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Enabling Waste Elimination, Learning, and Continuous Improvement through Standardization

by

Mark E. Stover

BS Industrial Management, Carnegie Mellon University, 1999

Submitted to the Sloan School of Management and the Department of Civil & Environmental Engineering in partial fulfillment of the requirements for the degrees of

Master of Business Administration
and
Master of Science in Civil & Environmental Engineering

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Abstract

Many manufacturing companies have developed their own operating system, usually based upon the Toyota Production System, in an effort to improve productivity, quality, and profitability. Continuous improvement is a central theme to most operating systems. Typically large continuous improvement projects or kaizen bursts are used to improve processes. However, these often lead to variable and unsustainable results.

A hypothesis is that a detailed standardization of processes will enable opportunities to be quickly revealed. Then a focus on incremental improvement through experimentation can lead to dramatic sustainable results. This thesis is based upon my experience at Mighty Motors in an attempt to gain a deeper understanding about standardization and continuous improvement. I obtained this understanding through direct observation by working with operators on the assembly line to standardize the process and make improvements.

I developed the following conclusions:

> **Focus on standardization** to achieve sustainable continuous improvement. Without standardization, randomness and variability will hide the wastes and improvements will deteriorate.
>
> **Value the incremental improvement** approach to continuous improvement. Through simple, common-sense, and low cost experimentation a great deal of process improvements can be made.
>
> **Creating an organization that values standardization and continuous improvement** is the hard part. This involves more than using a set of problem solving tools.

Thesis Supervisor: Roy E. Welsch
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1.0 Introduction

"Why are you wasting so much time with all these labels and minor changes? There are bigger and more important things to worry about in this station." said an operator after I had spent several weeks standardizing and experimenting on process improvements in this station.

"The little things *are* causing most of the bigger problems in this station," I replied. The operator continued to argue with me that he needed better equipment to improve the process. I was frustrated. I knew that buying new equipment would only mask the problems and solve nothing. He would just continue working an inconsistent process with a fancy new machine.

A Study of Standardization and Continuous Improvement

This thesis is based upon my research of standardization and continuous improvement conducted at a major manufacturer of recreational vehicles and powertrains. The company is headquartered in the Midwest United States and will herein be referred to as "Mighty Motors." I performed my research as part of an on-site internship from June to December 2004 at a Mighty Motors manufacturing facility. The site manufactures powertrains as a major component of the final product. My primary research focused on the powertrain assembly line area.

1.1 Overview of Mighty Motors

Mighty Motors manufactures highly desirable products for the consumer market. The company is an established leader in this market with a dominant market share. The company has a rich history and a strong culture displayed in customers and employees. Over the past several years, Mighty Motors made numerous improvements in its manufacturing ability in order to benefit its customers and further maintain its position in the market. Quality and production capability improved such that Mighty Motors created growth within its industry for several years. Although industry growth has slowed a bit recently, Mighty Motors continues to hold a dominant market share.

1.2 Mighty Motors Powertrain Assembly Line

The Mighty Motors Powertrain Assembly Line assembles various components to build the final powertrain product. There are approximately thirty stations on the U-shaped assembly line (Refer to Figure 1). A motorized J-hook, named for its resemblance to the letter J, carries the powertrain from one station to the next. At each station, operators assemble and attach their specific parts to the powertrain. All J-hooks move on the assembly line after a set period of time and stop at the next stations. Therefore, each station is given the same amount of time to complete the process. This type of line is known as an indexed line.

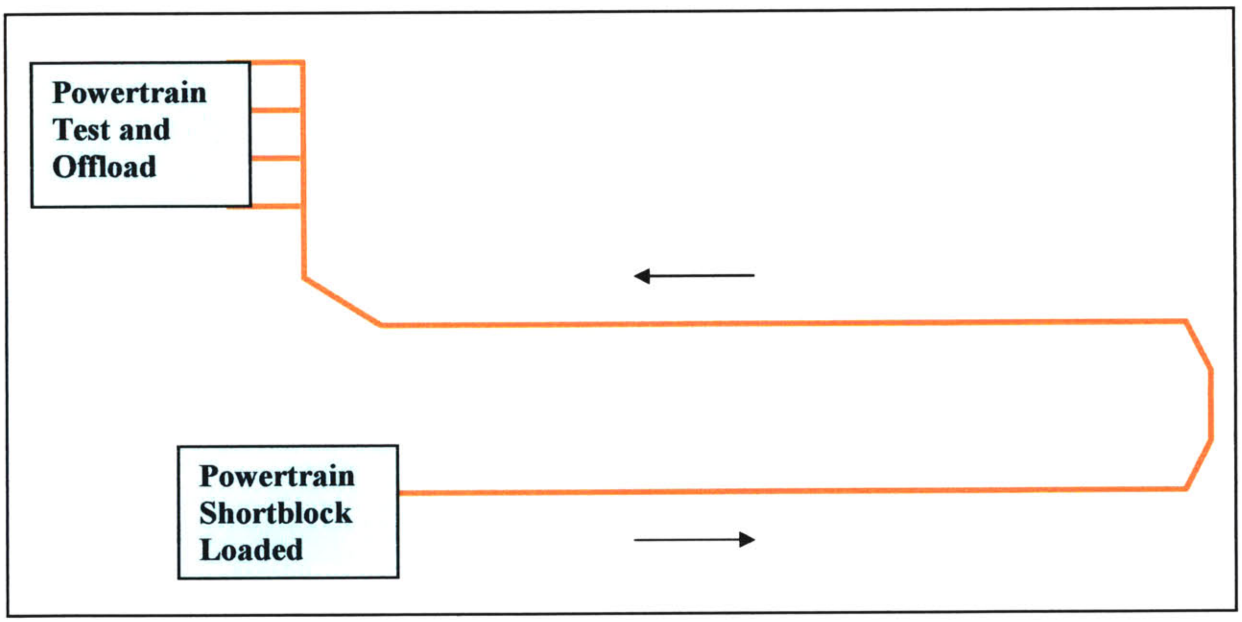


Figure 1: Graphical Depiction of Assembly Line

Cost of Downtime

Due to the indexed line, a single down station on the assembly will cause all other stations to be down. For example, Station 15 might be stopped because an operator installed an incorrect part on the powertrain. As a result, all other stations on the line will be stopped until the problem is corrected. During my time at Mighty Motors, the cost of downtime numbers was estimated to range from $38 to $600 per minute. The $600 per minute rate is based upon the principle that there is a ripple effect to the supporting areas. The $38 per minute is based upon the labor required to run the line during overtime. For calculations in this thesis, I will use the $38 per minute downtime rate to ensure conservative estimates in improvements.

Line Monitoring

If an operator does not complete the process within the allocated time, the entire line will stop if the operator pushes the stop button on the J-hook or if they failed to complete a critical step that is linked to a computerized line monitoring system. For example, if an operator fails to scan the barcode of a critical item within the cycle time, the line will not continue and a bell will sound to alert repair operators for assistance.

1.3 Mighty Motors Operating System

Although Mighty Motors still performs well in the market, there are many reasons to be concerned for future success. The success of Mighty Motors led competitors to develop very similar products in attempts to improve their market positions. These products are available at prices that are as much as to 20-50% lower than Mighty Motors products.[1] This competition is also recognized as having higher quality products and manufacturing costs which are significantly lower than Mighty Motors. In addition, Mighty Motors manufacturing costs continue to increase making higher prices necessary in order to maintain the same profit margins. Over the past few years, these prices have increased at a rate higher than the increase in disposable income used to buy their products.[2] Growth is becoming increasingly difficult as the market matures.

A few years ago, the leadership at Mighty Motors recognized this increasing competition and their own relatively weaker manufacturing position. As a result, they created the Mighty Motors Operating System (MMOS). MMOS is a standardized operating system largely based upon the principles of the Toyota Production System. Additionally, the President of Mighty Motors issued a cost imperative to maintain the same costs while increasing capacity. MMOS is

[1] Based upon Manufacturers Suggested Retail Price and discussions with other consumers
[2] From presentation by Marketing representative at Mighty Motors

considered a major factor in how Mighty Motors will achieve this objective and make future improvements.

A study of Mighty Motors Operating system was performed in the year prior to my study by Gregory Dibb. In his thesis, *A Study of the Mighty Motors Operating System: Making Sustainable Improvements at a Powertrain Manufacturing Facility*, Dibb explains four high-level philosophies of the Mighty Motors Operating System. Much of the work I performed at Mighty Motors is based on these four principles:

- People are Key
- One by One Approach to Customer Demand
- Go See the Problem
- Continuous Improvement Everyone, Everyday

The following describes each of these principles in more detail using examples from my experience at Mighty Motors:

People are Key

Many organizations, including Mighty Motors, view their employees as their most valuable asset. However, many organizations are unable to achieve high asset utilization, especially in terms of encouraging and using their ideas. The central belief of the "People are Key" philosophy is leveraging employee knowledge at all levels of the organization. This especially holds true in a manufacturing organization, where the employees working the processes often understand the operations at a deeper level than engineers or supervisors. Mighty Motors truly believes that the best ideas to improve a process will come from those who work the process. However, the challenge is enabling these employees to come forward with ideas and put them into action.

Mighty Motors experiments with various tools in an attempt to uphold the "People are Key" philosophy. One such tool is an Ideas Board (Refer to Figure 2). Workgroups have a common area to meet and review metrics each day, as well as take breaks. In this common area, the Ideas Board is posted on a large piece of paper with a grid pattern. The three primary columns of the grid represent areas for posting an idea, a response, and a decision for implementation. The rows of the grid represent the categories of the 3-4 high level focus areas. For the assembly line in 2004, these were: Safety, Quality, Uptime, and Cost. An additional row is labeled "Other" for ideas that do not seem to fit in these categories. Colored Post-It® Notes are used by any employee to write their ideas and post to the Ideas Board. Each day a team reviews the ideas posted and gives a response to the person directly, as well as a written note for the entire group to view. The responses are posted for at least one week and later archived in a binder kept near the Ideas Board.

Figure 2: Ideas Board

The Ideas Board is not Mighty Motors only solution for leveraging employee knowledge. However, it does function well as a simple and easy to use visual communication medium to keep the entire group aware of ideas and potential improvements.

One by One Approach to Customer Demand

"One by One" is meant to imply that each situation is unique. The keyword within this philosophy is "approach" – to imply that each situation is unique therefore a unique solution is often required. The "customer" within the philosophy of One by One Approach to Customer Demand refers to both external and internal customers. The commonly used lean terminologies are one piece flow and pull. Traditional mass production thinking taught economies of scale to achieve the lowest cost per unit and asset utilization, which leads to producing large batches. One piece flow is designed not necessarily to optimize equipment, but instead optimize flow of material in a factory. This, in turn, creates a tighter feedback loop for any problems. However, moving to one piece flow immediately can strain most organizations and create the wrong behaviors. Due to this, the "approach" is crucial– what is the right solution at this point in time?

The station that sub-assembles carburetors provides an example of this philosophy. In this station, the operator assembles the carburetors for the next station. Previously, the operator could build up a queue of several completely assembled carburetors. The operators in the next station would have difficulty knowing exactly which carburetor to use. As a result, several wrong carburetors were installed. The process was modified to require that no more than three carburetors could be built in advance. This dramatically reduced error. However, some errors still occurred, so a visual monitoring system was installed to verify the appropriate carburetor before installation. Errors at this point were minimal. The key to reaching this solution was the approach taken by Mighty Motors. If they had immediately mandated a zero stock buffer several bad practices would develop due to operators not wanting to stop the line. The incremental approach allowed for learning and training.

Go See the Problem

"This is where everything really happens."

– Assembly Employee at Mighty Motors

A key philosophy to problem solving and understanding operations at a deeper level is to go to the source of information, which is usually the plant floor. Many supervisors and managers have tendencies to rely on metrics and other measurements to determine where problems occur on the plant floor. To solve these problems, traditional management will hold tedious meetings away from the site of the actual problem. The MMOS philosophy counters the traditional problem solving method by going to source of the problem to observe and understand why it might have occurred.

The power of the Go See the Problem philosophy was demonstrated early in my research at Mighty Motors. I was asked to assume the responsibility of relocating some equipment closer to the assembly line. The typical method of relocating equipment involved many meetings with the technicians of the affected stations and AutoCAD drawings to determine the agreed optimal layout. In some meetings, attendees used scale cutouts of the equipment and arranged the pieces on a scale drawing of relocation area. We would then debate which arrangement was most optimal, although we were never quite sure if any of the options would truly be feasible. To bring the Go See the Problem philosophy to life, I made full size cardboard footprints of the equipment for a meeting. We all met on the plant floor to see the various arrangements and the amount of working space. This approach was not common at Mighty Motors and several employees walked by laughing at this experiment. However, the operators involved were able to see that actually none of the options we had developed were feasible. Although none of the layouts were deemed feasible, the full scale cardboard footprint experiment was a huge success and enabled the group to make a decision to halt this project due to the constraints. If we had not performed this exercise, we could have spent many hours debating the appropriate location and may have even attempted to move the equipment only to create a situation worse than the current one.

Figure 3: Example of "Go See" with Cardboard Equipment Footprint

Continuous Improvement Everyone, Everyday

The fourth MMOS philosophy involves making improvement as an ongoing activity. The idea is that everyone in the organization should think throughout each day: what can I do better today than I did yesterday? "Such small improvements in many processes gradually accumulate, leading to significant quality improvement, cost benefits, and productivity improvements." (Imai xvii) In the many dozens of articles and books written about the Toyota Production System, continuous improvement is generally considered the heart of the system.

Often, thinking small and simple is a good method for obtaining continuous improvement. This is illustrated in the following example of how a $0.50 hook can save hundreds or even thousands of dollars. While observing a station on the assembly line (Go See the Problem), I noticed that a piece of equipment had required bypassing due to a malfunction. The procedure for bypassing required that the operator note a reason for the bypass and some other information about the affected engine in a log. The malfunction would prevent the line from moving until the notation was made. I observed that the operator had to walk ten feet to obtain the bypass log, make the notation, and walk back ten feet to return the bypass log.

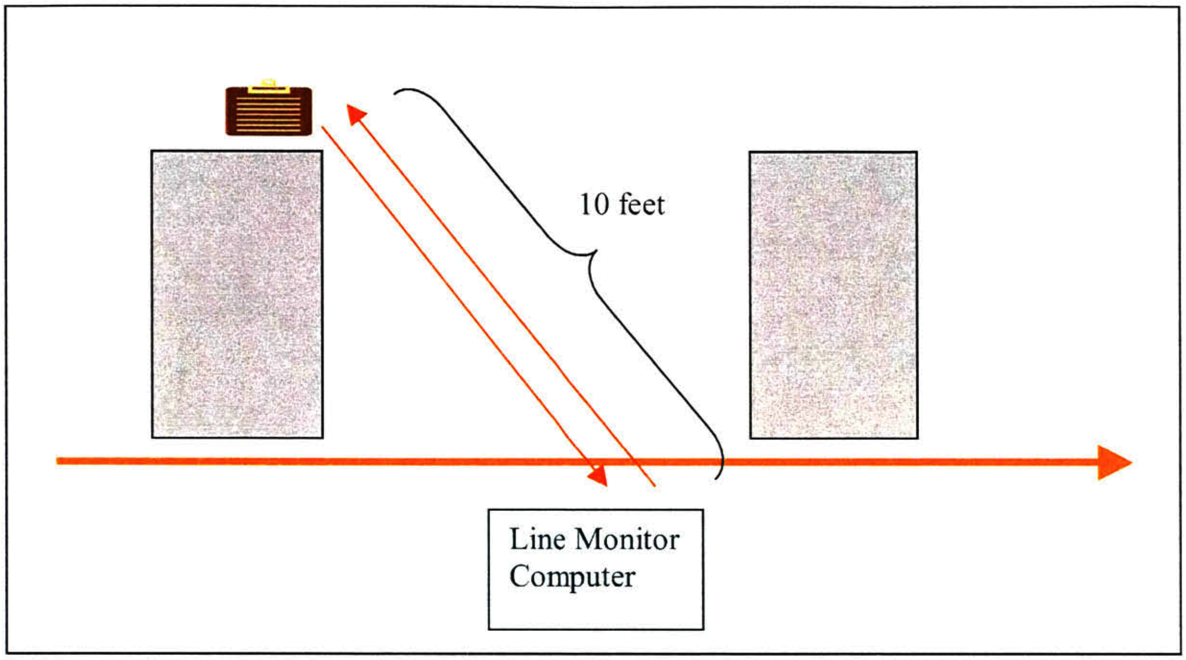


Figure 4: Initial State of Bypass Log Process

I asked if there was a reason the bypass log was located there. The operator replied "No, we could have it located near the monitor, but there is no place to put it." I looked around the monitor and found that a small adhesive hook could be used on the side to hold the log. Although the bypassing process is infrequent, by relocating the log adjacent to the monitor we eliminated unnecessary walking and reduced downtime dramatically with a $0.50 hook.

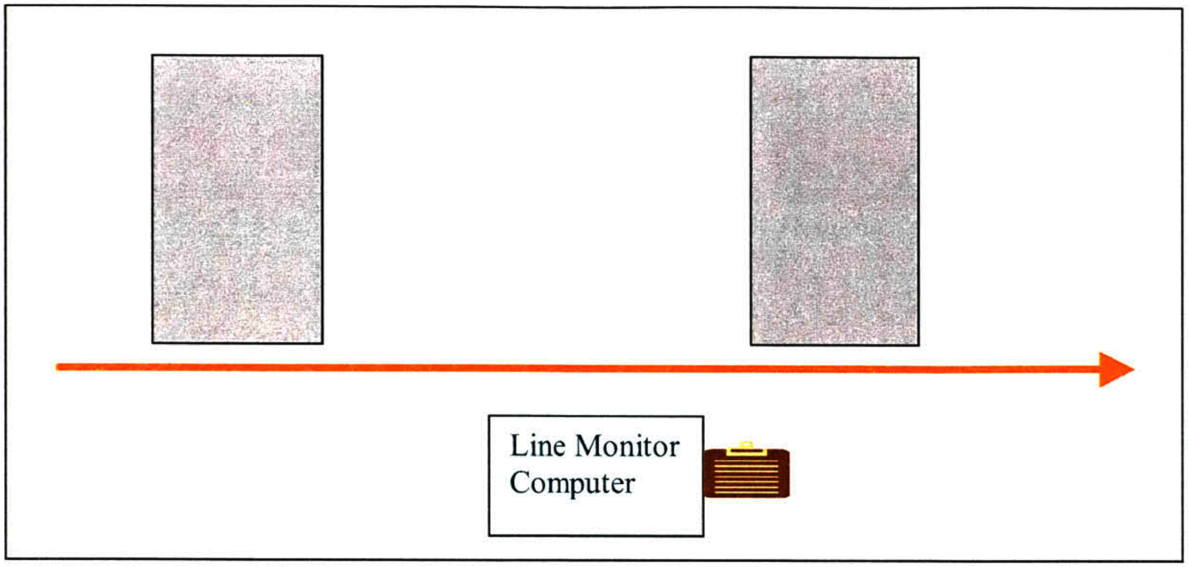


Figure 5: Modified Bypass Log Process

While the improvement may seem somewhat insignificant in execution, the impact becomes apparent with the magnitude of the hook's function across an entire assembly line. Figure 6 illustrates that nearly $1500 can be saved annually by applying across the entire assembly line.

