprint. The measurement is for all maintenance performed in a region. National metrics are reported in the annual business plan and are standardized for all regions.

Regional MOEs measure the performance of a RRC and other cost centers within the region. The data is collected quarterly and provides the input for an annual report. Included as regional measurements are manpower utilization, responsiveness (measured by turn around time (TAT)), shop throughput and contracted costs. These metrics are standardized in all regions.

Mid-Atlantic Selected Metrics are selected measurements by the Regional Business Office. They are defined as performance measurements for the RRCs. These MOEs are titled as Navy Enlisted Classification (NEC) Tracking, Quality, Adherence to Schedule, Overtime, RRC Utilization, and Personnel Utilization. The selected metrics are unique to the Mid-Atlantic Region.

5.3 Specific Definitions of Each Metric

5.3.1 National Metrics

A. Regional Cost – Cost of the operation of a RRC and cost of similar work being performed in the region measured against the BCA Baseline footprint.
B. Regional Square Feet – Total space occupied by a RRC and total space utilized for similar work in the region measured against the BCA Baseline footprint.
C. Regional Personnel – Total personnel (military and civilian) assigned to the RRC and personnel in the region performing similar work measured against the baseline foot print.

5.3.2 Regional Approved Metrics

A. Utilization - Is categorized into two (2) groups, Production and Support Percentage:

A1. Production - Number of production man-hours (MH) expended against a 2,008 MHs work year. The 2,008-hour work year is pro-rated by workdays in each quarter and is compared against the number of expended man-hours for the RRC in the quarter. A percentage is used as the number of man-hours utilized per person. The expected average percentages are 85% for civilian and 65% for military.

$$\frac{\text{Expended MH's}}{\text{Gross Available}} = \text{Production Utilization}$$

A2. Support Percentage - Number of support personnel based on a total head count minus persons assigned to direct labor. Number of personnel is determined from the RRC employment database. Support man-hours are also tracked to measure indirect overtime.

$$\frac{\text{Support Personnel}}{\text{Gross Personnel}} = \text{Support Percentage}$$

B. Responsiveness – Average number of days to complete a component in a RRC (Turn Around Time).

$$\frac{\text{Sum of (completion date – induction date)}}{\text{Number of jobs completed}} = \text{TAT}$$

C. Throughput - Total number of units processed through a RRC in a given timeframe (each quarter).

D. Contract Cost - Quantity and cost of components normally worked by the RRC that are completed by a private resource. A percentage in this metric indicates the amount contracted by private resources compared to the total amount of components completed by the RRC.

5.3.3 Mid-Atlantic Selected Metrics Description

A. NEC Tracking - Number of military personnel onboard with appropriate Navy Enlisted Classification (NECs) or training to perform work in a designated RRC versus number of personnel required.

$$\frac{\text{NEC's On Board}}{\text{NEC's Required}} = \text{\% of NEC's Achieved}$$

B. Quality - Total discrepancies found by either the RRC's Quality Control/Assurance in the backshop or other portions of repair process or by the customer after the item has been tested and turned over. The quality process is RRC specific due to the differences in their primary functions. A percentage is used to identify the components with or without discrepancies.

C. Schedule - Components meeting the required delivery date that is agreed between the RRC, RSG Production Control and the Customer.

D. Overtime - Number of hours worked in excess of a 40 hour work week.

$$\frac{\text{Expended Overtime}}{\text{Expended Straight Time}} = \text{\% of overtime Utilized}$$

E. RRC Utilization – Number of components worked in a RRC versus components worked in the region (Applies to regional repair centers that are not in their end state).

$$\frac{\text{Units Processed in a RRC}}{\text{Units Processed in the Region}} = \text{\% RRC is Utilized}$$

F. Personnel Utilization – Number of personnel assigned to a RRC versus number of personnel in the region performing similar work (Applies to regional repair centers that are not completely consolidated).

$$\frac{\text{RRC Personnel}}{\text{Region Personnel}} = \text{\% RRC Personnel are Utilized}$$

G. RRC Cost – Total operational cost.

H. RRC Space - Total space occupied by a RRC.

I. RRC Personnel - Total personnel, both military and civilian in a RRC.

6 Test Case in the Electric Motor Regional Repair Center

The customer's greatest expenditures are for pump overhauls and secondly for motor repairs. The Electric Motor RRC was chosen for the first Lean Sigma improvement workshop since the motor shop has a more manageable scope and logical flow than the myriad of pump styles and types of problems occurring in the Pump RRC. The motor repair layout is logical and appears to have a single piece flow basis and had some lean ideas already in place. Its relative importance as the shop with the second largest volume of work could result in a visible victory, to get organizational buy-in and momentum to carry on future Lean Sigma applications to the other shops in the region. The pump repair shop is planned for the next Lean Sigma effort since it performs the largest volume of work. The experience and corporate exposure gained from the motor repair LIW can be used to gain endorsement for a pump repair LIW.

The Electric Motor RRC metrics maintained and monitored by the customer are manpower utilization and support percentages, average turn-around time (from receipt to shipping back the refurbished motor), throughput in motors per quarter, contract costs (to compensate for shop overload), schedule adherence, quality and overtime usage. This test case LIW focused on improving TAT, throughput, and contract cost.

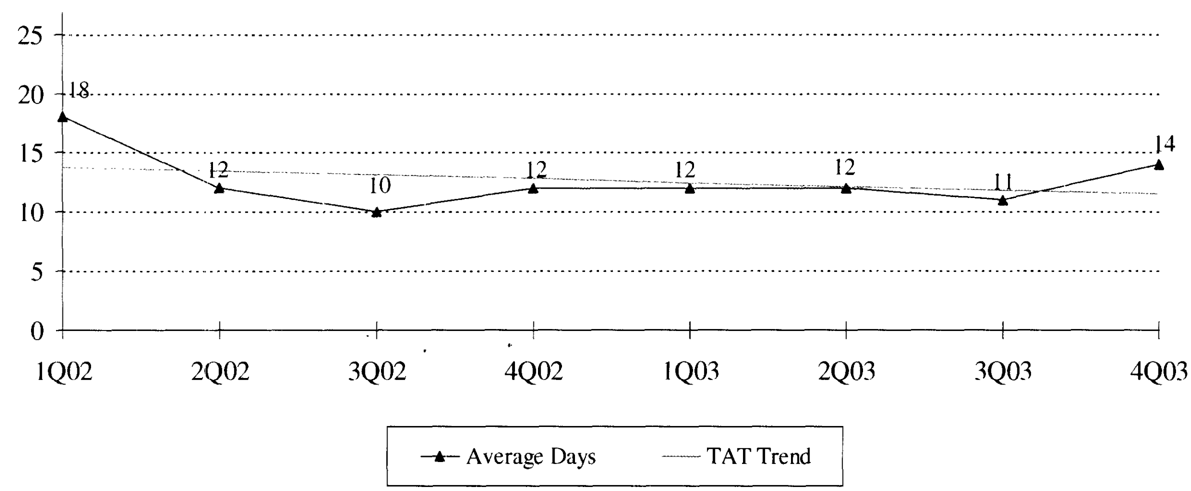


Figure 8 Motor Repair Shop Turn Around Time (TAT)

Currently the TAT is 14 days per motor with a throughput of 210 motors last quarter. Due to shop overload the contract cost was $210,000 for work that the Motor RRC could not do last quarter. The LIW goals are to reduce TAT, increase throughput and eliminate contract costs. Figures 6, 7 and 8 show the Motor RRC performance on these metrics over the past two years.

