Continuous Navy Ships Process Improvement: Six Sigma, Lean Thinking, and Theory of Constraints

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Abstract — *Long waiting time in the equipment repair process in Norfolk Naval Shipyard is an actual problem. The main cause of this problem is the poor knowledge of the continuous process improvement techniques as Six Sigma, Lean Thinking, and Theory of Constraints. The actual equipment repair process steps were verified in an effort to reduce the time, cost and having a well organization, making NNSY a better workplace. The three methodologies were implemented and analyzed. This article will demonstrate that the best choices for this specific case were six sigma and lean thinking methodologies because of the culture of the organization. They both produced time saving in the equipment repair process, some costs saving and a better organization in the shipyard.*

"Key Terms" — *DMAIC, TIM WOODS, Waste, 5S.*

PROCESS

A process is "a series of steps and decisions involved in the way work is completed. Processes are everywhere and in every aspect of our leisure and work. A few examples of processes might include: preparing breakfast, placing an order, developing a budget, writing a work order, training a sailor, changing oil in a car, refueling a ship, etc. It is any activity that takes inputs, performs action on the inputs, and results in outputs" [1]. A process structure has 5 components; suppliers, inputs, process, outputs, and customers and is shown in Figure 1.

Suppliers - the internal/external people or organizations that provide materials, information, or other source for a process.

Inputs – the resources that are supplied.

Process – the series of work steps that transform inputs to outputs.

Outputs – the product, service, or information that is delivered to the customer.

Customers – the people, organizations, or process that receives the output (external and internal customers).

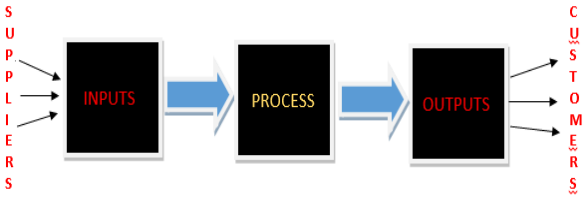

Figure 1
Process Structure

For this specific Article the process structure is define as:

Suppliers – NNSY (Norfolk Naval Shipyard).

Inputs – Navy ships improvement.

Process – Equipment repair process.

Outputs – Repaired equipment, ships, and submarines.

Customers – The NAVY.

Work Area Related

Shipyards and dockyards are places where different types of ships and submarines are built, repaired or modernized. These yards contain dry docks where the ships and submarines can be parked to be repaired, modernized, and contains large areas for fabrication of the ships. Also contains warehouses for inventory and repairing machines and cranes for moving items or equipment inside or outside the ship and warehouse. In this article the shipyard worked is the

NNSY (Norfolk Naval Shipyard). The current problem that NNSY has is the poor equipment repair process. The completion time of an equipment repair process is about 31 days (1 month) which is unsatisfactory for the customer.

Voice of The Customer

External Customers are those persons or organization outside the "process" that uses the products or service and which are an output of the process. Internal Customers are those persons or organization within the "process" that use the products or service of prior steps in the process. There are two sources of the customer voice: Reactive and Proactive. Examples of reactive are customer complaints and warranty issues and examples of proactive are surveys, direct contact, and focus group. The NNSY works with both sources of the customer voice, and that's why is known that the time has been unsatisfactory. These voices of the customer are something that every company should have knowledge about it because the main focus for a business to be successful is to satisfy the client that, in this particular case, is the NAVY.

CONTINUOUS PROCESS IMPROVEMENT

A continuous process improvement "is an ongoing effort to improve products, services or processes. These efforts can seek "incremental" improvement over time or "breakthrough" improvement all at once" [2]. There are some types of methodologies that were implemented during this article: Six Sigma, Lean Thinking, and Theory of Constraints that helped to improve the situation that NNSY has been going thru. The selection of a process improvement methodology is dependent on the culture of the organization, that is why the three methodologies were implemented in this article but the three did not necessarily have to be used at the end.