	2	Bypasses / day on entire assembly line (conservative estimate)
x	5	Seconds of downtime from unnecessary walking
x	5	Days / week
x	50	Weeks / year
x	1/60	1 minute / 60 seconds
	41.67	Minutes downtime / year
x	$38	Estimated labor cost / minute of downtime
	$1583.33	**Total estimated annual labor cost savings**

Figure 6: Calculation of Estimated Annual Saving of $0.50 Hook

The one year return on a $15 worth of $0.50 hooks to locate bypass logs near the point of use is over one hundred fold. I doubt there is a manager in the world that would refuse such a return on investment.

1.4 Sustainable Improvement

Simply stating these four Mighty Motors Operating System philosophies to all employees does not create a magical transformation to a competitive operation. The MMOS philosophies must be embedded in culture or as Mighty Motors employees would put it: "part of the bricks and mortar."

For several years, Mighty Motors has made various attempts to foster continuous improvement from all levels of employees. They believe that the employees themselves know best how to improve their job. Improvement efforts can be seen throughout the operations. However, the challenge has been in engaging employees on all levels and making sustainable improvements.

As mentioned in Section 1.3, a study of Mighty Motors Operating system was performed in the year prior to my study by Gregory Dibb. In the thesis, *A Study of the Mighty Motors Operating System: Making Sustainable Improvements at a Powertrain Manufacturing Facility*, Dibb discovered that sustainable improvement is a major goal of an operating system. Dibb made five conclusions for sustainable improvement:

- Go to the floor to make firsthand observations
- Standardize all activities by making them highly specified according to content, sequence, timing, and outcome
- Standardize each link to create one clear, direct, unambiguous signal
- Solve every problem and make every improvement in accordance with A3 and the scientific method
- Provide sufficient support to the operators by way of a robust help chain

Based on these conclusions and observations, my supervisor, Dan Glusick, and I determined that I should delve deeper into these conclusions and study standardization and continuous improvement. Some of the questions we hoped to answer:

- What is meant by standardization?
- Will standardization work at Mighty Motors?
- How do you engage all levels of employees?
- Does standardization enable continuous improvement with everyone everyday?
- How do you enable *sustainable* continuous improvement?

1.5 Hypothesis: Standardization Enables Continuous Improvement

The hypothesis I developed is that rigid standardization of processes will enable an environment of waste elimination, experimentation, and continuous improvement. This hypothesis was largely based upon the Toyota Production System, a benchmark for Mighty Motors. This thesis will explore methods of achieving standardization, continuous improvement, and the relationship between standardization and continuous improvement.

I will provide many case examples based upon my experience at Mighty Motors to illustrate each topic. A brief overview of the thesis structure is as follows:

Chapter 2: Research Methodology discusses the approach to examining standardization and continuous improvement.

Chapter 3: Getting to Standardization reviews the definition of standardization and methods of achieving standardization.

Chapter 4: Continuous Improvement provides an overview of continuous improvement approaches, analysis of continuous improvement at Mighty Motors, and case examples based on my experience.

Chapter 5: Value of Standardization and Incremental Continuous Improvement discusses the link between standardization and continuous improvement and overviews the potential value of incremental improvements.

Chapter 6: Organizational Process Analysis examines the Mighty Motors organization to highlight barriers to achieving standardization and continuous improvement.

Chapter 7: Conclusion summarizes some of the key lessons from the thesis.

2.0 Research Methodology

"Understanding current reality requires deep observation."
– Jamie Flinchbaugh, Lean Learning Center

In order to truly understand the effects of standardization and how it enables continuous improvement, my supervisor and I set a plan for me to study the current reality on the plant floor ("Go See") and work towards standardization and continuous improvement with a select few stations on the assembly line. As opposed to a major initiative, we wanted to see how standardization and continuous improvement could work at Mighty Motors. We considered this approach to be an inch-wide and mile-deep study.

2.1 Data Collection Methods

The primary data collected for my research is a result of direct observations on the plant floor, interviewing and coaching the operators, making actual modifications, and studying modifications for improvement gains. The majority of my data is qualitative data based upon this experience. However, I will present some quantitative metric data to illustrate the impact of standardization and improvements made.

For the in depth study of stations, the following methodology was used:

- Identify set of stations for study
- Observe the current state
- Note differences between shifts and deviations from written procedures
- Interview the primary operators of each station
- Coach operators on standardization and improve current standardization
- Identify improvement opportunities from observation and operator input
- Perform activities for improvement and standardization
- Monitor improvement and standardization activities

This methodology follows the Standardize – Do – Check – Act (SDCA) cycle for stabilizing a process and the Plan – Do – Check – Act (PDCA) cycle for improving a process (see Figure 7) (Imai 4-6).

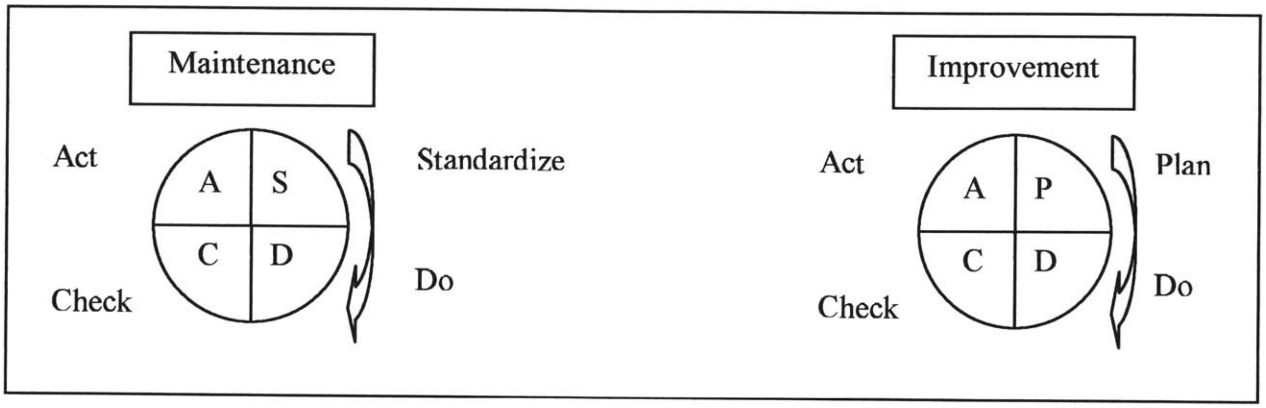


Figure 7: Standardize - Do - Check - Act (SDCA) and Plan - Do - Check - Act (PDCA) Cycles

Based upon input from the Assembly Group and other projects during my internship, the following stations were the primary areas of study:

Pistons

In the piston station, the operator sub-assembles pistons and installs them on the powertrains. The piston sub-assembly requires installing rings on the piston manually followed by ring installation with an automated machine. The operator completes the sub-assembly with the pin and clips that hold the piston to the flywheel. After the sub-assembly, the piston is attached to the powertrain. There are five different types of pistons that are used.

The majority of the work I completed occurred in the piston station and many of the following examples will be used from this experience.

Head Torque and Carburetor Sub-Assembly

This station uses an operator aligned machine to automatically torque the powertrain head to specifications. The operator then sub-assembles carburetors or electronic fuel injectors (EFIs) for use in the next station. There are over ten different types of carburetors and EFIs to use on the powertrains.

Carburetor / EFI

The carburetor / EFI station attaches the sub-assembled carburetor or EFI to the engine. This requires a series of torques to ensure proper seating.

Primary Cover

The primary cover station sub-assembles the primary cover with a clutch cable and places it on the powertrain. There are over five different primary covers and three different clutch cables making multiple combinations of primary cover and clutch cables possible.

I spent a significant amount of time on the plant floor in these stations. Throughout my experience at Mighty Motors, I kept a journal of conversations and ideas. In addition to collecting the nearly 100 pages of notes in my journal, I gathered several digital photos and collected metric data from information systems.

Some of the work to standardize and improve was performed individually; however I relied heavily upon the input, assistance and experience of the employees in Mighty Motors Assembly Group.

2.2 Visual Management: A3 & Project Management

Mighty Motors makes extensive use of visual management tools, including Idea Boards (Refer to Section 1.3), A3, and Visual Planning. I made use of these tools throughout my project.

A3

Pioneered by Toyota, A3 is a problem solving tool used to capture the problem, analysis, corrective actions, and action plan on a single sheet of A3 paper (similar to 11" x 17" paper in the United States). (Marchwinski and Shook 1). Mighty Motors uses the A3 for many strategic initiatives and displays them throughout the plant. A3 provides a simple, standardized, easy to use, and (more importantly) easy to understand format. Mighty Motors also encourages using diagrams to better illustrate the problems. There are various formats of the A3, however all are basically a framework for problem solving. Figure 8 shows an A3 format with several sections for detail. A simplified version might only include the Business Case/Problem Statement, Current State, Target State, Implementation, and Metrics.

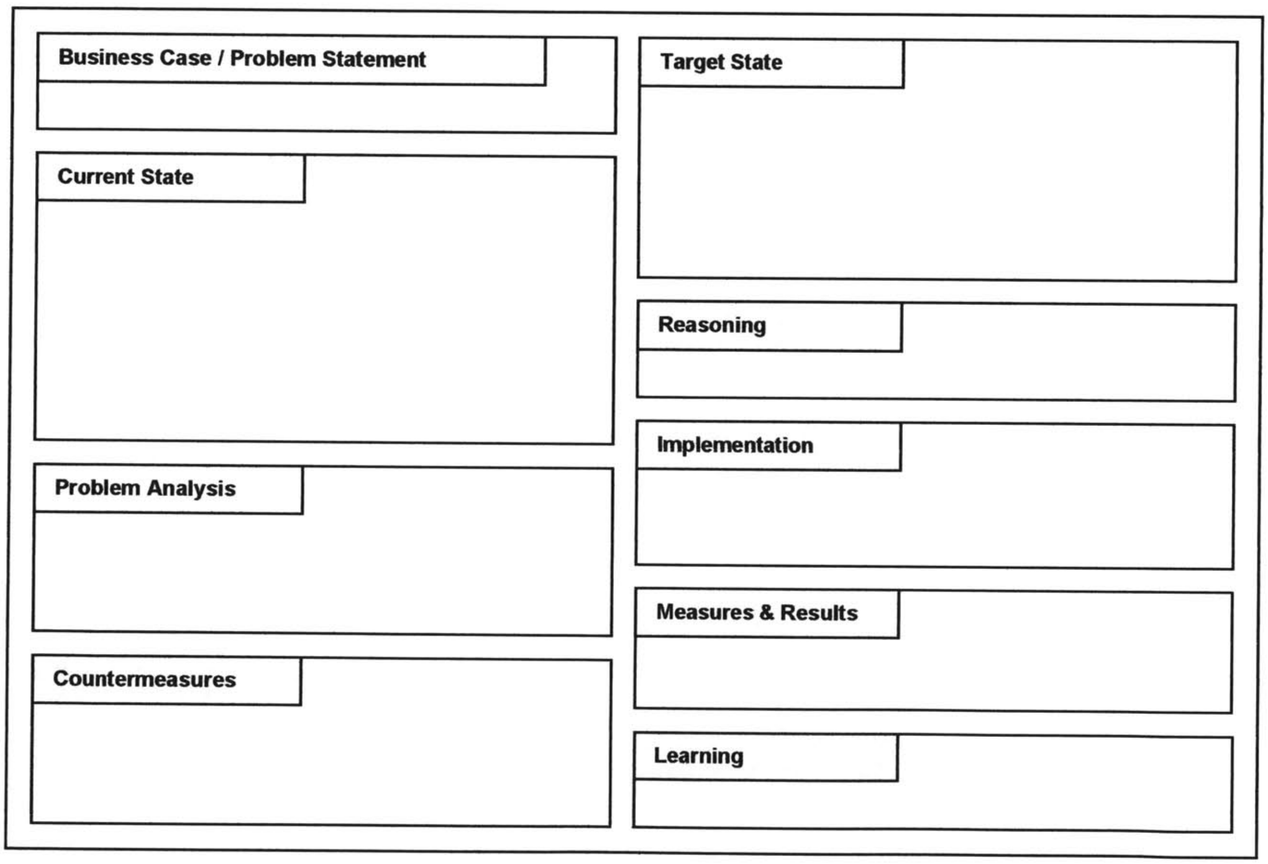


Figure 8: A3 Format for Problem Solving

After more than six weeks of observation on the plant floor, I developed a basic format A3 for the problem of how to better enable continuous improvement at Mighty Motors. (Figure 9) (See Appendix 1 for larger version).

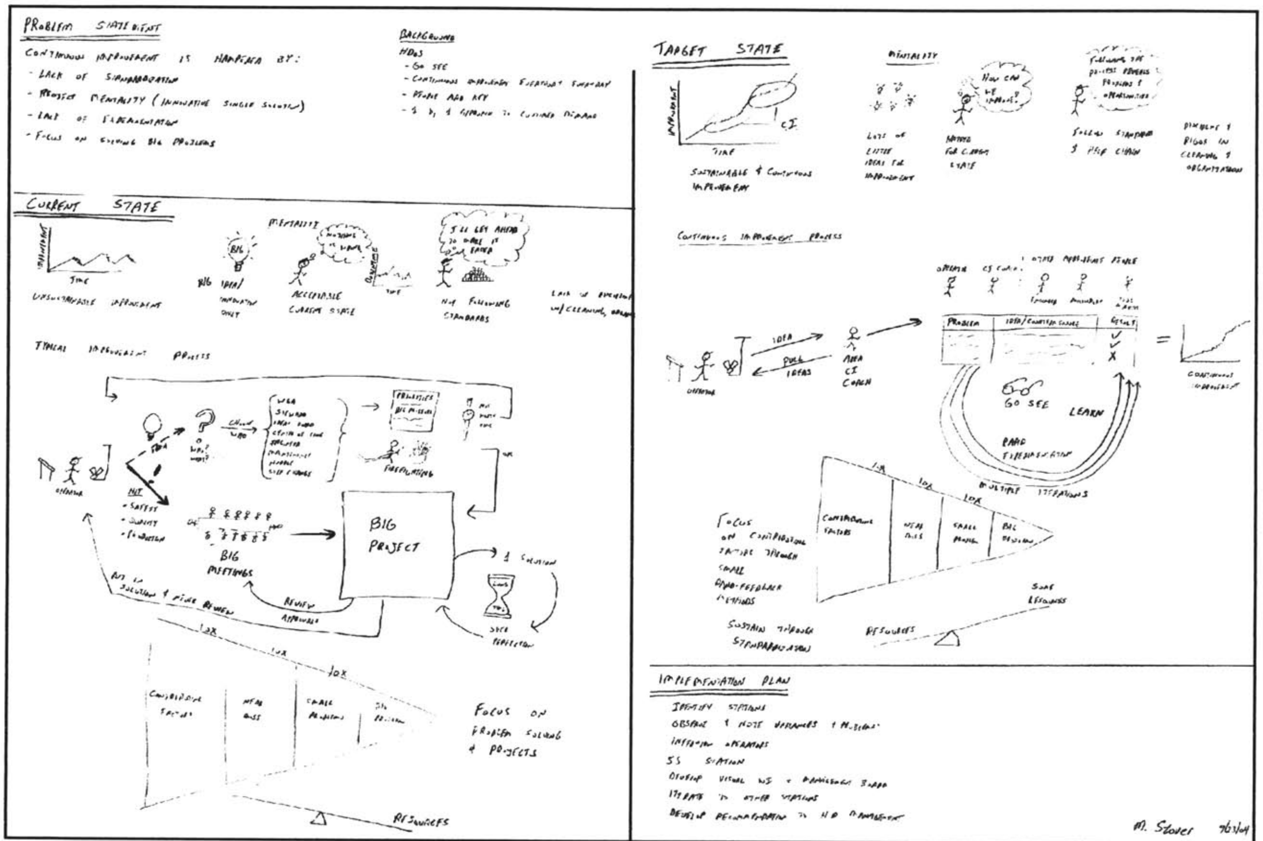


Figure 9: A3 for Continuous Improvement at Mighty Motors

Visual Project Management Plan

After developing an A3 for my project, I developed a Visual Project Management Plan. Rather than using Microsoft Project to develop a timeline, I used a large 3'x 5' sheet of paper. This sheet hung in an area near my desk. Various sizes and colors of Post-It® Notes were used for creating the timeline and deliverables. For instance, small blue notes were used for milestones and small pink notes were used to post issues or problems with a deliverable. When a deliverable was missed, the note was moved to the expected completion date. Then a red box was drawn where the note was previously located with a reason for the delay written inside the box. (Refer to Figure 10)

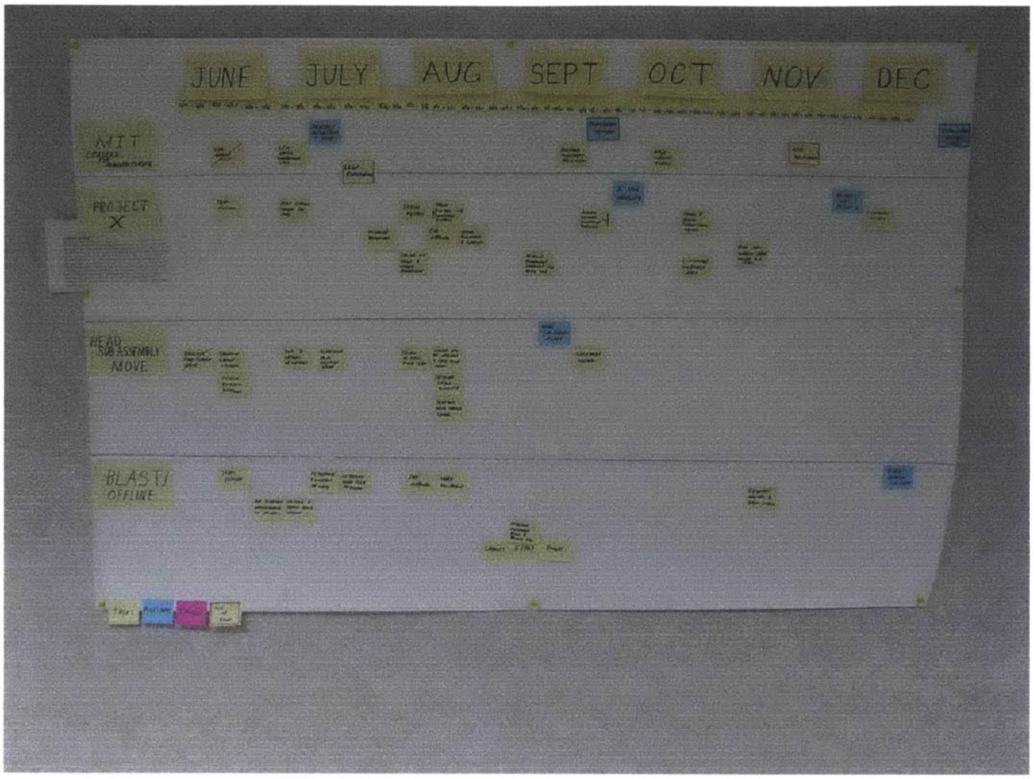


Figure 10: Visual Project Management

Although Microsoft Project (or other project management software) can be a great tool in detail planning, it requires access to a computer, software, and time to open or print the file. This is often a barrier to using it on a routine basis and hides the plan in a file on the project manager's computer. The Visual Project Plan is out in the open for everyone to see and ask questions. I would routinely receive questions from employees walking by the project plan. Often they would see something related to a current or previous project and offer advice. It also offered advantages for the project teams. We would perform a standing meeting by the plan and update it within a few minutes.