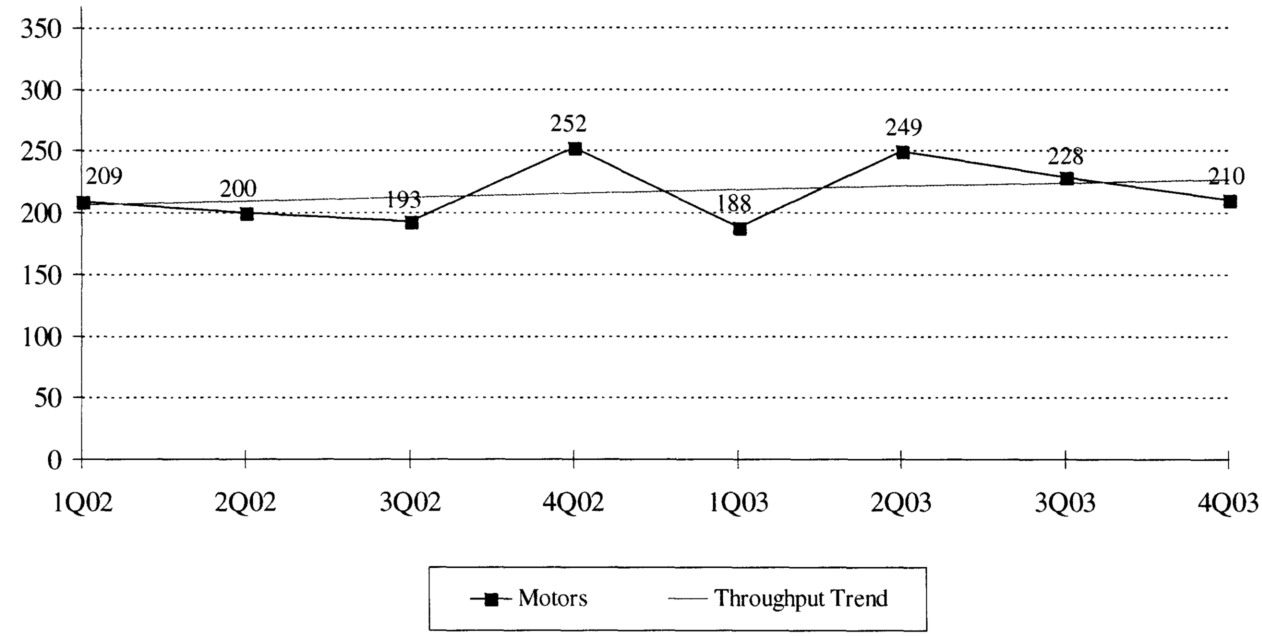


Figure 9 Motor Repair Shop Throughput

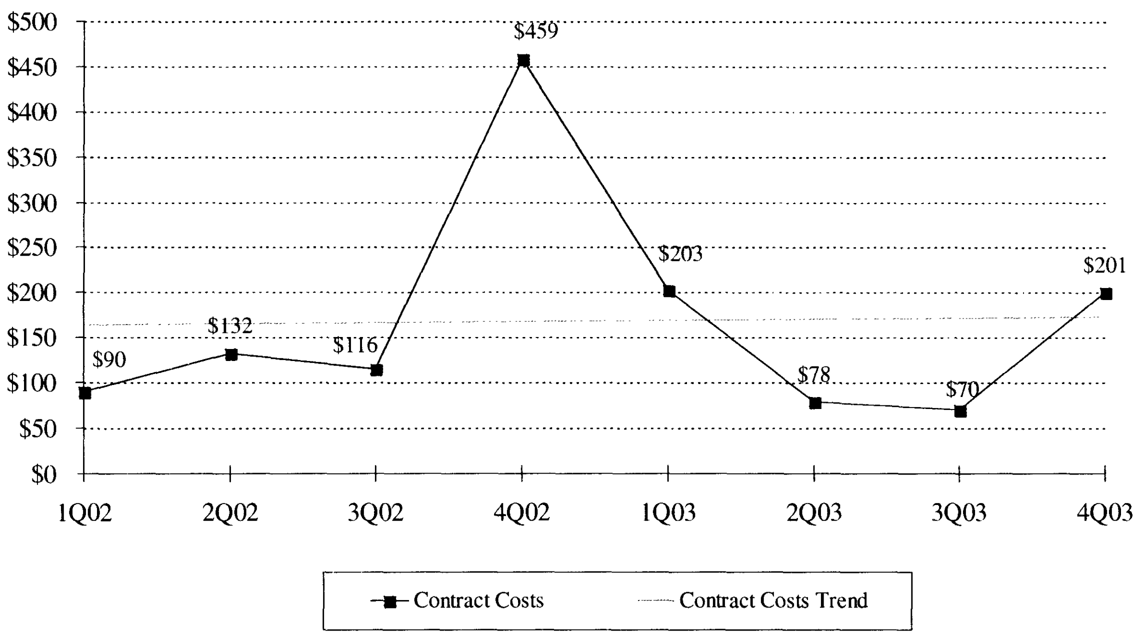


Figure 10 Motor Repair Shop Contract Cost (x 1,000)

6.1 Customer Focus

Focus on the constraints, to deliver customer value by continuously striving to improve processes and products. Any step or activity in a process is considered value added (VA) if it meets all of the following criteria. The customer wants it, it changes the form, fit, or function of the product or service, and it is done right the first time. The primary RRC customer is the Commander of Naval Air Forces, Surface Forces and Submarine Forces Atlantic Fleet, making up over half the RRC workload. Other motor customers include the Naval Inventory and Control Program (NAVICP), Shore Intermediate Maintenance Activity (SIMA), NAVSEA, the US Coast Guard (USCG), the US ARMY, the Submarine Maintenance Engineering and Planning Program (SUBMEPP), Johns Hopkins University, Assault Craft Units (ACU-2 and 4), Public Works Center (PWC), Superintendent of Shipbuilding (SUPSHIP), and NNSY ship overhaul projects.

6.2 Electric Motor Repair Organization, Capacity and Capability

50 military and 26 civilian workers man the Electric Motor RRC. The military crew is comprised of electricians, mechanics and machinists. The civilian crew is comprised of experienced journeymen in the same three disciplines from NNSY. The production team operates 3 shifts per day, and is located in an open warehouse structure of 36,000 square feet.

The shop is staffed to repair, overhaul, and test approximately 1000 motors from the fleet annually with a desired output loading of 4 motors daily. Deployed vessels returning to port for equipment failures and other emergent motor work will be serviced as necessary to meet the operational needs of the ship. Average in shop cycle time for routine repairs is 12 workdays for overhaul and 16 workdays if the motor required rewinding. Vacuum Pressure Impregnation (VPI) treatment of the motors requires an additional week of processing and testing.

The shop has the capability to complete disassembly, inspection, machining, parts manufacturing, parts renewal, re-assembly, and in-shop operational testing of motors. Overhaul, rewind, and operational test of generators up to 2500 kW, submersible pumps, motor-generator sets, and surface and submarine AC and DC motors up to 600 HP, in sea water, fresh water, lube oil, fuel oil, or sanitary systems. The shop has full engineering support including sound analysis, component disassembly, trouble shooting, and assembly.

The floor layout shows the production line components and the space utilization. It is a useful tool to map out the workflow and to identify inconsistencies or wasted movement in the workflow. The actual path the workers take to perform their sequence of tasks can be observed and annotated on the floor diagram. This is called a spaghetti diagram and it will show areas where work sequencing may need to be changed to eliminate the unnecessary movement. Unused or outdated equipment can be annotated for removal or replacement on the diagram.