Six Sigma Methodology

"Six Sigma is a data-driven approach that focuses on reducing variation in order to solve both process and business problems. It applies a very structured and rigid methodology to meet customer specifications and assumes that variations are the cause of defects that impact customers negatively. Six Sigma also assumes the entire process to which it is applied will be improved by implementing variation reductions for multiple elements" [3]. A sequence of steps called the Six Sigma DMAIC (Define, Measure, Analyze, Improve, and Control) is shown in Figure 2 and is typically used to guide implementation of Six Sigma statistical tools and to identify process wastes and weaknesses. During Breyfogle article he defined Six Sigma DMAIC phases as:

- *Define.* This phase focuses on defining the project improvement activity goals and identifying the issues that need to be addressed to achieve a higher sigma level.
- *Measure.* In this phase, the aim is to gather information about the targeted process. Metrics are established and used to obtain baseline data on process performance and to help identify problem areas.
- *Analyze.* This phase is concerned with identifying the root cause(s) of quality problems, and confirming those causes using appropriate statistical tools.
- *Improve.* Here, implementation of creative solutions - ways to do things better, cheaper, and/or faster - that address the problems identified during the analysis phase takes place. Often, other lean methods such as cellular manufacturing, 5S, mistake-proofing, and total productive maintenance are identified as potential solutions.
- *Control.* This phase involves institutionalization of the improved system by modifying policies, procedures, and other management systems. Process performance results are again periodically monitored to

ensure productivity improvements are sustained. [4]

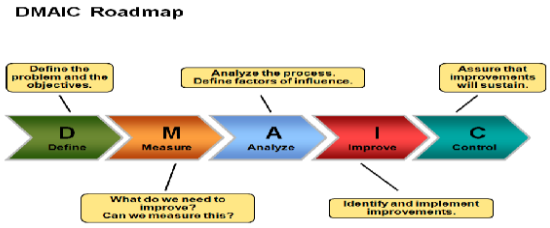

Figure 2
DMAIC Phases

Lean Thinking Methodology

Lean Thinking "focuses on the removal of waste, defined as anything that is not necessary to the production of the good or service and does not add value to the final customer. There is an emphasis on the flow of processes. Some of the assumptions underlying the methodology include that waste is the main limitation on profitability and that many small, rapid improvements are more beneficial than analytical study" [3].

"Kaizen, or rapid improvement processes, often is considered to be the "building block" of all lean production methods. Kaizen focuses on eliminating waste, improving productivity, and achieving sustained continual improvement in targeted activities and processes of an organization"[5].

Lean production is founded on the idea of kaizen – or continual improvement. Soltero, Conrad and Waldrip agree that this "philosophy implies that small, incremental changes routinely applied and sustained over a long period result in significant improvements. The kaizen strategy aims to involve workers from multiple functions and levels in the organization in working together to address a problem or improve a process. The team uses analytical techniques, such as value stream mapping and "the 5 whys", to identify opportunities quickly to eliminate waste in a targeted process or production area. The team works to implement chosen improvements rapidly typically focusing on solutions that do not involve large capital outlays" [5]. These wastes can be categorized in 8 of them as shown in Figure 3.

Figure 3
Types of Wastes

An easy way to remember the wastes, per I Six Sigma webpage dictionary, is using the acronym TIM WOODS. This webpage dictionary defines this acronym as:

T – Transport – Moving people, products & information

I – Inventory – Storing parts, pieces, documentation ahead of requirements

M – Motion – Bending, turning, reaching, lifting

W – Waiting – For parts, information, instructions, equipment

O – Over production – Making more than is IMMEDIATELY required

O – Over processing – Tighter tolerances or higher grade materials than are necessary

D – Defects – Rework, scrap, incorrect documentation

S – Skills – Underutilizing capabilities, delegating tasks with inadequate training. [6]

Theory of Constraints

The Theory of Constraints (TOC) "logic-driven approach focuses on system improvement. It views the system as a chain of interdependent links that work together toward the primary goal of transforming inputs into sold outputs, thereby increasing throughput (the rate at which the organization generates goal units – usually dollars)"[3]. The performance of the entire system is limited by the weakest link, or the constraint.