2.3 Toyota as a Benchmark

Toyota is widely studied and benchmarked for their world-class operations, especially the Toyota Production System (TPS). Standardization and continuous improvement are key enablers to their success. Therefore I will use Toyota as a reference and benchmark. In this section, I will present a few of the studies that are relevant to my study of standardization and continuous improvement.

In 1999 Steven Spear and H. Kent Bowen presented their key findings after a multi-year study of Toyota in *Decoding the DNA of the Toyota Production System* (HBR Sept – Oct 1999: 99 - 106). Their primary conclusion is that the Toyota Production System is really a system of rules and not just the tools we see such as Kanban and andon. They specified four basic rules:

> *Rule 1*
>
> All work shall be highly specified as to content, sequence, timing, and outcome.
>
> *Rule 2*
>
> Every customer-supplier connection must be direct, and there must be an unambiguous yes-or-no way to send requests and receive responses.
>
> *Rule 3*
>
> The pathway for every product and service must be simple and direct.
>
> *Rule 4*
>
> Any improvement must be made in accordance with the scientific methods, under the guidance of a teacher, at the lowest possible level in the organization.

"These principles lead to ongoing improvements in reliability, flexibility, safety, and efficiency, and hence, market share and profitability." (Spear 78)

The Toyota Production System is often presented as a house with a foundation, pillars, and roof as depicted in Figure 11 (adapted from Liker 33). The ultimate goals are in the roof: best quality, lowest cost, shortest lead time, best safety, and high morale. The pillars holding up the roof are Just In Time (JIT)[3] and Jidoka[4]. Supporting the entire house is the foundation of level production, stable and standardized processes, visual management, and the Toyota Way Philosophy. Toyota believes that the foundation and pillars enable the goals to be achieved through continuous improvement.

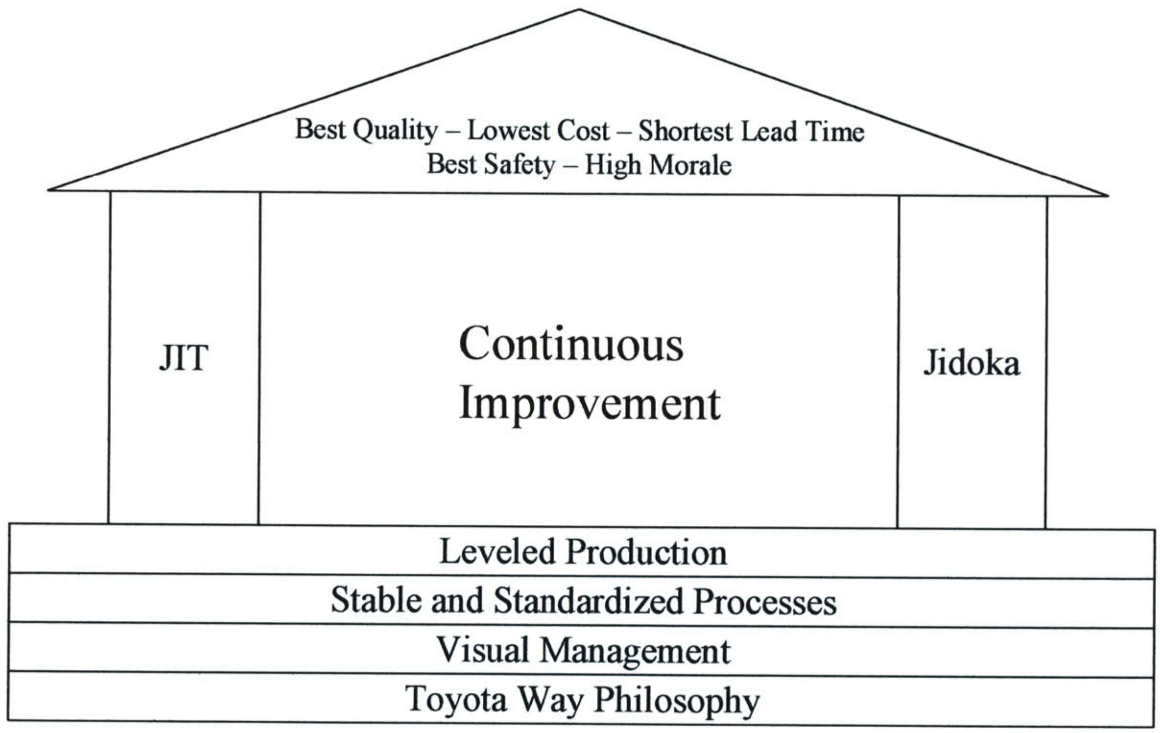


Figure 11: Toyota Production System

[3] JIT – a system of production that makes and delivers just what is needed, just when it is needed, and just in the amount needed. (Marchwinski and Shook 34)

[4] Jidoka – providing machines and operators the ability to detect when an abnormal condition has occurred. (Marchwinski and Shook 32-33)

3.0 Getting to Standardization

"What is supposed to happen on a normal day?"

– Dan Glusick, Assembly Group Lead at Mighty Motors

3.1 Definition of Standardization

Standardization in production environments is often thought of in terms of the methods that Frederick Taylor pioneered, commonly referred to as Taylorism. Taylorism made production a science by breaking down processes into time and motion components. Industrial engineers would observe employees to develop standards and management would hold employees accountable for meeting these standards. This developed into a view of management controlling employees, thus deepening the rift between management and employees.

This definition and connotation is not an ideal approach to standardization. Standardization is intended for processes and not people. By taking a process based approach, both management and employees will have a common language for discussing problems and opportunities.

A standardized process, according to the Toyota Production System, means having a highly specified content, sequence, timing and outcome (Spear and Bowen 98). This level of detail is required such that there is little ambiguity and minimal variance in processes. It is intended that the standardized process will be the safest and easiest known way to perform a process.

At a more theoretical level, standardization is a means for obtaining high agreement. There are two dimensions for achieving high agreement – what and how (Refer to Figure 12) (Lean Learning Center 2004). High agreement is "valuing a common way or process with clear understanding more than we value our own way" (Lean Learning Center 2004).

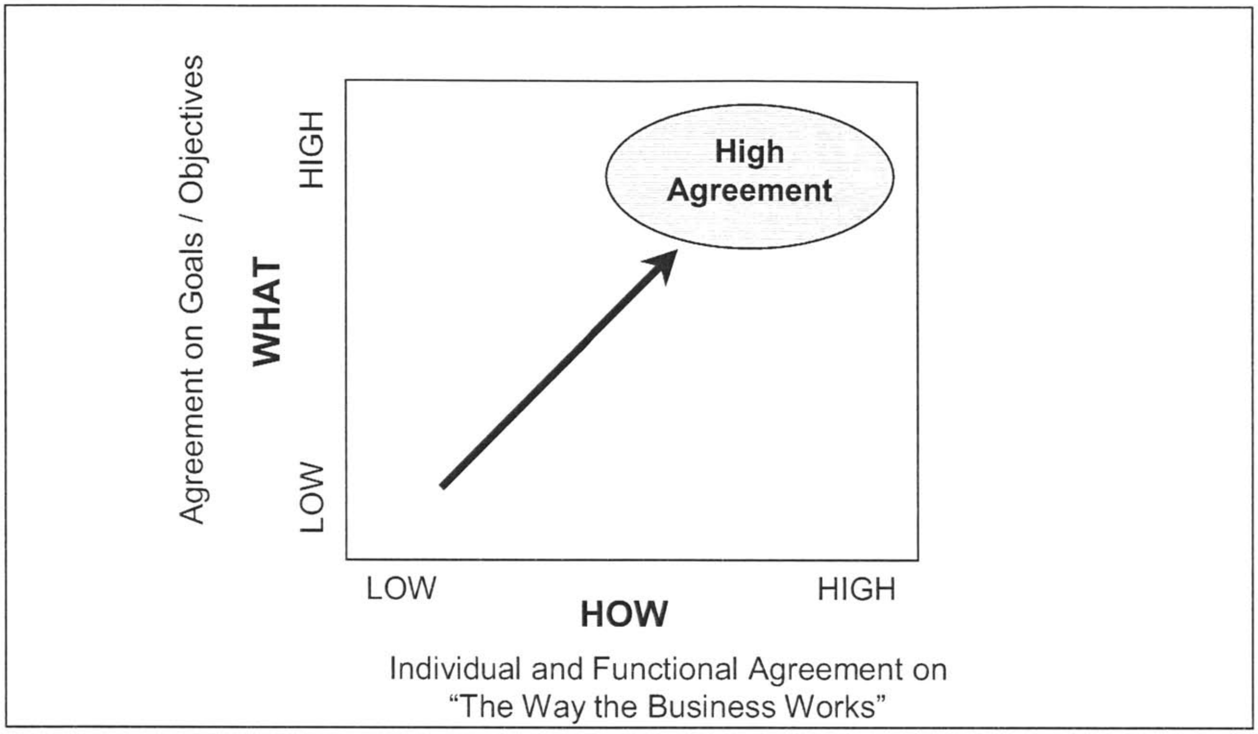


Figure 12: Two Dimensions of High Agreement

There is an important distinction between the different levels of what is considered standardization. Figure 13 shows the differences as defined by Toyota (Kuhlman-Voss).

	Standardized Work	Standard Work	Work Standard
Purpose	Most efficient considering safety, quality, quantity, cost	Cost assignment, standard efficiency, piece work incentive	Guideline for quality and safety
Responsibility	Team Leader / Group Leader	Industrial Engineering	Quality and Safety Engineering
Flexibility to Change	High – change with motion and machine kaizen, layout changes, Takt time changes	Medium – requires reevaluation by Industrial Engineering and Accounting	Low – Requires changes to quality specifications or safety standards

Figure 13: Comparison of Standardized Work, Standard Work, and Work Standards

There are specific objectives to this level of process standardization and high agreement:

- Reduce ambiguity
- Reduce variability and increase predictability
- Enhance repeatability, confidence, and consistency
- Clarify procedures
- Ease communication
- Ease troubleshooting
- Set good discipline
- Develop awareness
- Provide a basis for improvement, measure baseline
- Provide a mechanism to improve problems
- Provide a base for education and training
- Eliminate rework, rejects, safety problems, etc.

Toyota defines the objective of standardization as a tool for problem solving. "Standardization is not for the purpose of control or even for capturing a best practice per se. Rather, standardization – or more precisely, the explicit specification of how work is going to be done *before it is performed* – is coupled with testing work *as it being done.* The end result is that gaps between what is expected and what actually occurs become immediately evident" (Spear 78-79).

The following questions can serve as a checklist for obtaining standardized work (Lean Learning Center 2004):

- Can someone step in and perform a task easily?
- Will all people interpret the process the same way?
- Will someone know if high agreement is violated?
- Do defects, errors, or breakdowns result in changes to the process?

3.2 Methods of Achieving Standardization

There are many methods of achieving standardization. The following are examples of the more common approaches:

- 5S
- Visual Work Instructions
- Visual Management
- Error Proofing
- Common forms
- Color Coding
- Minimum and Maximum Inventory Levels
- Checklists
- Production Control Boards
- Line Stop Procedures
- Signage

I will discuss 5S and Visual Management in more detail in Sections 3.3 and 3.4.

3.3 5S

"The purpose of 5S is not for making things clean and pretty, the purpose is to *expose* problems."

- Lean Experience, Lean Learning Center 2004

5S is a commonly used housekeeping tool that aids in obtaining high-agreement. It is often a first step in the journey of a company towards lean manufacturing. The term 5-S refers to the Japanese terminology for each of the five parts of the process: Seiri, Seiton, Seiso, Seiketsu, Shitsuke.

Sort or Sift (Seiri)

Separate the essential materials from non-essential materials. The goal is to simplify the work environment. A method of removal is to "red tag" the materials and move to a separate area for a set period of time, such as thirty days.

Sweep or Straighten (Seiton)

Remove non-essential items from area. In this step, the red tag items from the sort that have not been used are to be disposed.

Sanitize or Scrub (Seiso)

Regimented and scheduled cleaning of work area.

Standardize (Seiketsu)

Organize the essential materials in the workplace. There should be a place for everything and everything in its place.

Sustain (Shitsuke)

This is the most difficult step to achieve: maintain 5S on an ongoing and routine basis. Typically checklists and audits are used, however the level of sustainability is primarily developed from the expectations of management.

Piston Station 5S

The piston station provided an ideal opportunity to apply the principles of 5S. There was a low level of routine housekeeping and operators on both shifts would setup the station differently. The station had some signage for the various parts; however, significant ambiguity still existed in where work in progress (WIP) sub-assemblies were to be located.

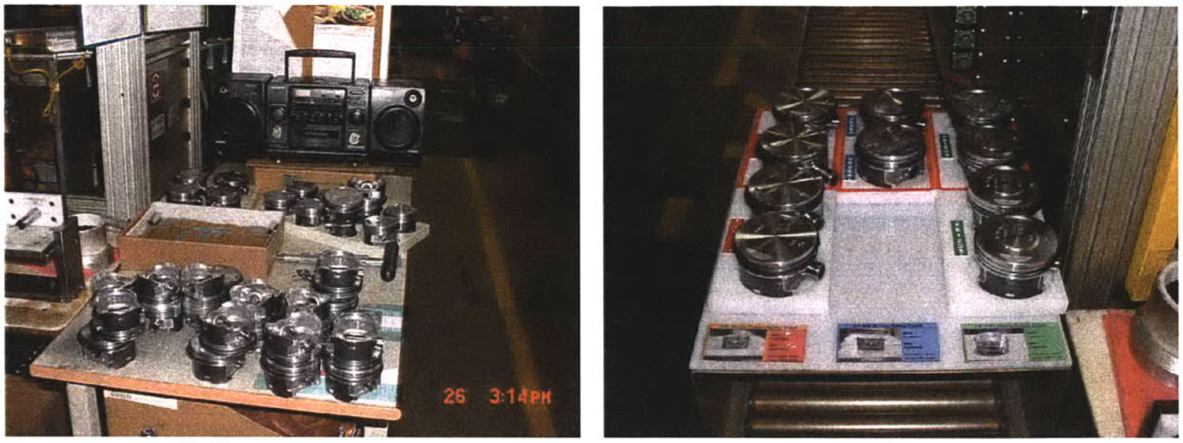
The sort and sweep portions removed a great deal of debris and unnecessary tools from the station. Operators aided in identifying the necessary parts and tools. We identified nearly three hundred parts that were difficult to identify as acceptable or reject material and were therefore removed as nonconforming material. The operators previously had a habit of accumulating broken piston rings around the machine surface area rather than removing them from the station. When the parts were piled in aggregate, the operators realized this practice was unacceptable and problematic. Figure 14 exemplifies the before and after condition of a machine in the piston station.

Before **After**

Figure 14: Piston Machine Before and After 5S

The standardization phase required significant negotiations between shifts in order to reach an agreement about the locations and quantities for WIP sub-assemblies and safety stock. Labels were made for the parts that included the part number, a picture of the part, and a background color that matched the color of the powertrain build card. Easily removable adhesive was used on the labels such that the labels could be moved as needed. We experimented with a variety of configurations until we reached a common agreement between operators.

Previously, safety stocks of sub-assembled pistons were located in a set of trays at the piston station. However, there existed ambiguity in whether the pistons could be stacked in these trays. WIP was placed on a table with no clear identification of the part. Since there were five different pistons to choose from, often the wrong piston was installed. Some initial countermeasures were implemented. The documentation was revised to reflect a clear safety stock minimum and maximum level. The trays held the maximum level and red tape visually indicated the minimum level. For WIP, labels were placed on the table to indicate a location for each piston type.



Before **After**

Figure 15: Piston Safety Stock/WIP Before and After 5S

The sanitize and sustain phases proved the most difficult. At the time, 5S was not high on management's priority and operators were not held accountable for housekeeping. The fixtures and labels proved more sustainable than the daily routine cleaning. Operators gradually drifted back to allowing nonconforming parts to be placed around the station. I would visit the station routinely and clean up these parts, usually without saying a word. After a few weeks, the operators improved in housekeeping. I believe this is due to the attention factor that I gave to such a small issue. From this I established that for 5S to be successful, leadership must be willing to set the example of what is important.

Race Shop Clean vs. 5S

One of the challenges I observed in implementing 5S in a station at Mighty Motors, was the perception that this was a very Japanese method. Many employees seemed to feel that, since Mighty Motors is an "American company," they were different in their methods. In discussing this perception problem with a senior manager at Mighty Motors, I learned about a Mighty Motors facility that approached 5S in terms of "Race Shop Clean." Race Shop Clean refers to the racing teams, such as those in NASCAR, which maintain their pit stalls and garages in immaculate condition. This neat and orderly system allows for quick responses during pit stops and emergency work. Additionally, the garage floors, where cars are worked on between races, are usually comprised of spotless white tiles. This level of cleanliness is not only for show and pride. It allows a race team to very easily identify if there are problems such as an oil leak or a missing bolt.

The Race Shop Clean mentality would be easier for employees to embrace than 5S. It can provide a medium which they can relate to more easily. When employees understand the importance of something, it will stand a much higher chance of success and sustainability.

3.4 Visual Management

Visual Management is simply the providing of a more visual means of understanding a requirement as opposed to a written procedure. Highway signs are an example of this tool. Nearly all drivers can recognize the meaning of a road sign by the color, shape, and the text. This idea can be taken to the plant floor in a similar manner.

Visual Documentation Center

An example of visual management on the production floor was the result of a corrective action to a major problem. I was asked to aid in determining a solution for document control on the assembly floor. The problem was that many documents are used in each station on the line including process sheets, deviation reports, change notices, and quality alerts. However, there was no standardized method on the assembly line for presenting this information to operators. Some forms were tacked on bulletin boards, others laid on tables, some taped on machines, and some simply could not be found anywhere. The problem with this lack of a standardized method was that many of these documents were dated for a specific time frame and therefore many expired documents would remain on the plant floor. Additionally, if an operator was a short term replacement, they might not know about a document that states a planned departure from procedure.