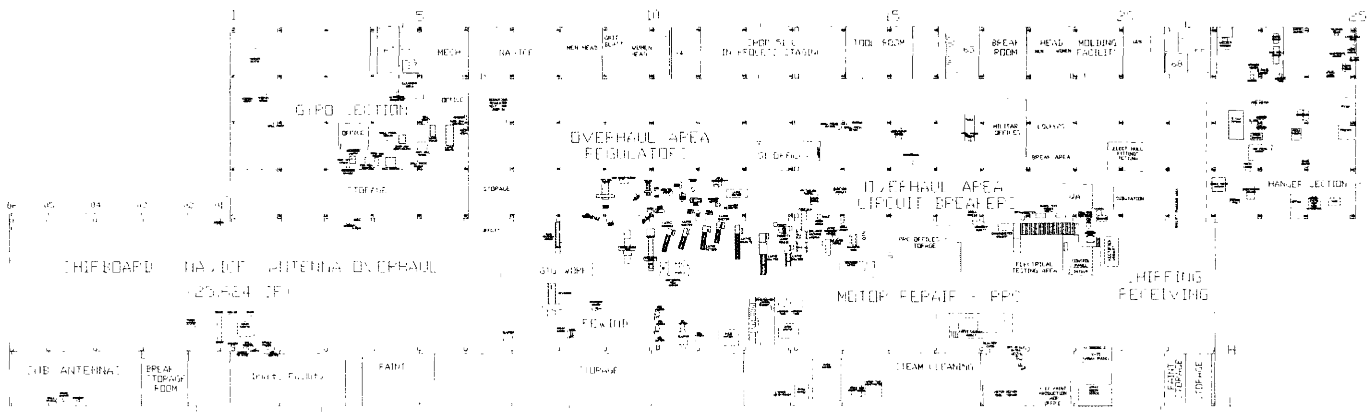


Figure 11 Motor Rewind and Repair Floor Layout

6.3 Value Stream Map (VSM) Creation

Lean manufacturing is the process of eliminating waste to improve the value stream. The value stream is a collection of all actions required to produce a product or service. Those actions that change the form, fit, or function of the product add value. The customer only wants to pay for work that adds the desired value to the end product and everything else is waste. Value in the eyes of the customer is those attributes and features that will satisfy the customer's expectations such as quality level, delivery schedule and cost.

The value stream mapping event is used to develop cross-functional team understanding of the current value stream. The VSM is determined by evaluating the production process in a step by step manner, including decision points and do-loops. Then the workers on the floor validate the VSM. To separate the value-added steps in the process map the team will vote on each step to determine its relative value to the product. The steps must be separated into categories defined as Value Added (VA), Non-Value Added (NVA), and a subset called Non-Value Added but Essential (NVAE). The team then defines the desired future value stream through the elimination of waste. The VA or NVA determinations are made and duration times measured for each step. The wait times or "white space" between steps are also measured. Rapidly implemented "near state" changes typically provide some immediate results but it is essential to create a Lean Action plan for follow-up and continued improvement.

The early versions of the shop VSM were done in VISIO ™ software. The final version, Figure 12, was done in a newer software program called iGrafx ™. The VSM is too large to show the text detail, however it is shown here to illustrate an example of the end product from the mapping event. The legend in

Figure 13 describes the color-coding and symbols of the VSM. Non-Value Added actions are waste. The seven wastes are over-production; excess inventories; producing defective products; over-processing; waiting; and unnecessary motion or transportation. Some examples of waste and complexity are multiple sign-offs and inspections, special or non-standard parts and materials; varying standards and procedures; low yields; high rework; misapplication of cutting-edge technologies; and multiple and incompatible tools.

The goal for the "future state" VSM would be to eliminate all NVA (red) blocks and reevaluate the policy or process that has deemed certain blocks as non-value added "essential" (NVAE or yellow). The NVAE blocks shall all be considered for elimination through policy or procedural changes to develop the future state, which should be the most efficient arrangement within governmental and operational constraints.

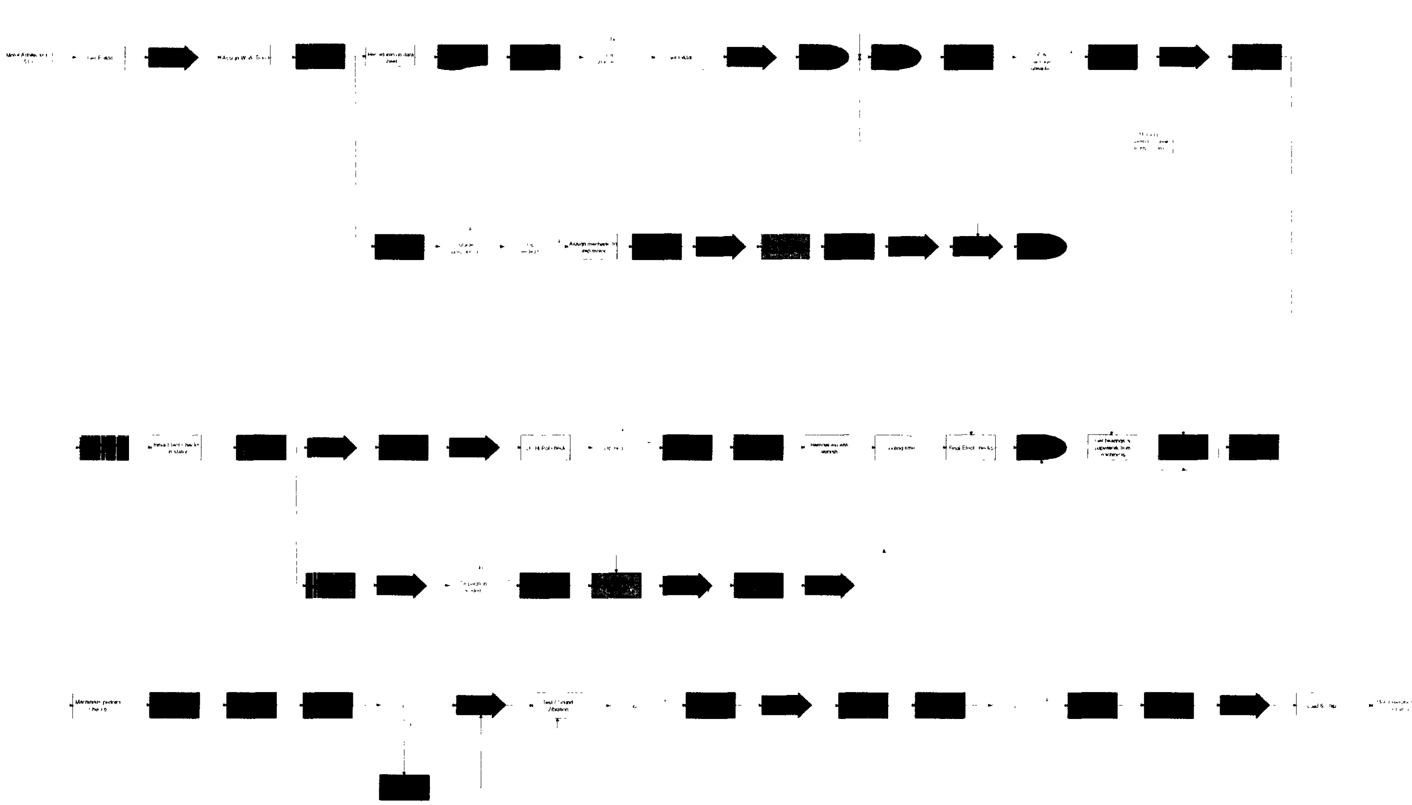


Figure 12 Motor Repair Value Stream Map-Current State

There are 62 steps in the motor repair process as well as 7 decision points. The results of eliminating ten of these NVA steps are described in section 6.5.2 "Value Stream Improvements". Lean Sigma focuses on the value of time because time is common throughout the seven wastes. Over-production is time spent on unnecessary work. Transportation is time spent on excess movement of material. Motion is time spent on unnecessary or inefficient movement. Waiting is time spent waiting for the process or product to be able to move forward. Over-