Renard mentioned that “all improvement efforts should be aimed at this constraint through the use of three focusing steps:

- *Identify the constraint* – can be a physical process or a policy
- *Exploit the constraint* – decide how to do everything possible to utilize the constraint to its maximum capability
- *Repeat the cycle* – once the previous constraint is broken, go back to Step 1 and identify the new constraint; before starting again, be sure that old habits, policies and rules are re-evaluated considering the changed environment” [3].

Pojasek talk in his article about Theory of Constraints and mention that “this technique consists of some helpful tools that will help during the implementation. 5S is a system to reduce waste and optimize productivity through maintaining an orderly workplace and using visual cues to achieve more consistent operational results. Implementation of this method "cleans up" and organizes the workplace basically in its existing configuration, and it is typically the first lean method which organizations implement. The 5S pillars, Sort (*Seiri*), Set in Order (*Seiton*), Shine (*Seiso*), Standardize (*Seiketsu*), and Sustain (*Shitsuke*), provide a methodology for organizing, cleaning, developing, and sustaining a productive work environment. In the daily work of a company, routines that maintain organization and orderliness are essential to a smooth and efficient flow of activities. This lean method encourages workers to improve their working conditions and helps them to learn to reduce waste, unplanned downtime, and in-process inventory” [7]. He define the 5S as follows:

1. *Sort.* Sort, the first S, focuses on eliminating unnecessary items from the workplace that are not needed for current production operations.
2. *Set In Order.* Set in Order focuses on creating efficient and effective storage methods to arrange items so that they are easy to use and to label them so that they are easy to find and put away.
3. *Shine.* Once the clutter that has been clogging the work areas is eliminated and remaining items are organized, the next step is to thoroughly clean the work area.
4. *Standardize.* Once the first three 5S's have been implemented, the next pillar is to standardize the best practices in the work area.
5. *Sustain.* Sustain, making a habit of properly maintaining correct procedures, is often the most difficult S to implement and achieve.

EQUIPMENT REPAIR PROCESS ANALYSIS

The actual NNSY equipment repair process takes about 31 days (1 month). This process starts when some problem occurs inside the ship with specific equipment. The sailors need to inform the situation to their superiors and they let the engineers know about it. The engineers go and visit the site, see the problem and, from then on, the written instructions are sent to the electricians and mechanics. The instructions begin with the disconnection and removing of the damaged item or equipment from the ship and finish with the reinstallation of it. The complete old equipment repair process steps presented in Table 1, indicating the time in days that each one takes.

Table 1
Actual Equipment Repair Process

Process	Days
Remove Item or Equip	2
Test	1
Collection of Data	1
Transport	1
Inspection	1
Transport	1
Disassemble	2
Look in the inventory	1
Order	1
Waiting	10
Repair	3
Test	1
Collection of Data	1
Employees Motion	1
Transport	1
Installation	2
Inspection	1
Total	**31**

Implementation of the Methodology Six Sigma in NNSY Equipment Repair Process

During the implementation of the first methodology, Six Sigma, the DMAIC technique was completed as follows:

- *Define*: NNSY takes 31 days (1 month) to complete the equipment repair process and this time frame is unsatisfactory for the client. It's necessary to improve the time and cost.
- *Measure*: The time, in a day, that each step of the process takes was recorded in Table 1. By doing this, the actual time it takes for the complete process to end is known.
- *Analyze*: Data obtained demonstrates that some wastes of the Lean Thinking methodology were affecting the process completion time (31 days). The specific wastes founded during the analysis are: transportation, inventory, motion, and waiting time. It is possible to improve this process using the techniques discussed in this article, having as objective the equipment repair process time reduce.
- Improve: To improve the process, Lean Thinking was used to reduce or eliminate the wastes that are occurring.
- Control: These improvements would be controlled by training to all personal on the techniques applied and teaching them about the 5s concept.