The proposed solution was a Visual Documentation Center for each station. I designed a small bulletin board with several sleeves comprised of differently colored backgrounds for each type of document (See Figure 16). This created one standard method that could be used at every station on the assembly line. As a result of this change, operators and document authors knew exactly where a document could be found. As part of their daily start-up routine, operators would complete a build log located on the Visual Documentation Center. At this point, they would quickly know if there are any documents that apply to their process.

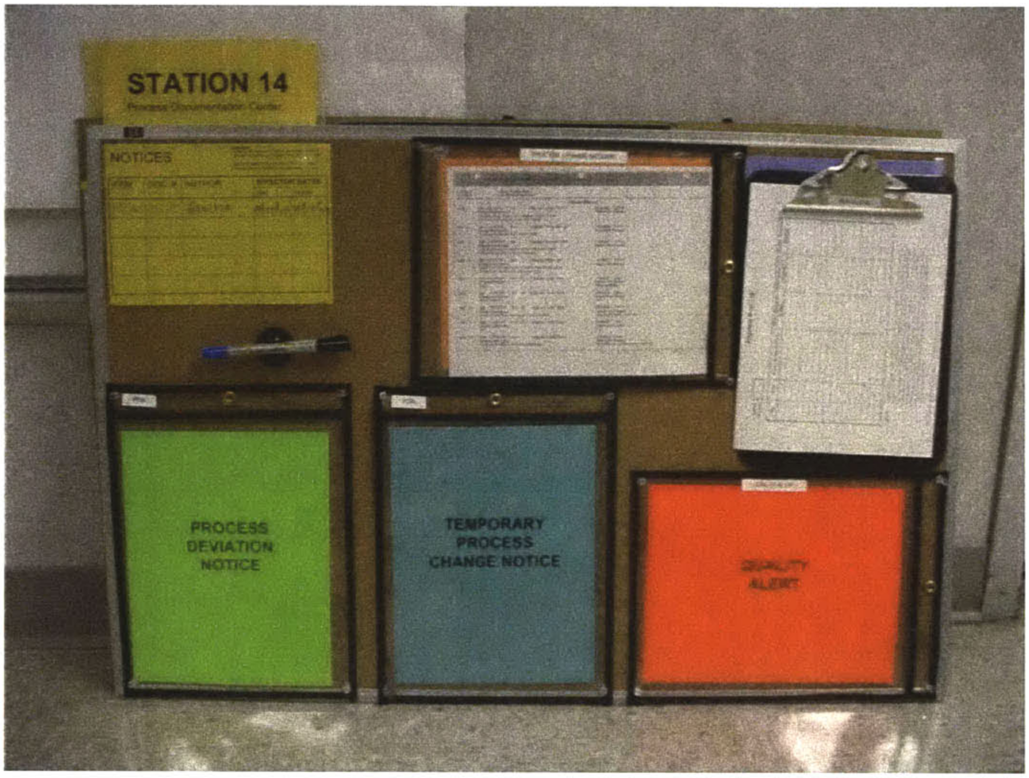


Figure 16: Visual Documentation Center

Visual Aids

Visual aids are an inexpensive and easy tool to use in standardization of processes. Visual aids provide a method of bringing the documentation of a process to life. Ideally a visual aid should not only be a reference, but part of the natural process flow. Although, if not designed correctly, visual aids can also make processes *more* complicated and ambiguous. A visual aid should be simple and intuitive to nearly anyone.

I observed several visual aids in use at Mighty Motors. Many of these significantly enhanced the process. However, some were ineffective and unused. For example, one visual aid in the piston station was intended to be a reference aid for obtaining parts (See Figure 17). The visual aid allowed operators to look at the powertrain build card color, look back at the visual aid, match the color to the part number required, and then obtain the part. This visual aid was essentially only useful for the first couple days that a new operator worked at a station. After that, the operator would memorize the build card color and required part. Although this appears acceptable, I observed that even experienced operators would occasionally obtain the wrong part.

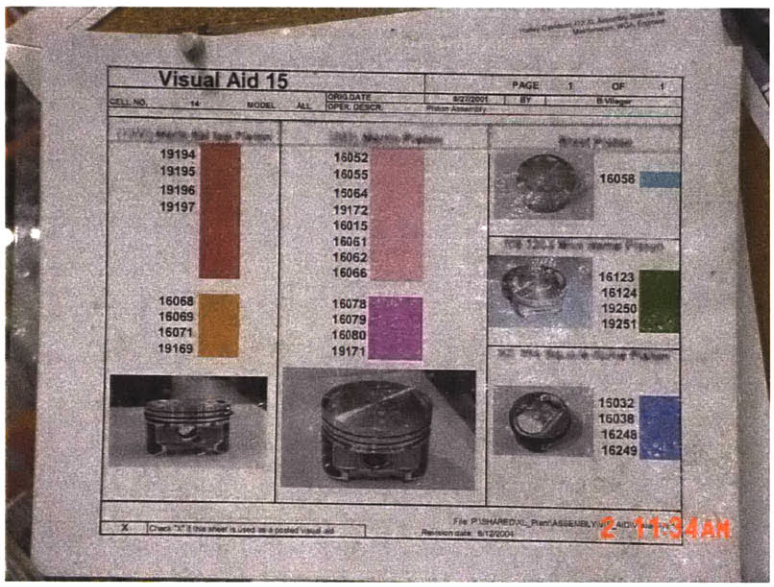


Figure 17: Visual Aid as a Reference

To improve the visual aid usage, I developed small labels with build card color match, part number and picture to use directly on the parts rack. (See Figure 18) This visual aid was now embedded in the routine process of obtaining parts. Operators now had an alternate mechanism for determining which part to obtain.

Figure 18: Visual Aid as Part of Process

3.5 Current Reality of Standardization at Mighty Motors

Similar to most manufacturing companies, Mighty Motors has a moderate level of standardization in its manufacturing processes. Around the plant floor, one observes process sheets, visual aids, kanban cards, part labels, and several other indicators of standardization. Yet, it falls far from extremely detailed standardization that is followed to a high level of detail.

Developing Process Standards

Process standards are developed at Mighty Motors using the traditional industrial engineering/Taylorism approach of time and motion studies. Industrial engineers then use a software program to record the elements of motion involved which translates it into an expected time. This creates a standards sheet that reflects all the motions from start to finish. From there, engineers will develop a process sheet up from the standards sheet. This process is a bit like translating a foreign language. "Obtain piece with 0-18 inch reach and align to pin-obst" becomes "Obtain gasket and align to powertrain." The result of this translation up from standards sheet to process sheet amounts to instructions that according to one operator "read like poorly translated Japanese stereo instructions."

Training on Process Standards

I interviewed several operators to learn about how they learned to perform their process. Each operator stated that another operator had trained them through a process of observation and practice. When I asked them if they reviewed the process sheets as part of the training, some would laugh and claim they never look at those unless challenging the time standard. A few operators knew their process standards, although, they would say "that doesn't mean we follow them all the time."

Following Process Standards

Based upon the training and development, it was not surprising that operators used the process standards only as general guidelines in understanding how a job should be performed. Many operators had developed their own unique way of performing a process and did not update the process sheets. Operators admitted that sometimes they "just mix it up to keep from boredom." It was extremely difficult to actually know if an operator was performing the work properly.

Other Standardization Efforts

Prior to my internship, Mighty Motors had attempted to implement 5S. From discussions with employees, they succeeded as far as the Sort phase to eliminate a great deal of unnecessary equipment and tooling, but the effort lost leadership emphasis and faded away. Many unnecessary items have found their way back into the stations.

The moderate level of standardization at Mighty Motors appears to be a major hindrance to sustaining improvements. In Chapter 5, I will discuss the importance of standardization for continuous improvement.

4.0 Continuous Improvement

"Continuous improvement beats postponed perfection."

- Anonymous

4.1 Definition of Continuous Improvement

Continuous improvement is a common buzzword stated in many corporate mission statements and strategic documents. The definition seems obvious, however it is a bit nebulous and ambiguous in practice. Continuous improvement should be thought in terms of progressing from the current state to the ideal state (See Figure 19).

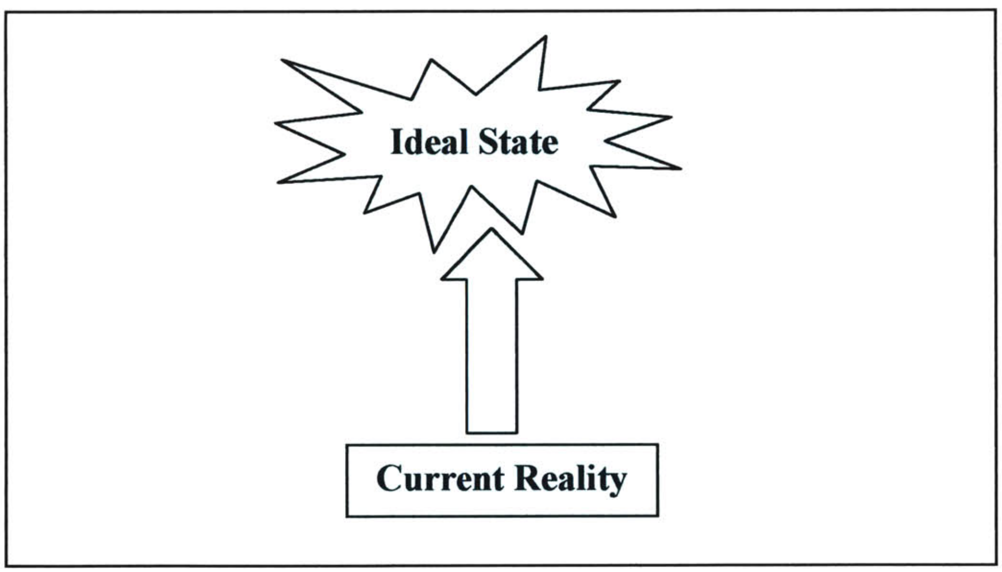


Figure 19: Continuous Improvement

Incremental Improvement versus Innovative Improvement

To reach the ideal state, there are generally two methods of approach: innovation and incremental improvement. The innovative approach is often project-based over a period of time and usually features an attention-getting result. Conversely, the incremental improvement approach is performed on a frequent basis with relatively low key results.

In the United States, managers tend to focus on an innovative, project-based improvement approach. Yet this can lead to problematic results (Imai 2). "Today's managers often try to apply sophisticated tools and technologies to deal with problems that can be solved with a commonsense, low-cost approach. They need to unlearn the habit of trying ever-more sophisticated technologies to solve everyday problems" (Imai xv). This is not to imply that the innovation approach is always inappropriate, as it can result in improvements. Rather, the implication is that the incremental improvement method is often ignored and not valued at many companies. It is frequently overlooked that small improvements can lead to significant improvements over time.

The continuous improvement work I performed at Mighty Motors primarily utilized the incremental improvement method.

4.2 Analysis of Continuous Improvement at Mighty Motors

"Here, you see, it takes all the running you can do, to keep in the same place."

- The Red Queen to Alice in Lewis Carroll's Through the Looking Glass, Ch. 2

Continuous improvement is considered of high importance to Mighty Motors. Mighty Motors uses this term in the Mighty Motors Operating System, Quality Policy, and in other company communications. In fact, Mighty Motors specifically requested that I study continuous improvement and how to better enable it. After several weeks of observation and interviews, I developed an A3 (Refer to Section 2.2 and Appendix 1) as a means of analyzing continuous improvement.

With such a high level emphasis on continuous improvement, it should be obvious what employees consider continuous improvement. Therefore, I interviewed employees to determine their understanding of continuous improvement and collect some recent examples. The common theme, amongst the answers of those interviewed, was that continuous improvement meant executing a big project to fix a big problem. This theme was consistent with my observation of how little problems would often be overlooked or temporarily fixed until a major downtime period or quality problem. At that point, an engineer or team would be assigned a project to fix the problem. This process often took several weeks or months to generate one optimal solution, often requiring some major capital equipment to automate the process or computer aided quality verification.

The focus on innovative improvement often lacks a focus of standardization or is, perhaps, too big of a change for an operator or organization to support over a long period of time. The result is decay in the improvement and sometimes the process drifts back to the initial state represented in Figure 20. At Mighty Motors, improvement does not drift completely back to the initial state, but it does appear to decline from the initial results.

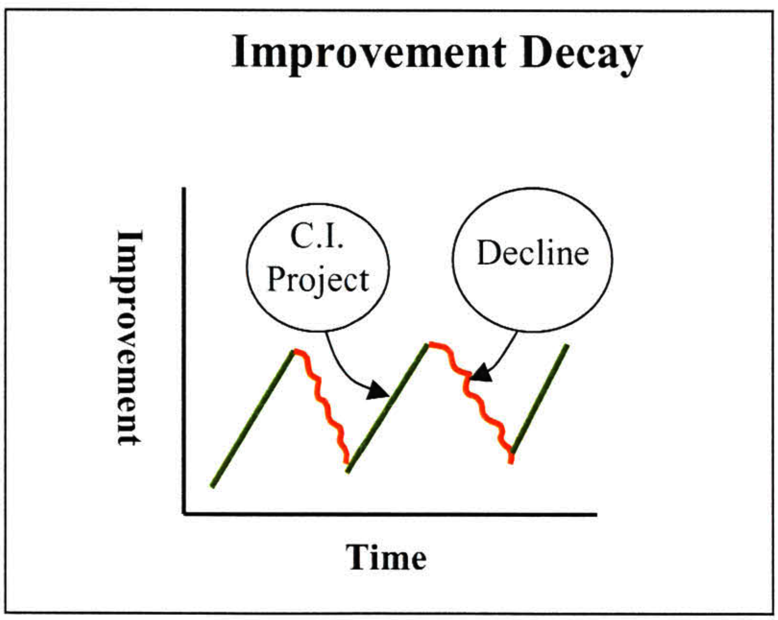


Figure 20: Improvement Decay

This method of continuous improvement appeared to quickly overload engineers with projects. As one operator explained: "they're always doing projects." The big project or big idea mentality will then be adopted by operators, as I observed through many of their ideas on the Ideas Board. Operators would present ideas about getting faster equipment or new tools. During my six months at Mighty Motors, I saw very few ideas about improving a *process* within a station.

At Mighty Motors, the innovative, big project mentality is heavily favored over the incremental approach to continuous improvement. There is a strong tendency to work on the major problems rather than the smaller contributing factors.

Figure 21 graphically depicts the magnification of big problems into contributing factors and the focus of resources on solving the big problems. These larger problems are typically symptoms of smaller problems, which, in turn, are a result of near misses and contributing factors. With a focus on the relatively few major problems, only a few contributing factors will be eliminated in problem solving.

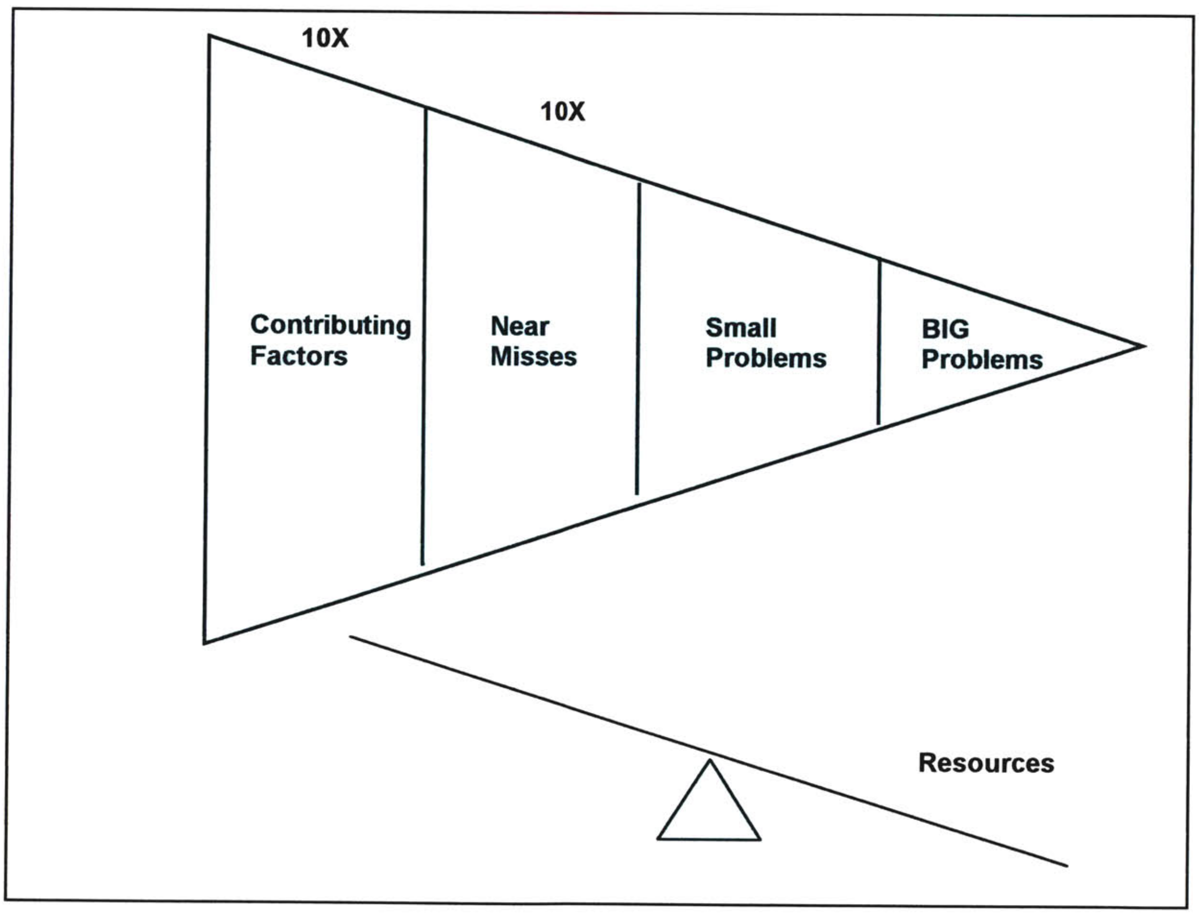


Figure 21: Magnification of Major Problems to Contributing Factors

Assembly Best Practice Circle

Realizing that focusing upon the big project innovation style of improvement was perhaps not ideal, my supervisor, Dan, and I led a small "Go See" exercise at a Mighty Motors Assembly Best Practices Circle (BPC) meeting. These meetings are held on a regular basis with various leaders across Mighty Motors sharing ideas from their respective plants. Dan and I decided to present the group with a challenge faced on the assembly line: reducing cycle time by six seconds through process improvements. We asked the group to visit two stations in thirty minutes to determine ideas for improvement. However, we stipulated that they could not use capital equipment as a means of finding the process improvements. After some moans and eye rolling, I presented the following slide to the group (Figure 22).