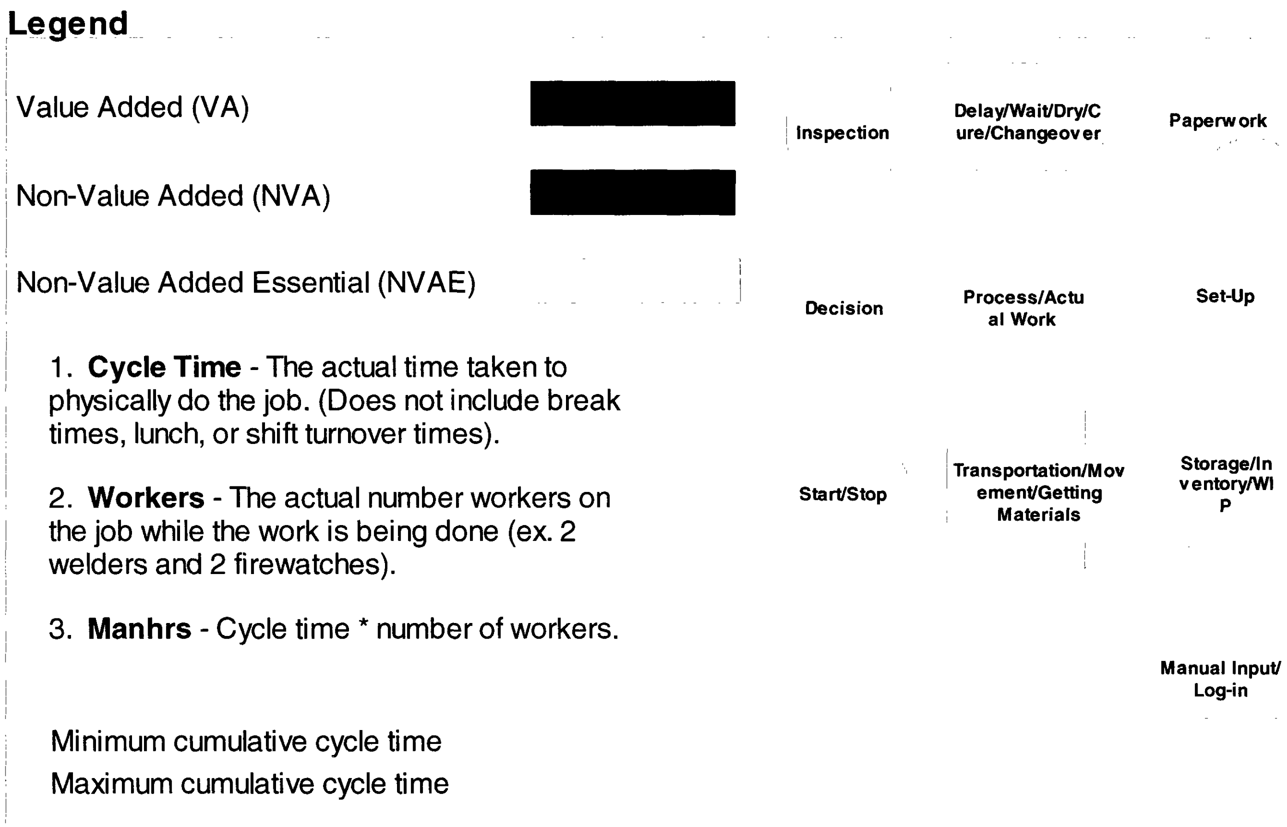


Figure 13 Legend of Symbols for Value Stream Map

processing is time spent on unnecessary reviews, inspections; and time spent making work exceed the necessary requirements. Inventory waste is time spent to track, monitor, and handle unnecessary product. Producing defective products is time spent on inspection, re-work, and additional handling. Making all of the Value Stream visible and reducing or eliminating the NVA portions of the process results in large time savings.

Traditional process improvement focus has been to improve the VA work steps with better tools, machines, or instructions resulting in small time savings. Often by large equipment purchases with little or no attention paid to the inherent capacity being wasted. The motor repair future state value stream map is essentially the current state minus as many NVA steps as possible. Additionally the flow and decision points can be adjusted for efficiency.

6.4 Lean Improvement Workshop Execution

The LIW began with Lean Sigma introductory training for the designated implementation team plus as many other personnel that could or would attend. A pair of Process Improvement

Engineers (PIEs) who have been trained extensively in the theory and application of process improvements guide the team training and all preparatory and follow-on team actions. One of their goals is to cultivate a Lean Champion within the shop to lead the sustainment efforts as well as continuing to evaluate the process for bottlenecks and waste. Continuous politicking on the shop floor and with management was beneficial to sell the potential benefits of the LIW project and develop some momentum before the project began.

The four phases of LIWs are presented graphically to show the preparatory and follow-on activities that are required to make the actual workshop a success.

[redacted] [redacted] [redacted] [redacted]

Assessment

- **Assess opportunity**
  - Product and flow
  - Processes
  - Equipment
  - Demand level
- **Examine readiness**
  - Need for improvement
  - Enthusiasm
  - Culture

Boundaries of the Process

- **Management education and expectations**
  - Purpose and process
  - Desired outcomes
- **Team selection**
  - Representatives of the process
  - Key stakeholders
- **Detailed plan and data collection**

Conduct Workshop

- **Teach lean principles**
- **Analyze process through actual walkthrough**
- **Teach steps of continuous flow**
- **Application of selected process**
- **Vision of area and flow**
- **Projects for this week**
- **Go do assigned**

Follow-Up

- **Walk through area**
- **Complete action items**
- **Resolve problems and conflicts**
- **Maintain momentum and attention**
- **Plan next workshop**

Figure 14 The Four Phases of Executing a Lean Improvement Workshop

The team defined the VSM as discussed, and observed the workers on the shop floor to create a spaghetti diagram identifying their wasted travel. All workers were casually asked for their opinions on the current state of affairs in the shop. Questions such as "What is your biggest headache?" or "What things need to be changed around here?" prompted valuable insight. The LIW team also identified equipment that was not in use. Large outdated equipment that is not easily or cost effectively removed is often referred to as "monuments". These preparatory steps were complete before the LIW workshop was kicked off. The information gathered from the people doing the work was presented to the LIW team during the workshop.

6.4.1 Observations and Brainstorming Results

After team training and a review of the VSM, several "no holds barred" brainstorming sessions were held with the LIW team. The brainstorming sessions were moderated by the PIEs. The first session determined all of the problems that existed in the shop from the LIW team perspective. The second brainstorming session was focused on determining possible solutions to the problems.