Implementation of the Methodology Lean Thinking in NNSY Equipment Repair Process

During the implementation of the second methodology, Lean Thinking, the wastes founded on the actual process are:

Transportation – There's 14 dry docks (ports) in the shipyard. Some of them are close to the warehouse but most of them are not. A dry dock can be 2 miles away from the warehouse. NNSY spent a lot of money on fuel and diesel used by wagons, trucks and cranes during the movement of an item or equipment from the ship to the warehouse or vice versa.

Inventory – excess of inventory in just one warehouse can create obsolete equipment or material. NNSY has been renting and outside warehouse to stock material incurring in expenses.

Motion – warehouse is not organized and labors waste too much time looking for tools and materials.

Waiting – the time spent waiting for an approval takes too long. Also the time lost waiting for the inspectors when the equipment is transported to the warehouse is unacceptable.

All these wastes are happening because NNSY has just one enormous warehouse to stock the inventory, suit the machines to fix the damage items or equipment, and to have labors and offices inside of it.

It is proposed then to create a warehouse in each port. These warehouses are not going to be as big as the present one, but big enough to have some essentials machines, inventory and electricians and mechanics in each one. For better

success, each port will have assigned some specific type of ships. Doing it like this the shipyard will have a better organization and a common language. Every person that works in a specific warehouse will know that all the equipment, tools, and materials located inside of it, will always be for the same type of ship. Also is proposed to train and give the authority to the employees so he or she can make decisions without waiting for supervisor approval. Forces the inspector to visit the field and observe the problem without wasting time. Train the personal about the 5S technique in the labor area and create them this habit.

After these proposed changes are implemented the following wastes will be eliminated or reduced:

Transportation – will be money saving, especially in fuel and diesel. Whenever you move an item or equipment from the ship to the warehouse or vice versa, there is use of combustible. Reducing this waste will also save transportation time.

Inventory –NNSY won't have to pay external rent for warehouse and would have more organization when each warehouse has their own ship designation.

Motion –the time spent looking for equipment or materials reduce and the organization in the warehouse is a better one.

Waiting – the time spent waiting for approvals reduce. Also the time lost waiting for the inspectors when the equipment is transported to the warehouse would not exist.

Implementation of the Methodology Theory of Constraints in NNSY Equipment Repair Process

During the implementation of the third methodology, Theory of Constraints, the equipment repair process constraint was identified. This was the waiting time spent. With the proposed, during the first two methodologies in this article, Six Sigma and Lean Thinking are strategies that will exploit the existing constraint making the Theory of Constraints unnecessary to be fully implemented. The 5s technique was just taken under consideration and was added in the improvement of the other methodologies.

Improved Process Step Time

After applying all the methodologies and techniques Table 2 shows the total days that the equipment repair process will take. After the wastes were eliminated the process was reduced from 31 days to 14. The difference in days is 16 days; two weeks of difference will be satisfactory for the client.

Table 2
Equipment Repair Process Improved

Reduced Process	Days
Remove Item or Equip	2
Test	2
Collection of Data	2
Disassemble	2
Order	1
Repair	3
Installation	2
Total	**14**

CONCLUSION

This article has demonstrated that the methodologies of Six Sigma and Lean Thinking were successful for the improvement of the NNSY equipment repair process, demonstrating a reduction of time and cost, making NNSY a better organization.

Six Sigma was implemented first and then in its fourth step (improving) Lean Thinking was implemented. During this methodology, in the elimination of waste motion, a technique of the third methodology (Theory of Constraints) was implemented, called 5S'.

The three process improvement methodologies make a few of the same assumptions. Each improvement methodology, when they were implemented, is set toward common tools and concepts. However, knowing that the organization values visual change and right now time, the focus

was on waste and flow time. That is why six sigma and lean thinking were fully chosen with just a small technique of theory of constraints.

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