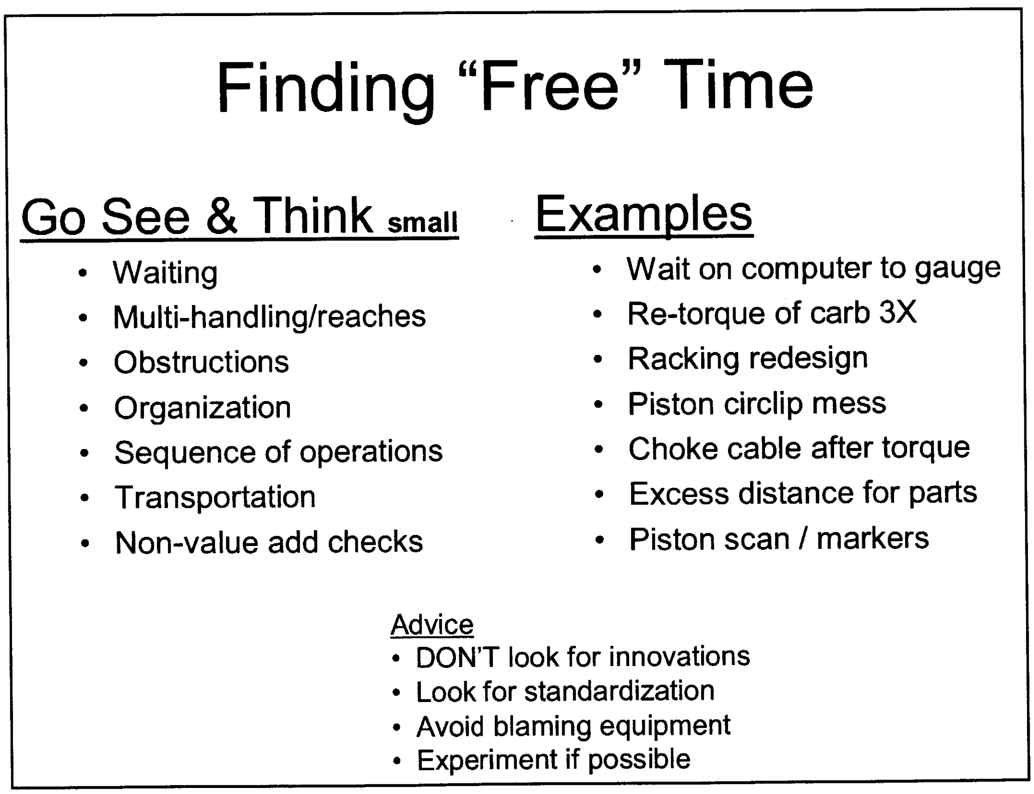


Figure 22: Assembly Best Practice Circle Slide

Most teams returned with at least five ideas for improvement. Attendees were amazed at how they were able to find the improvements using such simple ideas. This experience proved to many of the leaders that these improvements were not difficult but only required looking at the details. The thought question for the group remained: How do we institute this type of improvement process at Mighty Motors?

4.3 Waste Elimination

The idea of waste elimination as a means of continuous improvement was pioneered by Taiichi Ohno, considered the creator of the Toyota Production System (Ohno 19-20). Ohno classified waste into seven categories:

- Overproduction
- Waiting
- Transportation
- Motion
- Inventory
- Defects
- Overprocessing

Production efficiency can be realized by focusing on the identification and the elimination of these wastes.

Waste Elimination in the Carburetor Station

A production supervisor at Mighty Motors requested that I observe and improve the process in the carburetor station because the downtime in the station had recently increased with a newer operator. I spent a few hours observing the work performed and taking notes on the process. I routinely asked questions to gain a better understanding of the process.

I pointed out one observation to her: when she finished working on the powertrain in her station, she would obtain a gasket, step off a platform, and walk three steps to the next powertrain, place the gasket, and walk three steps back to her station platform. This was waste of overproduction and motion. She explained, "I do this to get ahead, otherwise I get behind." I replied that her extra steps are actually caused a waste of time and effort. In trying to get ahead, she was actually falling behind. She agreed to perform a few cycles of staying in her station to put the gasket on the powertrain. She discovered that she did not need to work at such a frantic pace to keep up.

After further observation, I noticed that the process required the operators to torque the carburetor four times with three different tools. This appeared to be a significant waste of overprocessing. The operators in this case only knew that this procedure was implemented several months ago by the resident engineers. I investigated further to learn that the resident engineers had requested the change in procedure due to some reports of minor leaks. They felt this would solve the problem. However when they checked the data since the change, had been no reduction in the minor leaks. Removing the additional torques freed up nearly 4 seconds of processing time or approximately 3% of capacity.

Waste Elimination in the Head Toque and Carburetor Sub-Assembly Station

As part of a cycle time reduction effort to improve capacity, teams of engineers worked with a series of stations to eliminate waste, improve the process, or transfer work to stations that had slack time. A talented young engineer, Megan, and I were teamed together on this project. The head torque and carburetor sub-assembly station was one of the stations we chose to improve.

In most respects, the process appeared to have few obvious opportunities for the amount of improvement we sought. Thinking at a more system level, in terms of waste, we observed that at the end of the process the operators rotate the J-hook 180° to position the powertrain for the next station. However, only three stations later the J-Hook is then turned again 180° to its original orientation (See Figure 23).

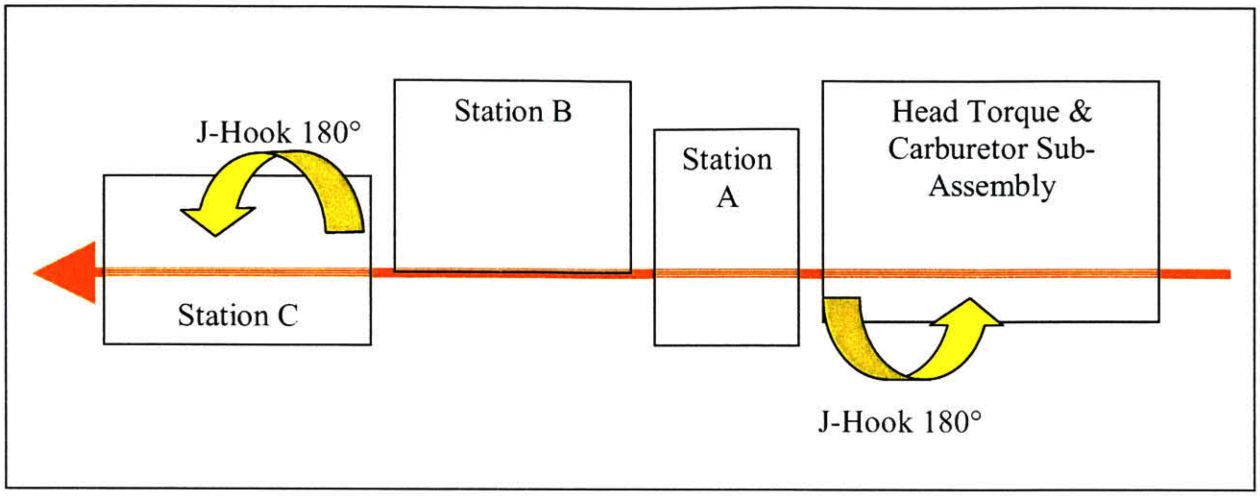


Figure 23: J-Hook Rotation

The rotation of the J-Hook was a completely wasteful process as it added zero value to the end customer. Eliminating the J-hook rotation was a bit more challenging than identifying the opportunity. Megan studied the affected stations and worked with operators to evaluate the possibility of rearranging stations to accommodate the powertrain in a different orientation. Although it seemed a bit of a challenge, we deemed it feasible. After proposing the change to operators, we received a backlash of complaints primarily from operators who did not work in the affected stations. Their primary complaint was that too much energy would be spent to only prevent two rotations of the J-Hook. They felt our time would be better spent "solving bigger problems."

We proceeded to make the changes to eliminate the J-Hook rotation and realized nearly a 7% capacity improvement in the station. The operators that challenged the idea could now see how much wasted time was spent on rotating the J-Hook.

Why was removing the rotations of the J-Hook resisted by operators? Why couldn't the operator see that she was actually making it harder to complete the process? Why did no one challenge the numerous torques? In Chapter 6, I will explore the cultural barriers to standardization and continuous improvement.

4.4 Experimentation

Focusing on waste elimination can enable a substantial level of improvement. However, there are often cases where the correct solution or the effect of a change is not obvious. Experimentation can serve as a valuable tool for testing ideas before they are fully implemented.

Toyota follows a scientific method in conducting experiments on the plant floor. Proposed changes are structured as experiments (Spear 81). Recall the 4th rule of TPS: Any improvement must be made in accordance with the scientific methods, under the guidance of a teacher, at the lowest possible level in the organization (Spear and Bowen 102).

Primary Cover Process Experimentation

The primary cover station was one of the stations under review for cycle time reduction, similar to the head torque and carburetor subassembly station mentioned earlier. Megan and I were teamed again to find process improvements in this station.

We observed both shifts at work in this station for a few hours. The operators in the station followed a very specific pattern each cycle and "had been doing it this way for years." At first, we felt it would be extremely difficult to improve this process. However, we did observe the operators appeared to double handle the parts frequently and walk a great deal. We focused our efforts on eliminating the double handing and walking. Megan and I diagramed the process to better illustrate the problem (See Figure 24).

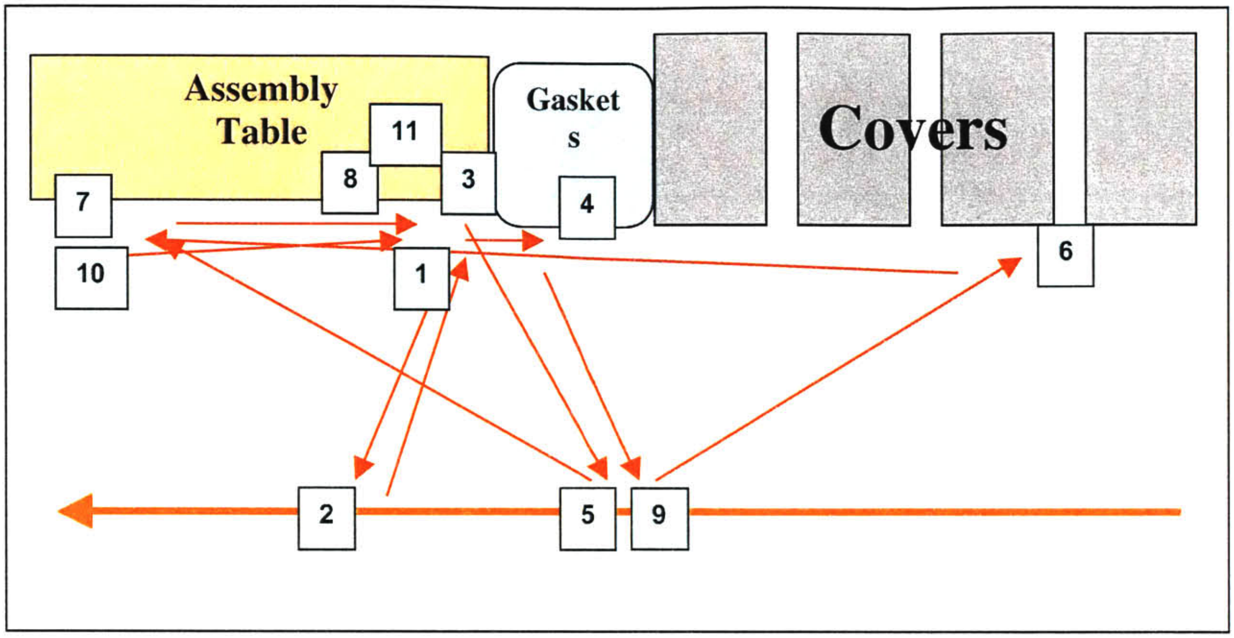


Figure 24: Primary Cover Initial Process Flow

The amount of backtracking and double handling of parts became obvious from the diagram exercise. However, we could not immediately determine a better process flow pattern. We worked with each operator to experiment on various process paths. For example, we tried moving a scanner to the assembly table instead of on the powertrain to eliminate a 180° turn and a couple steps. In this station, the operator actually worked on two powertrains. Previously the operators focused on completing the powertrain that just entered the station. Megan discovered that this caused the majority of the backtracking. The operators felt like they were getting ahead but were actually creating additional work on themselves. So, after a few iterations of experimental process flows, we developed a flow that completely eliminated the part double handling and reduced the amount of walking by over 3000 feet per day (See Figure 25).

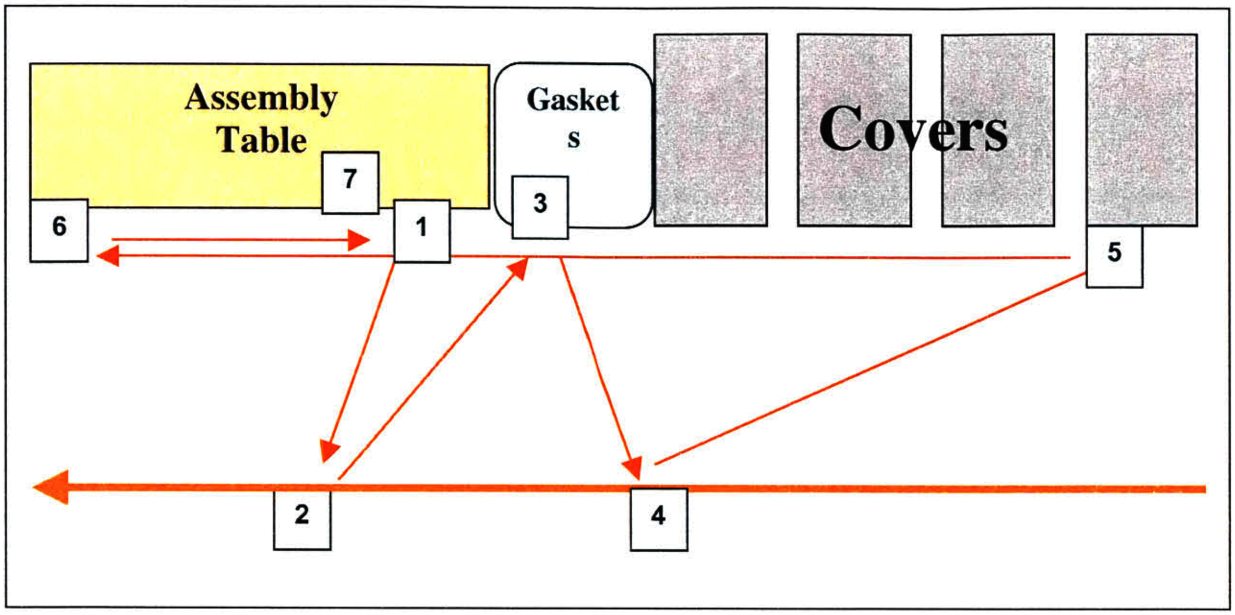


Figure 25: Primary Cover Modified Process Flow

It took less than two days and no capital expenditures to reach this solution. It did, however, take over two weeks of negotiations with one of the operators to accept this modified process flow. The operator would try the new process for only a few cycles, get frustrated, and revert back. We understood that she had, after all, been performing the original process for years. She was hesitant to give the new process a chance. Eventually, we had her observe another operator perform the process in the modified process. Ultimately, she finally that it was an improvement.

I reflected upon this experience to understand why was it so difficult to execute what appeared to be an obvious improvement in the process. I concluded that this problem was, in part, due to a lack of experimentation in stations at Mighty Motors. Operators will often work their processes for at least a couple years without making many improvements. The improvements that had been made were large scale project innovations, such as automated equipment and line monitoring equipment. This lack of smaller scale process improvement causes a bit of complacency. It is likely that if operators are given a chance with a continuous improvement coach to step outside of their process, they might find such opportunities and be more willing to change.

Carburetor Torque Sequence Experimentation

After elimination of the repeated torques (Refer to Section 4.3), I worked with operators to find additional improvements. I observed what appeared to be a minor difference in the sequence of operations between the first and second shift operators process. The minor difference in sequence turned out to have a major effect on the processing time. The following table (Figure 26) lists in simplified detail the difference between 1st and 2nd shifts.

1st Shift Process	2nd Shift Process
Place gasket on powertrain	Place gasket on powertrain
Thread 2 bolts to hold carburetor	Thread 2 bolts to hold carburetor
Obtain carburetor	Obtain carburetor
Attach carburetor to powertrain	Attach carburetor to powertrain
Thread 2 bolts to other side of carburetor	Thread 2 bolts to other side of carburetor
Put choke cable in position	Follow torque sequence on 4 bolts
Follow torque sequence on 4 bolts	Put choke cable in position

Figure 26: Carburetor Sequence of Operations

The process was ambiguous as to which sequence was correct. From observation, the 2nd shift sequence saved a great deal of time when compared to 1st shift, due to the choke cable not being in the way of the torque sequence. The 1st shift operator had to lift the torque gun around the choke cable and "fish" for the bolt. I estimated that there was at least a five second difference between the sequences.

I questioned the operator of the first shift about why she followed this sequence. She responded "This is how I was trained." I asked if she knew why she needed to follow this sequence. She answered "The previous operator who trained me said that he did it this way because it keeps the choke cable in place while you torque the carb." Apparently, the previous operator had determined that this method was better, yet had failed to document a new process.

At this point, I asked the operator to experiment by trying the other sequence. She appeared a bit reluctant initially, perhaps because it felt odd to be trying something different. She tried the other sequence for a few cycles and found it to be somewhat different and difficult at first, but she explained that it was because of the "muscle memorization" of the previous sequence. Eventually she gained a new muscle memory and found that it did save her time and effort in the process. We revised the process standard to reflect the appropriate sequence of operations.

This was one of my first observations in the necessity of detailed standardization of a process. The previous operator made his own adjustment to the process and relied upon training to capture it. Without the standardization, neither operator knew the one best way to perform the process, thus creating a great deal of variance.

4.5 Learning from Experimentation

The value of experimentation is not only testing an idea to see if it works. Value also comes from learning additional details and nuances about a process. By conducting small frequent experiments, one can learn what hinders and what enables a process, as well as discover new opportunities for improvement. One can quickly see where struggles occur, then rapidly test your understanding by implementing a countermeasure, thereby accelerating the rate at which you discover contingencies or interferences in the process (Spear 84).

When you combine the elements of standardization and experimentation you achieve a "deeper understanding of the product, process, and people" and then "that understanding is incorporated into a new specification, which becomes a temporary 'best practice' until a new problem is discovered" (Spear 79).

4.6 Case Study in Continuous Improvement: Piston Station

Background

The piston station was one of the greatest contributors to daily downtime and also would cause downtime in stations downstream. The downtime was typically caused by installation of the wrong piston on the powertrain. This incorrect installation would typically be caught, but often after it was secured to the powertrain. Thus, a special tool and a repair operator would be required. Engineers had implemented some countermeasures in the station to reduce the possibilities of error, yet they still recurred. As this major problem proved persistent, the line supervisors requested that I use the piston station as part of my study of standardization and continuous improvement. Additionally, as part of the cycle time reduction effort, this station needed approximately four seconds of work either eliminated or moved to another station.

Initial State

I observed the station for a few hours a day over a couple weeks. This allowed me an opportunity to observe deviations from the standard process flow, and also allowed the operators get comfortable working with me.