The team ranked the problems and solutions via a multi-voting process and then grouped similar problems into broad categories. Multi-voting is a group decision-making technique used to reduce a long list of items to a manageable number by means of a structured series of votes. Use multi-voting whenever a brainstorming session has generated a list of items that is too extensive for all items to be addressed at once. It is also a way to prioritize a large list without creating a situation in which there are winners and losers in the group that generated the list. The result is a short list identifying what is important to the team. Multi-voting provides a quick and easy way for a team to identify the most popular or highest priority items on a list, those that are worthy of immediate attention. The results are shown in the following table.

Brainstorming Problem List	**Brainstorming Potential Solutions List**
TRAINING / COMMUNICATION Lack of motivation Poor communication between shifts Poor teamwork Lack of knowledge among leadership Schedule & directions are tentative Lack of direction Lack of experience Disconnect between training and actual practices No continuous / refresher training Lack of training No training on new equipment Status of work not easy to determine	**TRAINING / COMMUNICATION** Shop Indoctrination Training Management Indoctrination Training Disassembly / Reassembly Classes Added on-site training Timeline for and issuance of Qualification Cards Military & Civilian support/billets for all shifts Single muster / morning meeting Visual Status Board Work assignment board
WORK DELAYS Tool boxes in way of each other Defective / broken equipment Out-of date bearings received from cog engineer Tools not at point-of-use, have to check out or borrow Couplings & fittings not available Not notified if coupling or fittings are broken until needed Tooling Changes Planner not notified when need for parts identified Hardware not at job site Hardware hard to locate	**WORK DELAYS** Shift specific tool boxes for each work area Tools (two sets) at each bench Tool boxes (2 per worktable) with full set of tools at each table Hardware cabinets located next to work tables Color coding of tools / boxes Clean and straighten coupling and fitting storage KanBan for hardware cabinets to be replenished

Brainstorming Problem List	Brainstorming Potential Solutions List
<u>EQUIPMENT</u> Large parts washer not cleaning adequately - still have to steam clean Lack of follow through on equipment purchase (ex: cutters, dremel tools, etc) Set-up time on dyno and balance machines Balance fittings need manual adjustment due to wear Small oven (next to large oven) not working Small parts washer not hooked up (do we need it??) New equipment not being used Timeliness of installation of new test units Lack of modernization plan Old equipment	**<u>EQUIPMENT</u>** Small oven removed and disposed of Industrial Engineer assigned to track equipment purchases and ideas Material Clerk assigned to replace worn fittings
<u>ATTENTION TO DETAIL/REWORK</u> Misplaced work packages Defects not addressed prior to forwarding to balance section Using wrong hardware Balance section having to clean motor Having to tap holes after motor has been dipped Deficiencies not known causing added work Defects not corrected before preps Not prepping parts before machine checks Misplaced / mislabeled items Components / parts mixed with items from other motors Motors require rework Missed defects discovered at assembly Needed items tossed	**<u>ATTENTION TO DETAIL/REWORK</u>** Parts racks labeled Note on status board when defects noted / corrected Visual flag on job jacket when defects need correction Add requirement (in paragraph for evaluation sig) to ensure defects reported for action
<u>PAPERWORK/DOCUMENTATION</u> Duplication of Quality Assurance (QA) checks QA pretest check is a courtesy check Supervisor QA check is redundant / not needed Too much paperwork	**<u>PAPERWORK/DOCUMENTATION</u>** Eliminate pretest QA checks Eliminate mech. and supv. pretest QA checks
<u>CRANES/FORKLIFTS</u> Waiting on crane operator Wrong people have crane license Painter doesn't have crane license Not enough forklift licenses No crane available or Slow cranes	**<u>CRANES</u>** Evaluate who has crane licenses (create more on floor, less in office)
<u>ASSIST ORGANIZATIONS</u> Criteria for bearings overly restrictive Assist shop services takes too long (cleaning, blasting) Equipment and Tool Calibration lab delays Only one painter - one shift Insufficient tech support	**<u>ASSIST ORGANIZATIONS</u>** Consider establishing satellite assist shop services in house (cleaning, and blasting of motors) Setup meeting with the Cal Manager
<u>OTHER</u> Pigeon droppings	**<u>OTHER</u>** Replace broken windows and remove pigeons from the building!

Figure 15 Brainstorming: Problems and Potential Solutions List

Unfortunately when the brainstorming results were briefed to the shop middle management, they remained somewhat defensive and shot down some of the potential solution ideas without discussion. For example the shop manager did not want visual work status boards, rather he wanted to keep control of production via the shiftly work list printout. Since the printout is not widely disseminated, then the workers would remain dependent upon verbal instruction to know what the work priorities and schedule are.

During the LIW project two people stood out as improvement leaders. It has been recommended to management that they carry on the improvement efforts as the Lean Champions for the shop. Once the team began initiating improvements some occurred in the first half day, some took weeks, and some have been moved to the long-term list which becomes the responsibility of the Lean Champion. A common remark during the early part of the workshop was that "It can't be done". This is simply a lean process challenge to find solutions that are easier to implement and to designate small teams to focus on how to make the more difficult ideas work.

LIW project success begins and ends with good planning because implementation will be difficult without a structured approach. Remaining confident and principle based will help keep the project on track. There must be an investment mentality throughout the shop. Relating local improvements to the organization big picture can motivate the team. Meaningful visits and the presence of upper management support are essential if any lasting change is expected.

6.4.2 Applying The Five Ss of Lean Manufacturing

What are the Five Ss? They are derived from the Japanese words for five practices leading to a clean and manageable work area: *seiri* (organization), *seiton* (tidiness), *seiso* (purity), *seiketsu* (cleanliness), and *shitsuke* (discipline). (*Womack and Jones, 1996*)

The exact number and words used is less important than the underlying idea of eliminating waste and creating value and efficiency in a process. A key component to the Lean approach is to establish a "visual workplace" where anyone can walk in and visually understand the current situation regarding the process flow and status of work.

This thesis classifies the Five S categories as Sorting, Straightening (simplifying), Shining (systematic cleaning), Standardizing and Sustaining. It is easy to simplify the concept of Five S into a housekeeping and cleaning project. There is some initial benefit to the organization (since there are areas that need a solid cleaning sweep), but housekeeping rarely addresses the underlying workflow problems. In fact, the "housekeeping" approach is often characterized as "rearranging the deck chairs on the Titanic". The true impact of Five S is missed if this is the prevailing attitude.

Five S is better characterized as culture change than a sweeping of the work area. To have a place for everything and everything in its place, clean and ready for use requires a complete understanding of the underlying work process and significant effort to make sure that substantive changes to these work processes are made. Five S has the potential to include continuous process improvement, total productive maintenance, workflow productivity, safety and ergonomic improvements. The steps can be done in different order or simultaneously but all must be done to effect change. One colorful way to put this was to "Do the 5Ss not half S".

Sorting is to divide items into two categories of necessary and unnecessary. Discard unnecessary items and categorize necessary items into rarely used, occasionally used, and frequently used. Identifying items for disposal was accomplished by attaching a red tag to all unnecessary items.

Straightening is to determine locations for needed items and to create visual locations. Move tools and materials to the work site for point of use storage. The goal is to have a place for everything and everything in its place, clean and ready for use, at the work area.

Shining is to build pride in work areas by eliminating dirt. Additionally it builds value in the equipment by using cleaning as a form of inspection. Machines will be better maintained if their true condition can be seen. Clean and sweep all surfaces.

Standardize by assigning "5s" responsibilities to the workers and integrate "5s" into their regular work duties. "5S" help-sheets for end of shift cleanup, tool inventory, and workplace scorecards can institutionalize the practices. Grade all areas on "5s" perfection and reward the winners to recognize and cultivate the desired behavior.