The basic process flow is in the following figure:

Piston Process Flow	
1	Select sub-assembled pistons from table
2	Attach pistons to powertrain
3	Barcode scan picture match of pistons attached (quality check)
4	Secure pistons to powertrain
5	Obtain pistons for next powertrain
6	Sub-assemble pistons
7	Place completed pistons on table

Figure 27: Piston Process Flow

The overall process was not extremely difficult; however there was a certain level of specialized technique in the sub-assembly process. I observed several potential root causes for the downtime and incorrect piston installation:

- Lack of housekeeping
- Lack of specific level of WIP (sub-assembled pistons)
- Operator not following process standard
- Sub-assembly machine jamming and operator not using safety stock
- Operator working ahead (sub-assemble extra pistons during cycle)
- Operator not paying attention
- Inaccurate use of barcode scanner for piston verification
- Incorrect build card on powertrain

Standardization

From this list, I determined that the initial area of focus should be to obtain an increased level of standardization in the station. Without a level of high agreement in the station, any improvement efforts would not be sustainable. In Section 3.3, I describe the initial state and the standardization effort. By obtaining a level of standardization and stability, I now had a baseline for improvement.

Incremental Continuous Improvement through Experimentation

I focused my efforts at this point on making incremental improvements to the piston selection process.

Experiment 1: Lanes for WIP

The first experiment basically established "lanes" for the five different piston types. The goal here was to simply establish different picking zones for the pistons.

Figure 28: Piston WIP in Lanes

Operators approved of this idea and it appeared to improve the piston selection process. However, there still remained too much WIP as operators would fill up the lanes with sub-assembled pistons. This occurred even though the process standard specified that no more than three sub-assembled pistons should be made. Thus, confusion still existed in the process.

Experiment 2: Zero WIP

Building from the first experiment, I experimented with a zero WIP option. I created color labels with pictures on the table surface to match the color of the appropriate build card. In this experiment, the operator would only build the set of pistons for the upcoming powertrain.

Figure 29: Piston Zero WIP

This one by one approach worked fairly well, for the most part. However, if anything went wrong in the process, the operators were required to use safety stock. With this method, the operators were uncomfortable dipping into the safety stock on a frequent basis. They felt the safety stock should only be used to handle instances in which the machine jammed.

Experiment 3 - Pull Process

One of the operators suggested after experiment 2 that we try a pull process. His idea was to have sub-assembled piston sets available – one of each type. Once the pistons are installed on the powertrain, the operator would build the piston set that they just installed. This allowed the operator to focus for an entire cycle on one type of piston as opposed to looking downstream to see what to build next.

Figure 30: Piston Pull Process

This process worked very well and we left it in place for a few weeks. Occasionally, the operators would drift back into building ahead just before break time, but overall they appeared to like this process.

Experiment 4: Scan Movement

Satisfied with the positive results from the pull process, I next focused upon finding a way to further decrease the chances of installing the wrong piston. I observed how operators were to scan a barcode beside the picture of the piston they had installed. The barcode picture scan was a corrective action put in place over a year ago to reduce incorrect piston installation. By matching the picture to the piston, the system would validate that the proper piston was installed. The problem with this corrective action was that operators would not look to match the picture; instead they would match the build card to handwritten labels on the pictures and ignore the piston type they actually installed. This completely nullified the purpose of the barcode picture scan.

I modified the barcode picture scan sheet so that it would not have handwritten labels. I explained to the operators that their method made the barcode scan a worthless process. They disagreed and were upset at me for changing the sign. I restored the handwritten labels and went back to thinking about how to fix this problem. I discussed the problem with Megan. She came up with the brilliant idea of putting the scan labels on the table, directly at the picking point. Operators would scan the label directly at the point of selection. Additionally, a 180° body turn was removed from the process.

Figure 31: Piston Barcode Scan Move Experiment

Operators were a bit skeptical of this idea, but gave it a try for a few cycles. It seemed to work well, however it required moving the barcode scanner which would take a few weeks to get scheduled with electricians.

Experiment 5: Un-stack Pistons

After a couple more weeks, we saw decent reductions in downtime and only a couple incorrect installations. However, incorrect piston installation was still a problem. I looked at how the operators always stacked pistons on top of each other, such that it was nearly impossible to tell them apart. If the pistons were not stacked, a person could more easily tell what type of piston it is. I asked the operators why they stacked the pistons. "We've always stacked them, I guess they are just easier to handle that way." I requested that we experiment with not stacking the pistons to see what happens.

Figure 32: Un-stack Piston Experiment

They agreed to not stack the pistons. One operator was very pleased with the process improvements to this point. However, one operator became extremely annoyed at this point because he felt that I was "making this process for an idiot." He continued "I'm not an idiot and I don't install the wrong pistons. I mean, yeah, mistakes are gonna happen and no one is perfect. So what if I put the wrong piston on every now and then? You cannot expect perfection."

This resistance to continuous improvement stemmed from personal expectations and a deeper cultural issue at Mighty Motors. The operator was "satisfied" with the level of improvement, yet I felt that we were only beginning to get somewhere with the improvements. I stepped back from the improvement process a bit to discuss this issue with the operator. The operator indicated that he "wants to think so that [he] doesn't get bored." I agreed that yes, he should be thinking, but not in making process decisions. Instead, he should be thinking about ways to improve the process. We continued discussions for a while and eventually involved leadership in the issue. I proposed the ideas for the final experiments to leadership. Leadership saw that these could further reduce the possibility of wrong piston installation and asked the operator to continue working with me.

Experiment 6: Cardboard fixture for pick to light system

Since the barcode scanning process failed to eliminate the errors of wrong piston installation and also caused additional non-value added work to the operator, I looked at finding a system that could replace the process but still serve as a quality check. A few stations on the assembly line used a "pick to light" system for selecting critical parts. The basic pick to light system worked as follows:

1. Powertrain enters station
2. RFID in J-Hook sends powertrain information to computer
3. Computer relays part selection to appropriate light module
4. Light indicates which part to select.
5. Operators breaks light curtain in selecting part
6. Light module relays part selection back to computer
7. Computer recognizes part selection

The pick to light system for this application would cost around $3000, so before we spent any money on this system I worked on finding an appropriate way to use the system. I developed some prototypes using cardboard to create a piston tray and a flashlight to simulate the pick light. One operator had the idea of the piston tray to keep the pistons in specific lanes as well as keep them from falling off the table.

Figure 33: Piston Cardboard Fixture Experiment

The experiment was a success and we moved forward with a pick to light system.

Result

The pick to light system was installed after a few weeks.

Figure 34: Piston Pick to Light System

The pick to light system and experimentation process led to significant improvements in the piston station. Some highlights:

- Eliminated 750 movements (reaches, turns, etc.) per day
- Eliminated 6 seconds on non-valued added work
- 75% reduction in wrong piston installation
- 70% reduction in downtime

Figure 35 shows a trend graph of the weekly downtime in the piston station. In the three months following installation, downtime was reduced significantly. What the graph does not reveal is that the cycle time at the time of the installation is over ten seconds faster than in the beginning of the year.

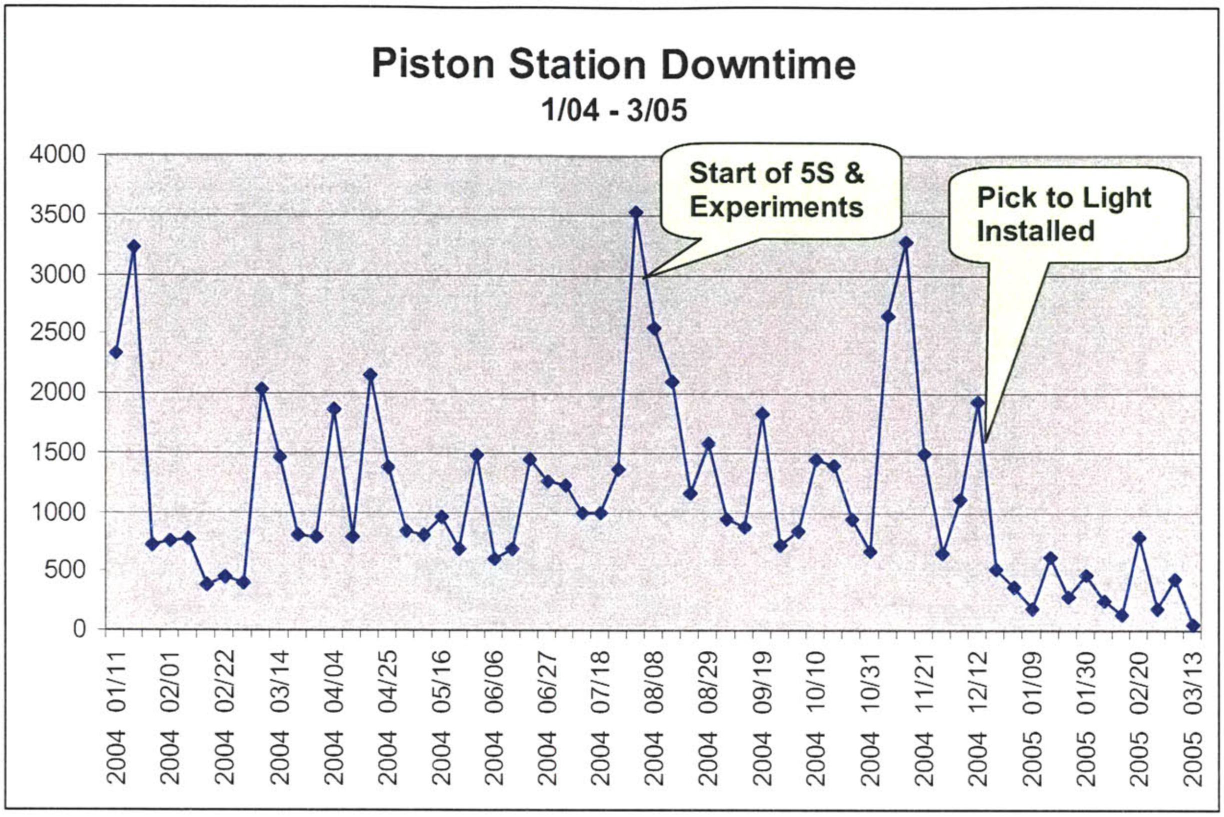


Figure 35: Piston Station Downtime Graph

Reflection

After completing this work in the piston station, I reflected on the methods and challenges faced to reach the end result. The experiments enabled a great deal of learning about the process. With each experiment, the operators and I would see something else that could be improved. Experiments also helped in allowing the operator to try out new methods before a full scale innovative change. Although experimentation caused a slower learning curve, the end result is a better process that has been verified to work.

The typical process of continuous improvement at Mighty Motors does not involve experimentation. What would the solution have looked like without the experimentation? I hypothesize that a similar solution could have been reached, but I doubt the operators would have felt involved in the process and may have therefore ignored the new system.

An additional point of reflection came after showing some mangers the graph in Figure 35. While many were very impressed with the results, they all asked about what happened during the weeks of high downtime. From analysis I knew that the answer was a major machine malfunction. None of the managers asked why there is so much downtime each and every week in the piston station. This should be more important as the total quantity of the "lesser" downtime weeks is far greater than the 2-3 high downtime weeks.

In Chapter 6, I will discuss how the organization can act as barriers and enablers. Additionally, I will discuss the role of managers and employees to achieving standardization and continuous improvement.

5.0 Value of Standardization & Incremental Continuous Improvement

"If I cannot do great things, I can do small things in a great way"
- F.W. Robertson

5.1 Standardization to Enable Continuous Improvement

"Standardization is the foundation of continuous improvement; create high agreement and no ambiguity. Without this you will not have continuous improvement."
- Jamie Flinchbaugh, Lean Learning Center

To prove that standardization enables continuous improvement would be extremely difficult in a dynamic setting like the manufacturing floor. Even without standardization there is typically some form of continuous improvement taking place. However, I would purport that without standardization, continuous improvement is more difficult to execute and more importantly, sustain.

Common Language and Baseline for Continuous Improvement

"You can't improve a process you don't understand."
- NUMMI Manager (Alder 104)

Perhaps the most important effect of standardization is that it provides the foundation and stability needed for improvement. A highly detailed process will have less ambiguity and therefore typically less variance. This ultimately leads to predictable results of a process. The more predictable results lead to a common language for identifying problems and making improvements. "Every time an abnormality occurs in the process, the following questions must be asked: Did it happen because we did not have a standard? Did it happen because the standard was not followed? Or did it happen because the standard was not adequate?" (Imai 6).

Identifying Opportunities for Continuous Improvement

"You cannot be creative in an anarchy."

- Lean Learning Center

Once a detailed standardized process is in place, opportunities for improvement become more visible. Process variability hides a great deal of waste. Once you are able to clearly see the waste, you can find continuous improvement. A team leader at NUMMI, Toyota's joint venture with General Motors, comments "standardization is not only a vehicle and a precondition for improvement but also a direct stimulus. Problems rise to the surface" (Alder 104).

Prior to implementing 5S in the piston station (Refer to Section 3.3) both operators performed the process in a similar manner except for the piston selection process. Lacking a single best way to perform the process, it was subject to a great deal of variability and therefore nearly impossible to improve because each operator performed the process in their own way. Through agreement of a single method as a starting point, we were able to find ways to improve the process. "It was as if the muddy water cleared to reveal problems," described an operator.

Sustainability

"You can have the temporary 'I', but not the sustainable 'CI' without standardization."

- Dan Glusick, Assembly Group Lead at Mighty Motors

Sustainability is perhaps the most important aspect of the improvement process, yet it also seems to be the most difficult state to reach. When a process is improved, the process standard must be revised to reflect the change, otherwise the improvement will deteriorate. Without a new process standard, how does a person know the right way to perform the task? If a new operator starts the process, how will they know the proper method? Without standardization, there will be a severe lack of sustainability.

5.2 Incremental Improvement

The incremental method of improvement is a common-sense and low cost method. By approaching improvements in this way, one is able to experiment with smaller ideas in a quicker manner. This increases the amount of learning about a process. Rather than spending time and money to engineer a solution to a major problem, you can use cheap materials like cardboard and labels to easily test ideas.

Incremental improvement focuses on the contributing factors and the near misses, as opposed to the focus on solving the major problems (See Figure 36). Improvements from this "side" should "narrow the funnel" such that fewer contributing factors lead to big problems.

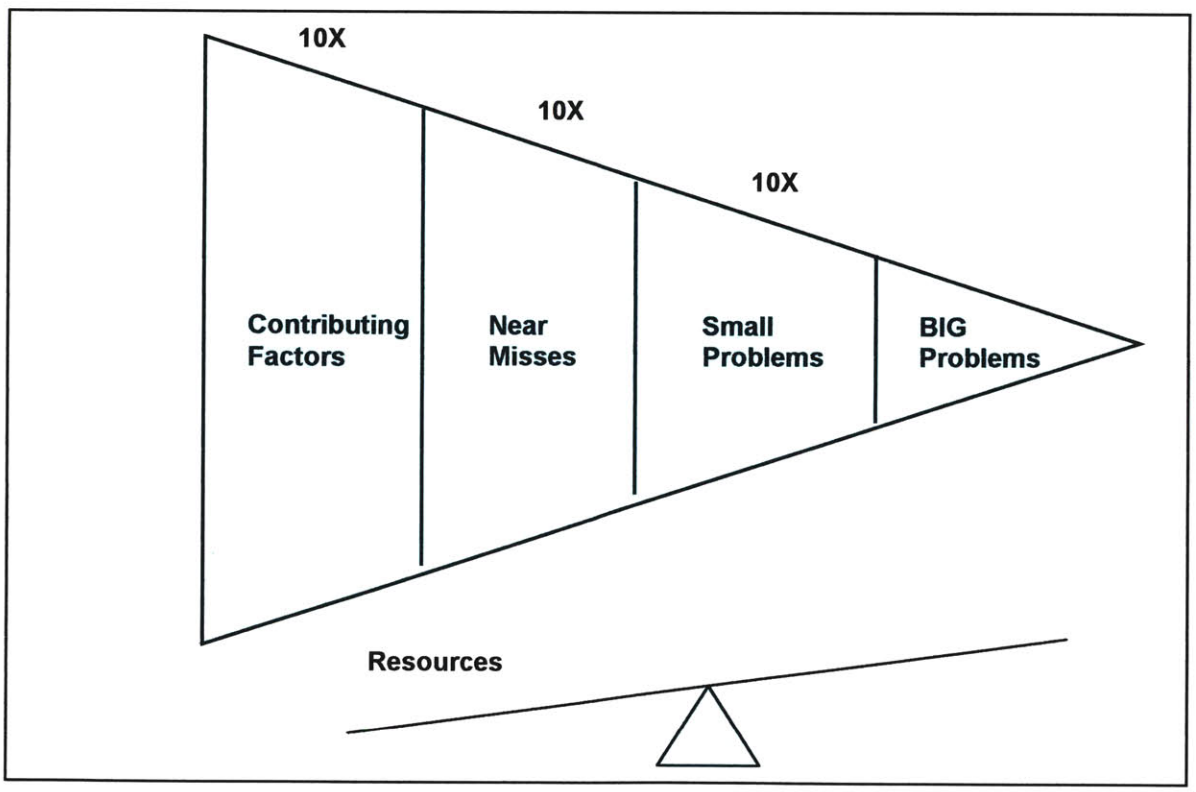


Figure 36: Magnification of Problems with Contributing Factors Focus

Incremental improvement should be used between innovative improvement projects. Incremental improvement allows a push of the process to a limit at which point an innovative style improvement may be necessary. Figure 37 is a representative diagram of this method.

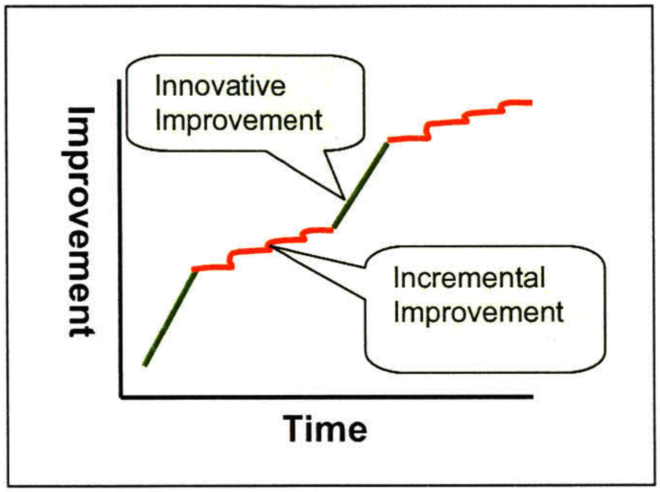


Figure 37: Incremental Improvement with Innovative Improvement

5.3 Value of One Second

"Why should I worry about a couple seconds?"

- Operator's reply to me after discussing a two second process improvement

The incremental improvement method can feel very tedious and unworthy of the effort at times. The operator's question is worthy of consideration. What is the value of finding a single second improvement? Although, we generally found improvements of four to eight seconds, I will use one second as the baseline.

Downtime Perspective

As mentioned in Section 1.2, one minute of downtime is estimated to cost $38 in labor to recover the lost capacity during overtime. The daily downtime goal at Mighty Motors is less than 30 minutes per day. Suppose we asked the operators in every station to reduce the average downtime by just 1 second. I imagine every employee would agree to this very attainable goal.

	30	Stations on Assembly Line
x	1	Second reduction in downtime at each station
x	2	Shifts / day
x	5	Days / week
x	50	Weeks / year
x	1/60	1 minute / 60 seconds
	250	Minutes downtime / year
x	$38	Estimated labor cost / minute of downtime
	$9,500	**Total estimated annual labor cost savings**

Figure 38: Estimated Savings from a One Second Reduction in Downtime

A single second reduction in daily downtime across the assembly line equates to nearly $10,000 cost savings. This is equivalent to a 30 second reduction in the average daily downtime. Note that this calculation is savings from direct labor cost only.

One must be careful in using a cost of downtime value, as it can drive the wrong behaviors in employees. For example, in order to reduce downtime, operators may be reluctant to call for help and find a way to fix a problem themselves. This behavior could result in larger problems and an even greater amount of downtime. This downtime savings should be used as a motivational “carrot” to employees in finding ways to eliminate the problems that cause the downtime. It should not be used as the “stick” to have employees not report problems.

Capacity Perspective

The cycle time of the line is a driver of capacity. The value of a single second in this case will vary depending upon the line cycle time. For instance, a 1 second reduction in a 60 second cycle time is a 1.6% (1/60) improvement whereas in a 200 second cycle the savings is only 0.5%

(1/200). I will use a cycle time of 130 seconds. Also, assume the assembly line runs 7 hours a day for 2 shifts. This equates to 50,400 available production seconds daily. At 130 seconds, 387.7 powertrains can be manufactured. At 129 seconds, 390.7 powertrains can be produced.

	390.7	Powertrains / day @ 129 second cycle time
-	387.7	Powertrains / day @ 130 second cycle time
	3	Additional Powertrains / day
x	5	Days / week
x	50	Weeks / year
	750	Additional Powertrains / year

Figure 39: Estimation of Capacity Improvement from a One Second Cycle Time Reduction

	750	Powertrains
/	387.7	Daily Production Rate
	1.93	Days of Lost Production
x	7	Hours / day
x	$1500	Labor Cost / hour (estimated)
	$20,265	**Total estimated annual labor cost savings**

Figure 40: Estimation of Labor Savings from Capacity Improvement

Although these calculations are a rough estimate of the potential savings, they provide a good idea of the magnitude of a one second improvement.

The calculations above only include the direct labor costs, yet yield numbers worthy of thought. Given the results of the above calculations, it is hard to ignore a single second improvement especially when the single second improvements generally require zero capital.

5.4 Metric Results

The estimated value of one second provides a general case of one second improvements across the line. For a different perspective, we can examine the metric results of the improvements made in the piston station, primary cover, and carburetor stations. The following metrics will be reviewed: safety, quality, downtime, and capacity.

	Piston	Primary Cover	Carburetor
Safety	750 movements/day	3000 ft. walking 400 movements/day	Eliminate tool - 400 reaches
Quality	75% reduction in incorrect piston installation	No double-handling; increase cosmetic review time	Decrease in installation of incorrect carburetor
Downtime	70% reduction		10% reduction
Estimated Downtime Labor Savings	$30,000		$8,000
Capacity	6 seconds	6 seconds	4 seconds

Figure 41: Overview of Metric Results

All of the above improvements were made through standardization and an incremental approach to standardization. There are other savings that are much more difficult to trace and value precisely, such as warranty costs and restricted or lost time work accidents due to operator injury.

The only capital required was in the piston station for the pick to light system which was less than $3000. The key conclusion here is:

Small improvements X many iterations = BIG Impact

6.0 Organizational Process Analysis

"Businesses are not about things, they are about people."

- Professor Jonathan Byrnes[5]

The majority of this thesis describes and analyzes standardization and continuous improvement methods. After performing a great deal of the work to achieve standardization and continuous improvement, I realized that the challenge is not truly about determining how to improve or standardize processes. Making sustainable improvements is more than a collection of mechanical tools of problem solving (Johnson 11). The real challenge lies in creating an organization that strives for continuous improvement. In order to achieve continuous improvement, the organization must value standardization.

How can Mighty Motors create an organization that embraces standardization and continuous improvement? What are the barriers?

In this chapter I will analyze the organizational processes at Mighty Motors in the context of standardization and continuous improvement to provide some recommendations. Although this analysis will be specific to Mighty Motors, the methods of analysis and recommendations can apply to a broader set of organizations.

6.1 Three Lenses Organizational Process Model

A useful model to analyze organization processes is the Three Lenses Model taught in MIT Sloan's Organizational Process class. The model provides three frameworks (lens) from which to analyze: strategic design, political, and cultural. The frameworks overlap and influence each

[5] Quote from lecture notes taken in Professor J. Byrnes class at Massachusetts Institute of Technology, Case Studies in Supply Chain & Logistics, Spring 2005

other to define the organizational processes. Often, one of the lenses dominates and drives the others. Below are brief overviews of each lens:

Strategic Design

The strategic design perspective examines the structure and strategy of the organization. The design of an organization influences the methods of achieving goals and carrying out tasks. Within this perspective, alignment and incentive mechanisms are structured to motivate employees towards the organization's common goals.

Political

The political perspective is a view of the organization from the power among stakeholders with different goals and underlying interests. Within this perspective, power is the ability to get things done, and organizational changes are not simply rational moves to accomplish goals (strategic design), but are also potential threats to those who hold power and opportunities for those who want more power.

Cultural

The cultural perspective examines the unconscious taken-for-granted beliefs that comprise the organization's culture. Culture develops over time with people in the organization learning the accepted ways in how "things" get done. It is often very difficult to "see" a culture, however through experience you gain a "feel" for the organization's culture.

6.2 Strategic Design Analysis

In terms of barriers to standardization and continuous improvement, the strategic design lens is not the dominant framework for Mighty Motors. However, there are some aspects that hinder improvements.

Organizational Strategy

Overall, the Mighty Motors strategy is to deliver high quality and desirable products at a reasonable price to customers. Marketing has developed and established this image within the customer base. The manufacturing operations are expected to deliver on this image.

The Mighty Motors plant that I studied uses the A3 (Refer to Section 2.2) to set the strategic direction. On an annual basis, a plant wide A3 is developed to establish the few key areas of focus. High level metrics are developed around these areas. The plant A3 is then used to develop more detailed A3's for the various departments in the plant, including the assembly line. The A3 is then taken to a further level of detail around the key areas identified in the previous A3s. More specific metrics are then created for these areas. Examples of these areas of focus include: safety, quality, production, equipment reliability, and capacity.

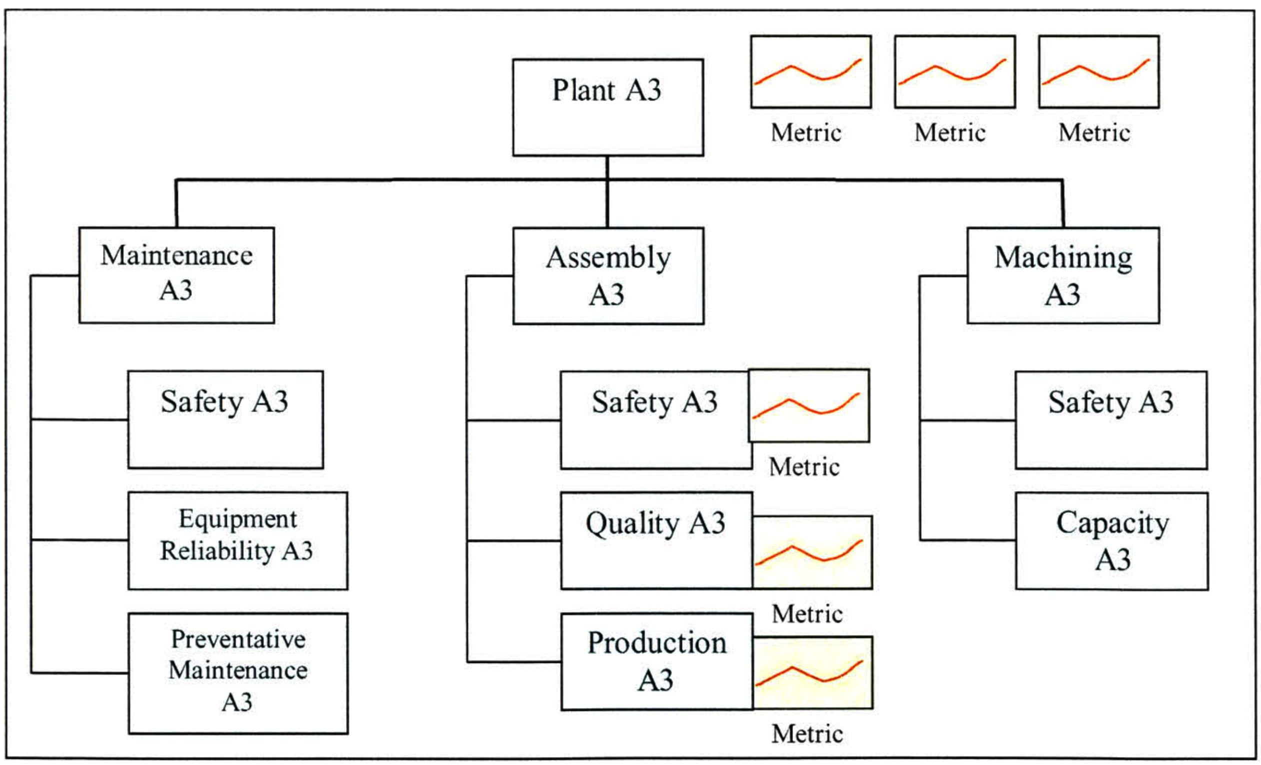


Figure 42: Example of A3 Strategic Planning Cascade

The cascading A3 deployment appears to be a very effective method of setting strategic direction for the plant. Perhaps the greatest benefit is that the A3 is a simple and easy to understand format on a single sheet of paper. The A3s for the plant and departments are enlarged and printed to display in the cafeteria for anyone to read.

In nearly every A3, there is a mention of using continuous improvement as a means to achieve the goals. A few A3s mentioned standardization. This leads to part of the problem with this cascading format – ambiguity in definition. Continuous improvement is mentioned nearly everywhere – however what does that mean for Mighty Motors? Is it the big burst innovation style or the small incremental approach? I believe managers at Mighty Motors would answer "yes" to imply that both methods are appropriate. However, as we will see in the organizational design and the culture, Mighty Motors favors the innovative approach. The second problem is that each department can have their own interpretation of standardization and continuous improvement. However, these are principles that need to be defined by upper management to obtain high agreement. Lastly, continuous improvement is of obvious importance, yet standardization is not. In this thesis I have stated how standardization is required for continuous improvement. (Note: the plant A3 for the following year did include 5S).

Organizational Design

In recent years, Mighty Motors has worked to develop a more team based organization. The plant is subdivided into several small workgroups. For instance, the assembly line has at least five separate workgroups with one Workgroup Advisor. Within each workgroup, there are various point people: safety, quality, productivity, employee development and administrative. Workgroups meet on a weekly basis to discuss issues and performance. On a monthly basis, the point person from each workgroup meets in "super-group" meetings to discuss the relevant plant-wide issues. In addition, each workgroup has a salaried support employee, typically an engineer. The salaried support person is generally called upon to handle the larger problems or projects. The entire group of operators, workgroup advisors, and salaried employees is supported by the Group Leader.

The following diagram in Figure 43 depicts the workgroup and super-group structure of the Mighty Motors Assembly Line.

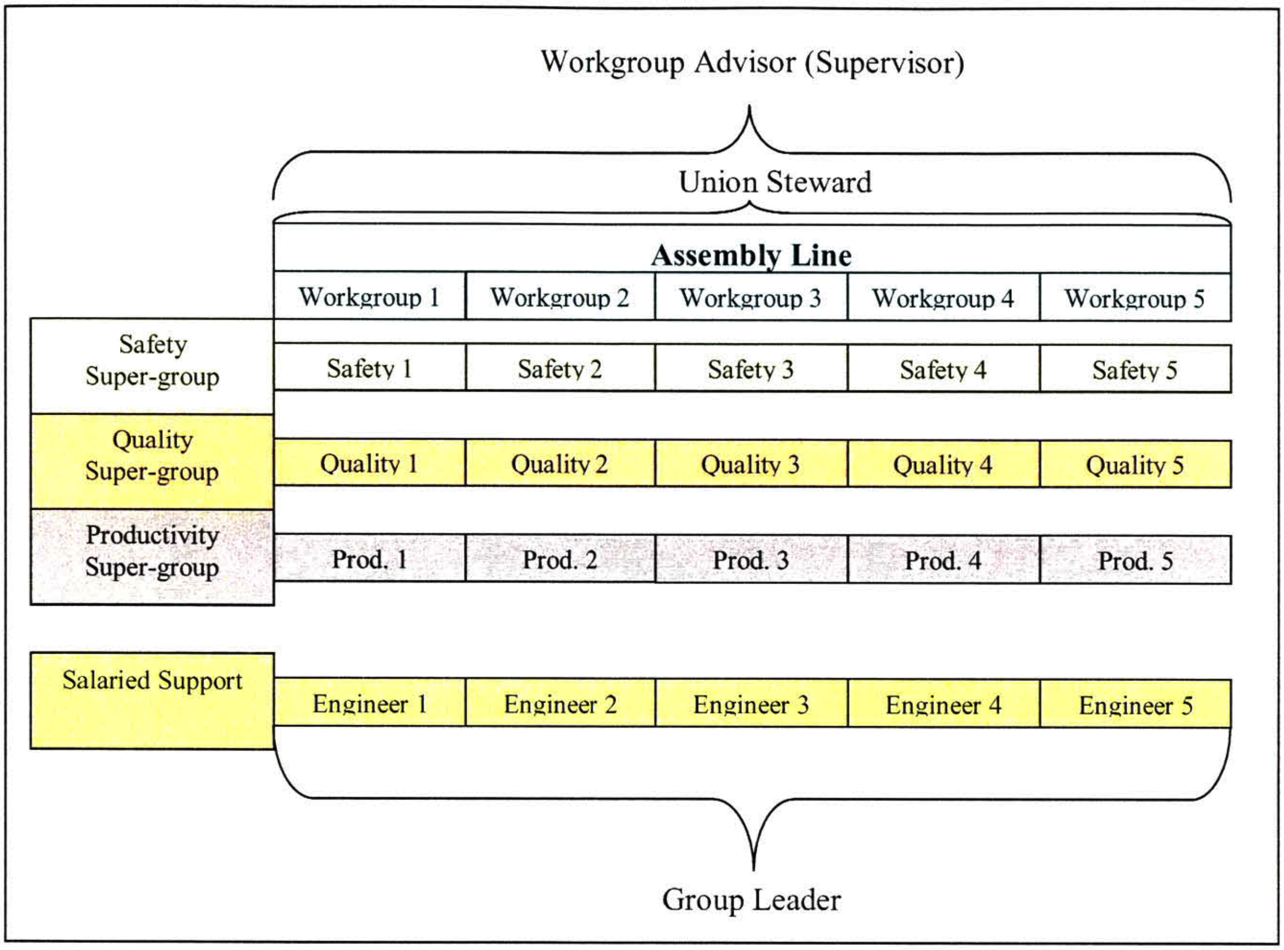


Figure 43: Organizational Design of Mighty Motors Assembly Line

This structure still has elements of a hierarchical reporting relationship, but also a matrix relationship. The overall structure is still evolving at Mighty Motors, as some groups are gaining autonomy to make independent decisions; however, the majority of the workgroups rely heavily upon the Workgroup Advisor and salaried support personnel to facilitate meetings.

In working at Mighty Motors, I observed this structure in action and found it to be effective in the distribution of information. Although, sometimes I felt as if too much information was sent from various directions. This often caused the information to be conflicting. However, too much communication is rarely a complaint. The challenge within this organizational design is actually the lack of a single point of contact for ideas and issues. In the A3 I developed on continuous improvement (Appendix 1), I noted that employees have over six different people they can go to with ideas. This result is often a great deal of frustration from employees on the line as ideas tend to get lost because everyone believes it is someone else's job.

In general, it becomes the job of the salaried support personnel to make the changes and improvements. Salaried support personnel quickly become loaded with projects causing more of these ideas to be put on the backburner.

Incentive Structure

Mighty Motors has a dual incentive structure – an annual individual performance bonus and a group bonus. The incentives at Mighty Motors are generally quite generous, as Mighty Motors has done well for the past several years. Most employees are happy with the incentives they receive. However, I did observe that the smaller "instant" incentives for employees were not prevalent. For example, I could not reward an employee for an improvement idea with a t-shirt or some other small token. This type of incentive goes against the union rules of rewarding the team and group as a whole. Lacking the instant incentives is a minor problem in encouraging continuous improvement however, it is not necessary in the right work environment.

Strategic Lens Recommendations

From the strategic lens, a few recommendations can improve standardization and continuous improvement at Mighty Motors:

Create a Standardization/5S Super-group. Standardization is key to continuous improvement and overlaps many of the other areas of importance. Standardization should be considered a means of achieving the goals.

Leadership should clarify the definition of standardization and continuous improvement. Management needs to set the expectations on how and what is meant by standardization and continuous improvement.

Establish a Continuous Improvement Coach. One of the problems noted in the analysis was the lack of a single point of contact for ideas. There should be a clear link to where ideas are channeled. Perhaps a coach can be a part of each workgroup.

6.3 Political Lens

The political lens, similar to the strategic lens, is not the most dominant framework. Although from the political perspective analysis we will see that the relationship power struggle has a great deal of influence on affecting standardization and continuous improvement.

Stakeholder Perception Mapping

Various stakeholders in an organization can have very different perceptions of organizational change. Driving the perception difference is often the feeling of gaining or losing power due to the initiative. A useful tool to visualize the perception differences is stakeholder perception mapping. In it, a diagram illustrates the reporting relationships and a +/- indicates whether they are for or against the initiative.

For continuous improvement, a stakeholder map is not necessary, as everyone within Mighty Motors supports the idea of continuous improvement. However, strong perceptual differences exist on how to go about achieving continuous improvement. At the individual operator level, there can be fierce resistance to continuous improvement as I experienced in some of the work I completed. This resistance appears to often be a result of the history in how continuous improvement was attempted in the past. Operators in the past felt as though change simply happened to them. Operators described to me that, basically, an engineer would come in and declare they are making a change. The change would be implemented and as a result, the operator usually felt as thought they now had more work to do.

This method of change and improvement created a distrustful environment between line employees and management. This approach made many operators feel powerless. The methods have since changed to more of a partnership approach in seeking out the operator's ideas and support. However, history will often take a while to fade from memory.