Sustain is the process of maintaining the improvements and always going further toward a truly lean organization. A structured plan with the following elements will aid in sustainment.

Strategy: The Five S program will sustain when there is a strategy for the program and a linkage to the organization's business and strategic plan.

Budget: It is unreasonable to expect changes to be funded and activities to be supported with informal budgets or special arrangements. Real financial backing from the top must be evident.

Metrics: The measures of success must be quantifiable and linked to the bottom line. Building support and momentum without tangible results will not endure.

Formal reporting structure: Designate individual responsibility for providing status reports on Lean Improvement schedules, results and ongoing measurements to ensure communication.

Governance: Methods for keeping the principles, resources and focus clear over time are a major sustaining component. Lean activities must be captured in shop policies and procedures.

Staff leaders must provide a visual demonstration of commitment to Lean Repair. Five S needs wide spread awareness of the sponsorship and the expectations of management. A significant role of the leadership is to provide advocacy to remain true to the principles of change and guidance when shop participants are confused. Communication, visibility, and sharing are the foundations of program sustainment.

There are many pitfalls that can undermine the efforts of a %S program. Five S can fail if it never grows beyond a house keeping mentality. If funding is not available and there is no management support "5S" will fail. The work area employees on all shifts must be included or "5S" will fail. If the workshop size, cost and team membership are not properly considered then "5S" will fail. If there is no knowledge base, no process for change and no continuous improvement framework then "5S" will fail. If the cost and benefits of improvement ideas are not considered then it is likely that "5S" will fail. Finally if you cannot break the "tyranny of production", that is that all personnel are too busy to spend time improving, then "5S" will fail.

6.5 Results: Both Tangible and Intangible

The Motor Repair LIW project reached the Closure or "sustain" phase in the improvement methodology. The shop metrics are published on a quarterly basis, however, the trend from monitoring two months worth of production shows progression toward all three success goals; reduction in TAT, an increased throughput and a savings in contracted costs.

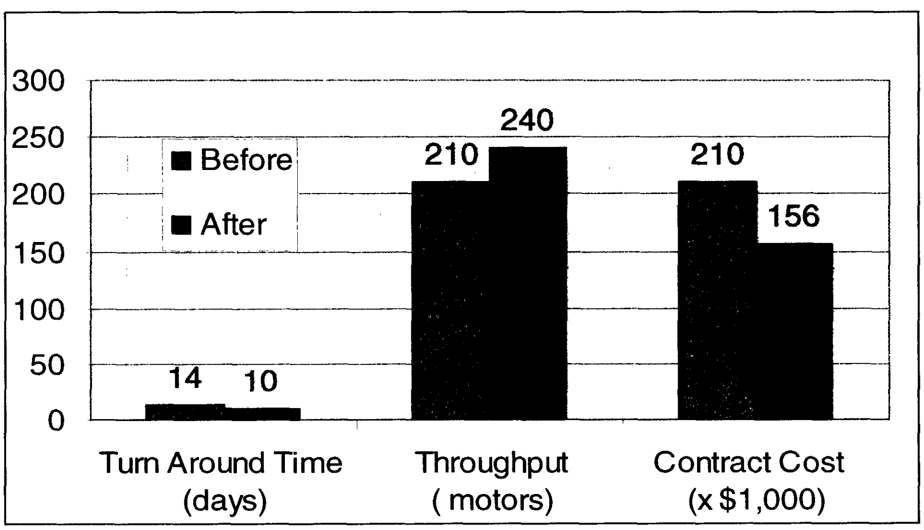


Figure 16 Comparison of Before and After Motor Repair Shop LIW

6.5.1 Waste Reduction Results

The brainstorming solutions that were implemented saved approximately 1560 feet of wasted travel per mechanic per shift by moving toolboxes to "point of use" and moving common hardware to the assembly/disassembly area. Monetary conversion can be done by knowing that the wasted travel takes thirty minutes, there are 3 shifts with 8 mechanics per shift at a cost of $75/hour. The result is $900 in saved labor costs per day. Tool cost and inventory was reduced by approximately $98,000 by turning in 36 individual toolboxes and creating 8 common sets; one for each work area.

Shipping and Receiving storage shelving was arranged in a "U" shape with no "laydown" area allowed in front of the shelving. This reduced forklift and pallet movement times previously wasted to get to the needed components on the shelf. Separating shipping from receiving also reduced movement and has contributed to the reduction in TAT.

Unnecessary material was scrapped and infrequent or emergency use material items were sorted and sent to the warehouse. Unused or broken equipment was removed, except where removal was cost prohibitive (monuments). During the sorting, the team found $20,000 worth of submarine motor screens and $6500 worth of misplaced stock.

Workflow was improved by organizing the shop floor and labeling work areas and storage to clarify the flow and identify parts bin contents. Old hardware storage areas were disestablished and commonly used hardware material was moved next to the motor assembly area.

Multiple Quality Assurance (QA) checks are redundant and wasteful. There is no real quality improvement since each subsequent inspector assumes "it's already been checked" and does a less vigilant check. Roadblocks to change are found in the written policy and the ingrained history of the shop in performing multiple QA checks.

Motor deficiencies were not flagged or communicated well enough and caused delays at assembly. For example a broken stud in the motor casing was not discovered until final assembly, resulting in rework. A visual flag for motor defects was developed for attaching to the component and for the work instructions that accompany each motor.

An outbrief to management highlighted some intangible improvements such as improved floor layout and appearance resulting in cleaner more organized work conditions. The level of knowledge in shop processes was raised through targeted indoctrination training. More lean improvement work remains to be done. The problem solutions that have not been implemented are being tracked on an "Open Lean Actions List" for future implementation. The workshop was conducted in the last quarter of 2003 and the next quarterly metrics have not been completed as of submittal of the thesis. Expectations are to see a reduction in TAT, an increase in throughput and a subsequent reduction in contracted work costs.

6.5.2 Value Stream Improvement

The NVA steps that can be eliminated result in fewer man-hours spent on each motor repaired. To the customer it would be a lower cost per motor. In a profit-based organization, the labor would be used to repair more pumps and the resulting increase in throughput would create more revenue. The Motor RRC can pass on the savings to the customer. Two redundant Quality Assurance (QA) checks were eliminated. Point of use tooling and hardware has been implemented to eliminate these NVA steps in getting tools and hardware. Some visual status boards are being implemented to eliminate waiting for assignments. The reorganization of shipping and receiving as well as using rolling carts has reduced waiting for forklifts. The wasted time in duplicate efforts for re-washing motors and having to correct deficiencies at assembly have been reduced by implementing the visual cues on the motor and its work package indicating whether either action is needed. The measured time and money saved monthly by eliminating these labor wasting NVA steps is summarized in the graph below.

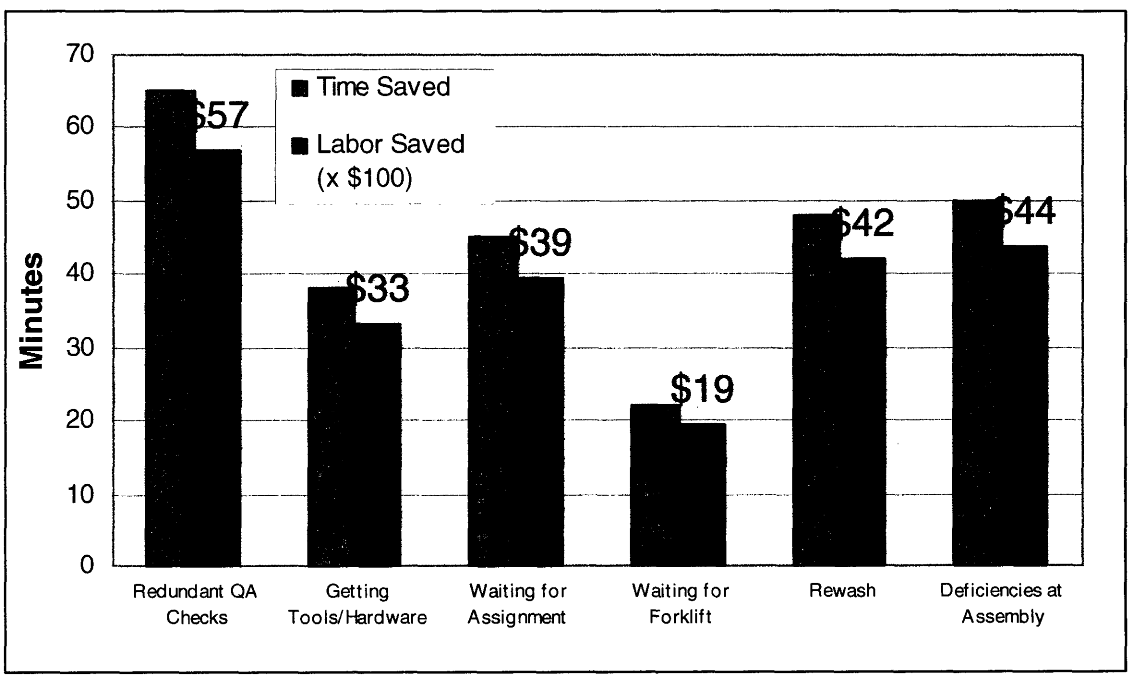


Figure 17 Monthly Labor Savings from Eliminated NVA Steps

At first, value stream improvement is in "freed capacity", another intangible until you raise throughput, then the ability to absorb more work with the same resources will increase revenue, a tangible result. Floor space (overhead) can be shown as a cost reduction if the space costs are moved off of the shop ledger. Standard measures for facility cost/square feet are $13 per square foot per quarter. Less rework (increased efficiency) will result in a drop in the cost per unit motor. Smaller inventories of parts show up as direct savings and secondarily fewer containers and forklifts will save on equipment costs.

These improvements take time to be realized and are hard to see on a general ledger. To ensure success the team must understand and remove waste and variation to create a stable process. Understand the capability of the shop, and aggressively make improvements but make sure that the improvements support the future state value stream plan.

When measuring for results, know what value means to your customers. Do management accounting by value stream and pick goal indicators related to customer value. Pursue change in those process indicators that support the goals, and create lean behavior in the workplace.

6.6 Capital Investment Analysis

To show a change to the organization's bottomline, a tactic called "Glass House Management" takes the freed capacity away from the improved area both physically and fiscally. Put it in a "glass house" for everyone to see, and account separately for it. This will give credit for the shop improvement, and makes managing the freed capacity everyone's responsibility. Additional savings may be realized for making work spaces available when the additional available space can be used for other mission contributions. Although floor space has been cleared, there is no other tenant in the building to shift the utility costs to.

The goal behind the microeconomic decisions of private ship repair businesses involves striving to optimize their operations and thus maximize profit. Since profit equals revenue minus cost, Lean Sigma efforts must be viewed as an investment to help reduce costs and as such support greater profit. In theory, all owners who are not yet operating with the leanest processes will be interested in reducing operation and support costs with Lean Sigma efforts.

In the short-term there will be implementation and training costs but in a short time (or payback period) the benefits will outweigh the costs and the net effect is a large monetary saving over time. The approach is to invest in those ideas with the biggest impact and relatively short payback periods first to most effectively reduce waste and costs.

The cost of implementing Lean Sigma ideas is generally a nonrecurring cost, but there will be a lean maintenance burden to institutionalize the practices. As with all capital investment decisions, there is an amount of uncertainty involved in the financial analysis, such as the actual number of mandays of labor avoided. Perhaps the union or the employment policy will not allow the maximum reduction of manpower. There are also U.S. Navy and NNSY policy requirements for specific actions or tasks required in the repair process. The goal of waste reduction should be to drive to the legal minimums and then revisit the basis for those legal policy limits.

The cost of this Lean Sigma Improvement Workshop in labor material and tools was $52,800 with predicted monthly savings of $23,500. The resultant payback period is 2.25 months. The more difficult and time-consuming improvements have not yet been accomplished. They will be evaluated on the potential savings and payback period. The estimated risk of Lean Sigma improvement actions is very low. The conclusion of this thesis is that Lean Sigma Investment to reduce waste and operating costs is a smart economic decision, for both US Naval and Commercial repair facilities.

7 Conclusions

7.1 Organizational History, Cultural and Policy Barriers

Recognizing the training function that the RRCs provide the sailors there is room for improvement in how the military workforce supports the civilians. Too often the military goals for military protocol and shore leave conflict with civilian goals for increasing throughput. Civilian RRC managers do not feel they can rely on the military resources when the workload demands increased effort. A false reduction in manpower is created due to military training requirements and to budget constraints from the customers to level load the men used per day.

Another policy constraint identified was that outside supporting work centers cause too many delays and affect the turn around time on the motor RRC. An improved method of tying the various support work centers together is needed. The shop must determine if it is best to perform the tasks in-house vice sending the motors to a support area. The following problem areas exist when outside assist shops are used: waiting on hydro blast cleaning efforts and the potential need for an alternate-blasting medium; pipe shop brazing availability; and machining functions. The shop also experiences material supply problems. Decisions are needed to determine the type and quantity of parts to be stocked to avoid supply delays.

Industrial Engineers assigned to the shops were associated with a Capital Purchase Program meaning that the first question being asked was "What can we buy to improve operations? These is a classic mistake where no one is looking at the sea of waste to determine where waste can be eliminated and plant reserve capacity found.

Resistance to the "flavor of the month" was experienced from those that had been in the shop longer and had seen various initiatives discussed, implemented and failed over the years. Common statements like "I've been trying to change that for twenty years, it ain't gonna happen" or "in my 35 years I've seen these ideas come and go-we've got a system that works"

The management sees the workers as unwilling to change, and they see management as not interested in improvement. Alleviate this by training the key stakeholders on Lean Sigma, and including key personnel early in the implementation process and strive for a representative from each segment of the workforce that is affected by the changes. Greater buy-in is achieved when those affected are part of determining the new system or method. Changes cannot be forced on a group, the changes must be accepted by the group to achieve a self-sustaining change. Cross functional groups also clear up misconceptions about policy, how things are done versus how things are written to be done. Capture the best practices in writing and help sustain the change by discussing tribal policy.

Frequent turnover of personnel, especially military, detracts from the sustaining process. Include influential workers that also have some longevity, in up front lean improvement planning sessions. Establish structured training mechanisms as part of the required sustaining effort in the shop. A heavy reliance on visual signals in the shop will also aid in acclimating new personnel.

The uniqueness of being a government job shop that is trying to implement ideas from the private sector can be minimized by placing a heavy emphasis on understanding the principles of Five S (instead of the applications). Spend significant time during the planning phase on understanding and defining the work processes. The uniqueness of the size of the equipment and product requires a willingness to design and fabricate unique material handling equipment where necessary.

Multiple shifts require that the second and third shifts be integrally involved in the planning of the program and well trained on the work agreements.

Disruption to the workshop, ("We don't have time to do this right now"), must be avoided by getting senior management to treat the Lean Sigma program on a par with ship repair work. Closely coordination between Lean Project Managers and Production Managers to schedule the workshops along with the ship repair work. Closely work with executive management and the shop leadership in selecting the right members for the team. The goal is to have knowledgeable representatives from each aspect of the value stream process, and not just get whoever is not busy or not an impact worker. The team members must be relieved of their normal duties to avoid being pulled away from the workshop focus.

There are many different lines of accounting and "Who will pay for this" is always a shipyard cultural problem. Unfortunately each group is trying to look fiscally healthy without regard to the effect on the organization as a whole. A lack of funding the improvement initiatives undermines the process and prevents achieving a sustained change. Shop management agreed that shop personnel should work on process improvement as part of their normal workday and that funding should not be an issue. This mindset must be developed throughout the shipyard. At the conclusion of the workshop, the team seemed very interested and growing in cohesiveness. They seemed to all agree this was a good first step, and they were ready for more. Some good team comments were: "Good ideas, should've been done a long time ago", speaking of the PIEs, "they have been trained and they will frustrate you to no end, but in the end, you will make a vast improvement", "I really believe in Lean...if I came off as a little slow out of the chute, I apologize...this is my house and I want you all to feel like it's your house".

7.2 Lessons Learned

First workshops should make a visible difference and should be shop floor events. Workshop momentum and focus can be maintained by having an end of day debrief with the full team and a second debrief among team leaders. Conduct introductory Lean Sigma training to as many workers as possible in the weeks leading up to the workshop as well as at the beginning of the workshop to develop lean thinking. Showing dramatic before and after pictures and metrics during management presentations will help gain their interest. It is best to use the same vantage point when taking the after pictures. Do not get bogged down creating VSMs if it will consume too much of the workshop time. It is better to start a VSM in advance of the workshop and use the team to validate the VSM so that the elements of brainstorming, Five S and the visual workplace can be given the same emphasis.

Most LIWs focus on the production floor. Do not forget to conduct subsequent LIWs above the shop floor in the areas of planning, material supplies, engineering, and accounting. These areas will also benefit the value stream and if neglected, will limit the scope of the improvements. A successful LIW was conducted in the Shipyard Payroll and Travel Office using the Lean Sigma methodology. The results are presented in Figure 18.

Payroll and Travel Office LIW Savings		**Based upon a three year period.**					
Office Workers	Time savings from eliminating NVA steps					Total	Dollars
Resource Manager	1	0.1	-0.1	-0.1	-0.1	0.8	$42,622
Runner	0.25					0.25	$8,171
Executive Assistant	0.25	-0.1				0.15	$4,782
Cycle time reduction	2	1					
Estimated Number of Travelers	6800	(over 3 years)					
Travelers	From	To	Difference	# of People	Time Reduction	Manhours	Dollars
Complete form with clerk	75%	40%	35%	2380	0.5	1190	
Return to ASC with completed form	25%	10%	15%	1020	0.75	765	
Reduced Time to Complete	100%	100%		6800	1	6800	
Reduced Time to Complete Partials	100%	100%		6800	1	6800	
					Subtotal	15555	$448,606
Clerk							
Complete form with clerk	75%	40%	35%	2380	0.5	1190	$29,500
						TOTAL SAVINGS:	**$533,682**
						Annual Savings:	**$177,894**

Figure 18 Payroll and Travel Office LIW Savings

7.2.1 Change Management in Lean Sigma Implementation

Increase organizational acceptance and buy in by creating a sense of ownership. That is the reason for tailoring and adapting the workshop schedule with all parties, and involving as many people as possible in the team selection and execution of the LIW. Widespread participation by influential members will increase advocacy for the Lean Sigma program; as in "I know that person" and "We did this".

Increase organizational motivation by selling the reasons for change as related to the organization's role in the bigger picture of naval readiness and saving maintenance costs to build new vessels. Attempt to get individuals to see the vision of a lean repair enterprise. Presentations are by invitation and not mandatory participation to encourage voluntary participation. Coordination of the PIEs, LIW team and the affected activities for both scheduling and training helps increase the understanding of everyone's role and part in Lean improvement. Management commitment of resources and commitment to Lean Sigma as one of the top priorities increases support and participation.

7.3 Requirements for Long Term Success

To effect a Lean Transformation, the organization should establish trained, full time, internal Lean Sigma specialists. The private industry standard is 1to 3 percent of the workforce. Consultant assistance and expertise is needed during the initial years of Lean Sigma implementation. Establish budget lines for the material and the education required for implementing Lean Sigma changes. Carefully choose the members of the teams involved in Lean Sigma improvement for their experience and breadth of knowledge on the processes. It is imperative that senior leadership commitment and participation is real and visible to the participants and the affected workforce. Commitment in the form of dedicated resources (money and people) is absolutely necessary. Leadership buy-in and continuous participation at all levels of the organization will lead to success.

Understand that Lean transformation is an on-going journey and that it fundamentally changes the organization's way of doing business. Collaboration with unions, labor and management will ensure that all parties will be changing the culture of the organization together.

7.4 Future Application to Other Repair Centers

This improvement methodology can be utilized in any repair center that has enough variability to warrant being treated as an unbalanced flow line or job shop. The process is generic enough to be tailored to any situation. The issues that were confronted in this implementation are probably common enough to be seen in many different repair centers. In summary, the Lean Sigma methodology used was an effective framework for implementing Lean Sigma and could be applied to any job shop environment.

7.4.1 Vision – Lean Ship Repair Enterprise

The vision for the shipyard becoming a Lean Ship Repair Enterprise is that the shipyard is well organized and uses visual systems for instruction, organization and monitoring of productivity and quality. All areas use point-of-use material, tools, and equipment. People, jobs, and material "flow" through the shipyard without back flow. The repair facilities are sized and organized to support value stream flow. Quality is built into the job through standard work, one-piece flow, accuracy control, and in-process inspection. Known defects are never passed downstream.

Customers and shipyards work together to define need and best value. The suppliers and customers are fully integrated into the work planning. Value stream management of ship repair drives cooperative working relationships. Work teams are organized by the skill sets necessary to support the value stream and the workforce is cross-trained in multiple skills.

Value stream managers have authority for the entire value stream including estimating, planning, execution, and delivery of all products within "product lines". Structure of the organization is designed to eliminate handoffs within the value stream. All employees are "Lean Thinkers", have the ability to see waste, and the tools and resources to remove it and the shipyard culture embraces standardization and continuous improvement. Materials are delivered to the right spot, at the right time, in the right quantities.

The resulting transformed shipyard has flexibility, capacity, speed and responsiveness, and delivers customer satisfaction at the lowest cost.

8 Glossary

BCA - Business case analysis

CPM - Critical Path Method

LIW - Lean Improvement Workshop, MA-RMC version of Kaizen events.

MA-RMC - Mid-Atlantic Regional Maintenance Center

MOE - Measures of Effectiveness

NAVICP - Naval Inventory and Control Program

NAVSEA - Naval Sea Systems Command

NEC - Navy Enlisted Classification

NNSY - Norfolk Naval Shipyard

NSRP - National Shipbuilding Research Program

NVA - Non-Value Added

NVAE - Non-Value Added but Essential

QA - Quality Assurance

ROI - Return on Investment

SIMA - Ship Intermediate Maintenance Activity

TAT - Turn Around Time

TOC - Theory of Constraints

VA - Value Added

VPI - Vacuum Pressure Impregnation

VSM - Value Stream Map

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