The perception of standardization is a much different scenario, as not all stakeholders are in high agreement as to what it means at Mighty Motors. The word standardization at Mighty Motors connotes control, largely due to use of "process standards," described in Section 3.5. These process standards are used at Mighty Motors to evaluate the amount of "work" within a station. An industrial engineer develops the standards based upon observation and operators are expected to meet the standard. This is a very confining and controlling method of standardization. This creates a struggle between the union representation and management on what is a fair amount of work.

The stakeholder map in Figure 44 represents my analysis of the perceptions of standardization at Mighty Motors. This perceptual difference in the definition of standardization creates the lack of support from the operators and union representation.

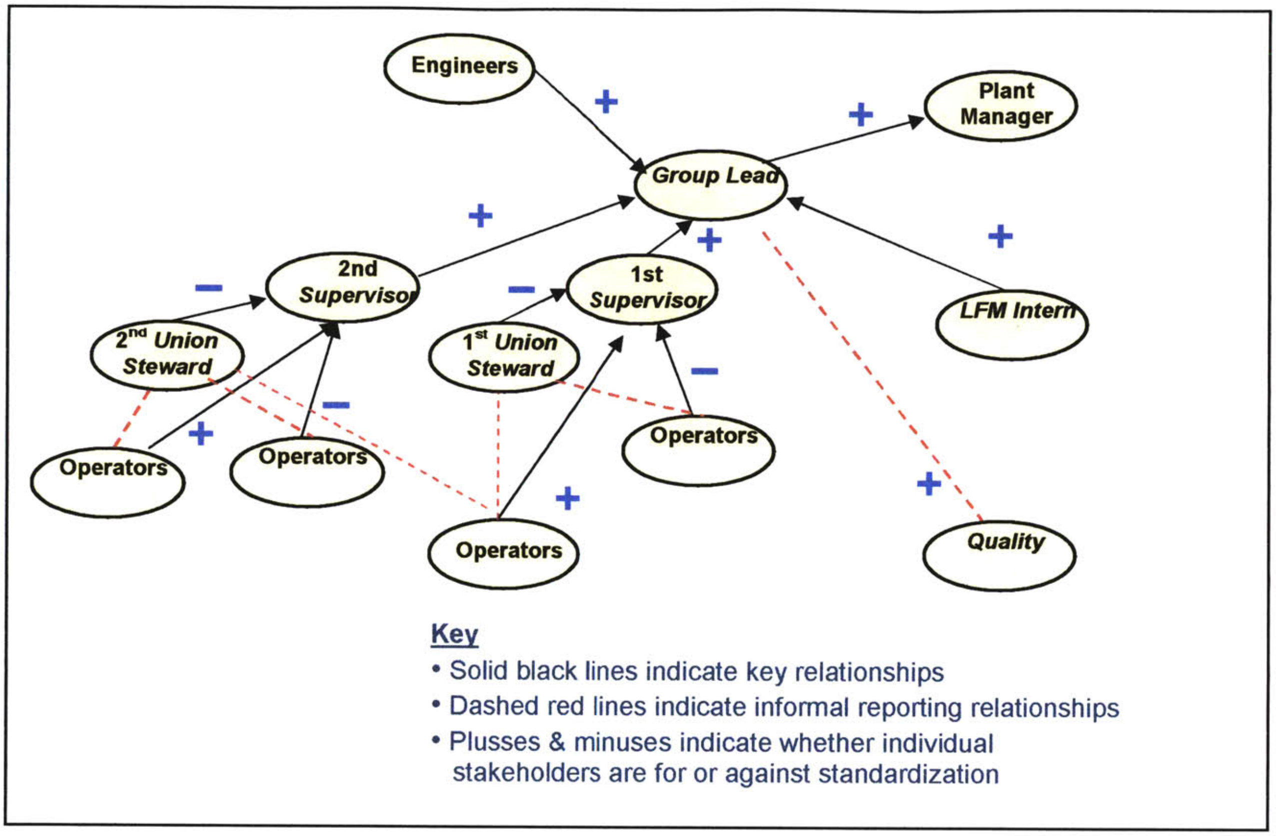


Figure 44: Stakeholder Perception Map of Standardization at Mighty Motors

Distribution of Power

Mighty Motors has a union represented workforce. The relationship between the union and management is in general quite good. Both parties have worked at fostering a relationship of solving problems together and consensus building. There appears to be a fairly equal distribution of power in the relationship. However, as a union employee told me, "The union can make your job easy or a pure living Hell." Although a bit exaggerated, the union does wield a great deal of power in the level of effort and effectiveness of initiatives. With union leadership backing an initiative, it will happen. Conversely, an initiative will struggle to survive without union support.

Gaining the support of union leadership is vital for standardization and continuous improvement to take hold at Mighty Motors. The perception of standards as a means of control will need to change for this to happen.

Recommendations

Continue partnership with operators in continuous improvements. The operators in each station know the process inside out. Although initially they will claim they have no ideas for improvement, asking questions about why things are done a certain way can lead to ideas. The second key is to follow through on making these ideas a reality. If the idea originated from operators, they are much more likely to understand and follow.

Allow operators to design standards. The strong negative attitude towards standardization can best be changed by distributing control to the operators. By providing operators with the tools and ability to design and change their own standards, standards will have a high probability of being followed and improvement ideas will result from the process. This process would demonstrate a great deal of trust by management

Mighty Motors should not simply make a full switch to this system as the organization is not ready for a change of this magnitude. However, experiments with a few workgroups to try out the process will show how well it can work.

Partner with union leadership to lead standardization. As mentioned in this section, the union has the power to make initiatives happen. Management needs to prove to the union that the standardization is not for purposes of work control, but for purposes of making improvements and reducing variability.

6.4 Cultural Lens

Analysis through the cultural lens provides perhaps the strongest insight into the barriers to standardization and continuous improvement at Mighty Motors. The culture at Mighty Motors is quite strong and has developed for several decades. Employees at Mighty Motors care deeply about the product and the quality image. They are very proud of the product and many are loyal customers as well.

However, the strong culture at Mighty Motors has created some strong barriers to standardization and continuous improvement. There will be some generalizations in this section, so please note that not everyone acts in the manners described. In this section I will discuss a few of the key barriers.

Fear of Management's Abuse of Power

Among my first observations in going to work with operators on the line was a sort of Pavlovian response to an engineer in the station[6]. Upon observing the station, I would receive a third degree line of questioning. Why are you here? Are you going to give me more work to do? What do you want to change? Why? Some operators would immediately develop a wall of resistance before I could even explain the purpose. Before I could actually perform work within stations, it was required that approval be granted by the operators and the union steward.

This lack of trust is a direct result of Mighty Motors' history in making "improvements." An operator explained to me why I received such initial resistance, "there are only two times we see engineers or supervisors in our station – 1) when there is a major quality or downtime problem 2) when they are looking to add work to our station." Additionally, one of the union's goals is to employ people. There is a fear that improvements made in processes will result in headcount reductions.

This fear has led to differing perceptions of management initiatives. For example, I was part of a team intended to increase capacity by decreasing cycle time. Leadership's primary reason for this initiative was to reduce costs because Mighty Motors is under pressure to maintain or lower production costs. The method of achieving this goal was through elimination of waste. Prior methods of achieving cycle time improvement were accomplished by redistributing work for increased line balance efficiency. Therefore, employees at Mighty Motors felt that we were just trying to make them work harder and faster. Eventually, most saw that we were actually making process improvements and supported the initiative. For instance, when some operators saw the improvements made to the primary cover station (Section 4.4), they actually praised our work.

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[6] Ivan Pavlov (1849-1936) studied conditioned reflexes and behavior. His famous experiment involved conditioning dogs to being salivating when they heard a bell instead of eating the food.

Cultural Perception of Job Functions

Just as an organization's culture develops over time, the perceptions of job functions develop. People develop an idea of what each job function entails. In this section, I will describe the perceptions I observed of the key stakeholders. Again, these are generalizations that do not apply to everyone in the groups.

Engineers

"Engineers should fix the equipment, not us."

- Operator comment to me as I made suggestions for process improvement

Engineers at Mighty Motors work extremely hard over many long hours on projects and supporting the assembly line. The perception that has developed at Mighty Motors is that engineers are the problem solvers. Whenever a problem happens on the line, a two-way radio transmission was sent to an engineer. The engineer would respond and save the day. Many of these problems could have been solved without the engineer, but most often the employees called the engineer due to fear or lack of training. During my time at Mighty Motors, the engineers were working towards changing this perception by responding to the problems, but also by stepping back to teach problem solving.

Engineers themselves have a perception of what their job should be. Many believe their job is to design and tinker with equipment. After years of education, an engineer feels as though spending time observing the process and making small incremental improvement feels like a waste of time. They want to work on big projects with visibility and impact.

The perception of engineers as problem solvers and project managers is a hurdle for making incremental improvements and efforts at standardization.

Operators

"We aren't paid to think."

- Operator's answer to me on why he hasn't made any suggestions to improve the process

Operators at Mighty Motors are highly skilled and always try to do the right things. They care a great deal about their job and ensuring a quality product. Only a few have the cynical view expressed in the above quote. However, this cynical view led me to a more realistic view that operators are not given *time* to think about process improvements. During my time at Mighty Motors, I rarely observed or heard of an operator given the chance to step back and observe the process to make improvements. For example, in waste elimination in the carburetor station example (Section 4.3), the operators never challenged the idea of repeating the torque sequence several times with three tools. They simply felt it was part of the process. Typically, if an operator does have an idea, it will be transferred to an engineer to make the improvement. This again reinforces the idea that engineers solve problems and operators are only meant to perform their process.

A second barrier with operators is that they do not rotate jobs. Many have worked their stations for more than two years. Operators get very comfortable in their stations and develop their own ways of performing the process. When an operator does move to another job, the knowledge in technique and process is lost. Without rotation, there are few challenges to the process standard and therefore little desire to improve the standard such that anyone could follow it.

Supervisors / Workgroup Advisors

The supervisors feel as though their primary job function is to keep the assembly line running. Supervisors spend nearly an entire day firefighting problems or attending meetings to update other groups on the status of the assembly line. The supervisors at Mighty Motors do a great job at this. If there was a problem that stopped the line, the supervisor would call in resources until the line was running again. As long as the line was running, the supervisors were satisfied.

This mode of constant firefighting prevents the supervisors from truly being advisors to the workgroups. Rarely are they given the opportunity to coach or teach problem solving to employees. Supervisors view line stoppages as extremely bad, rather than opportunities to solve problems and prevent reoccurrence.

Union Leadership

The union believes their job is to protect the workforce from poor management decisions. They have a primary goal of employing people over a long term with fair pay and a safe work environment. The union is involved in most meetings at Mighty Motors to ensure this goal.

Leadership / Management

Leadership views their role as establishing the vision and mission. Many leaders are also managers in executing on this vision. They tend to run the day to day activities and, similar to the supervisors, view their role is to keep the assembly line running and push for problem solving.

People Problem versus Process Problem

"We have got to hold the operators accountable for mistakes! What is so hard about doing that step of the process?"

- Engineer's response to a mistake made by an operator

A response like this was very typical at Mighty Motors from engineers and supervisors when an operator would make a mistake in their process. A common response by one of the supervisors would be "I'll go talk to them and make sure it never happens again." This is perhaps the worst form of problem solving – it lacks root cause analysis and sustainability. Through casual observation it is very easy to assume that the jobs the operators do is easy. However when allowed to do the job myself, I observed that there are several things to always do and keep in mind at one time. Even after much practice I struggled to meet the cycle time or do the tasks correctly every time.

Case Example

An example of this mentality occurred during my work at the carburetor station. One of the first steps in this station is to obtain the carburetor from a visual verification machine that checks to ensure the right type of carburetor is selected. The operator is to look at the line monitoring screen to ensure that the correct carburetor has been selected as the light will either be green (correct) or red (incorrect).

One day it was discovered downstream that the wrong carburetor was on a powertrain. Engineers and supervisors were puzzled as to how this could have happened. However, due to the observations I had made earlier in the station, I had a strong suspicion as to what had happened. I had observed that occasionally the visual verification machine would fail to verify the carburetor because it was not seated properly. The operator would obtain the carburetor and begin attaching it to the powertrain. The operator did not look at the line monitoring screen until later in the process. At that point they would realize the mistake. With an emphasis on not stopping the line, the operators would obtain a carburetor of the same make to insert into the visual verification machine. This would allow the line to continue without downtime. Operators would check visually to ensure the right carburetor had been selected. However, in this case they failed to see that they had placed the wrong carburetor on the powertrain. After a discussion with the operator, they agreed that is what most likely happened.

"What is so hard about looking up at the line monitoring screen?" said at least two engineers after telling them what happened. The supervisor responded as stated above, "I'll go talk to her and tell her to make sure she looks at the screen every time."

Through deeper observation of the process I had actually noted that it was quite easy to miss the line monitoring screen as it was oriented 180° away from the location where one picks up the carburetor. Also, the operator does not need to look at the screen until after the carburetor is attached. I proposed installing a simple green light at the carburetor pickup point to verify the correct carburetor was in the visual verification machine. This would make the verification part of the natural motions of the process instead of requiring the operator to look away from what they are doing.

The lesson from this is that there was actually something wrong in the process making it difficult to perform the step every cycle. No one at Mighty Motors is intentionally doing a bad job or the wrong thing. Everyone wants to do the right thing. As in this case, the operators felt they were doing the right thing by trying to keep the line from stopping. Everyone at Mighty Motors needs to recognize that problems are usually a result of the process and not a result of the people. 99.9% of the time there is something to be resolved in the process, you just have to "go see" to find it.

Lack of Root Cause Problem Solving

As mentioned in the prior sections, as long as the line is not stopped, people are fairly happy. The behavior that has been driven by the "reduce downtime at all costs" mentality can drive the wrong behaviors. When an operator experiences a problem on the line, a repair operator is called to help solve the problem. Sometimes these are just simple and infrequent problems that are solved on the spot. However, there are many problems that repeatedly occur and a repair operator continue to fix it until it becomes so annoying that they call for an engineer to help. Even at this point, the desire is to simply make the problem go away as opposed to finding ways to prevent the problem from recurring.

For example, the piston station operators had the occasional problem of installing the wrong piston. A few countermeasures were taken to prevent the problem, including a barcode visual verification. The problem frequency was reduced, however it still occurred. There was no later evaluation of the barcode visual verification process to determine why it was ineffective. The countermeasure at this point was to give the operator a tool to remove and replace the piston. Although this nearly eliminated downtime, this countermeasure did not address the root cause.

Root cause problem solving is key to continuous improvement. In order to have root cause analysis, there must be a high level of standardization. Otherwise, the root cause may simply stem from the variability in the non-standard process.

Freedom Culture

The Mighty Motors culture is influenced by the products they manufacture. One of the product's images is a sense of freedom. Rules and regulations are considered to just be guidelines under this mentality. Standardization appears to be exactly the opposite of freedom. I witnessed basic safety rules, such as fork lifts stopping at all intersections, not being followed largely due to this mentality. If employees are not going to follow basic safety rules, it will be extremely difficult to convince them that standardization is an important value.

Lack of Crisis

"Companies are either hungry or satisfied."

- Professor Jonathan Byrnes[7]

Mighty Motors has been doing very well in their industry for over ten years. Even with pressure from the competition, Mighty Motors has consistently delivered growth and profits. Much of the growth is a result of aggressive marketing. The operations side aided the initial growth periods by improving quality and production methods. However, over the past few years a sense of complacency has developed in operations. Although there are certainly improvements in operations, there exists a lack of urgency about the need to make improvements.

It is extremely difficult for leadership at Mighty Motors to say, in the same breath, that "You guys are doing a great job, but you have to get better." This is a difficult message to believe due to the performance of Mighty Motors over the past several years.

[7] Quote from lecture notes taken in Professor J. Byrnes class at Massachusetts Institute of Technology, Case Studies in Supply Chain & Logistics, Spring 2005

Recommendations

The culture at Mighty Motors appears to contain major barriers to standardization and continuous improvement. Culture is the most difficult to change due to its long term development. However, by at least recognizing some of the barriers, Mighty Motors can make progress towards the ideal state. The following recommendations could aid in taking the culture a new direction:

Create a safe environment for process improvements. Union members would be much more likely to aid in continuous improvement with a guarantee that no headcounts will be reduced due to process improvements.

Supervisors and engineers must be seen in stations at times other than when problems occur. Supervisors and engineers should try to take a proactive approach to problem solving. Operators need to see engineers and supervisors during normal operating periods and not only when there is problem. Operators can then gain a sense of trust for engineers and supervisors. Through time spent in observation a great deal can be learned and improved. There needs to be a willingness to work on the smaller ideas rather than major projects all the time.

Focus on the process, not the people. Blaming operators for problems will not solve any problem. No one is trying to do a bad job. Instead of making assumptions about the people, observe and challenge the process. Use A3 and "5 Whys" to help in problem solving. Do not think about "what went wrong?" but rather "what can be better?"

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Establish a crisis. There needs to be a higher purpose to making improvements. Employees should have a hatred for the current state and seek out the ideal state.

Leverage the culture of high quality and caring about the product. Fortunately, the culture already has a desire for quality. Leadership needs to leverage this culture in convincing employees that standardization will help increase quality and lead to continuous improvement.

Teach everyone to be a problem solver. Operators need to be given the time and training to improve their own process. By providing training and facilitation on standardization, waste elimination, and continuous improvement, Mighty Motors will move towards a culture where everyone can be problem solvers.

Establish a high value for standardization by management and union leadership. To be successful in continuous improvement, the basics must be in place and followed. Management and union leadership should set the expectations and mentality of the workforce.

7.0 Conclusion

Throughout this thesis many ideas and lessons about standardization and continuous improvement have been presented. This final chapter will present a summary of the key lessons for enabling waste elimination, learning and continuous improvement through standardization.

7.1 Standardization as a Priority

"We need stability before some of this pie in the sky stuff."

- Mighty Motors employee

Before even attempting improvement activities there must be a level of standardization to build upon. Otherwise you are always chasing randomness and variability. A standardized process will enable waste to become more visible. Furthermore, sustainable improvement can be realized. With standardization alone there will be significant gains in performance simply by knowing the expected result of a process.

"If you think of 'standardization' as the best you know today, but which is to be improved tomorrow – you get somewhere. But if you think of standards as confining, then progress stops.

- Henry Ford in 1926 (Liker 141)

7.2 Value the Small Incremental Improvements

Improvement is about moving from the current state to the ideal state. The incremental approach is a simple, common-sense and low cost means of accomplishing improvements. Simple and frequent experiments provide a significant amount of learning about a process such that one understands the nuances and variables that can improve the entire process. Too often, we look at major innovation to improve a process, yet I learned that through observations and modifications to the minor details, major improvement can be achieved. Keep in mind:

Small improvements X many iterations = BIG Impact

7.3 Create an Organization with Everyone as Problem Solvers

"If management is always tied up in problem solving and improvement, they will have little bandwidth for strategic decision making."

- Professor Charles H. Fine[8]

If an organization expects to reach the next plateau, the entire organization must be problem solvers. This creates a learning organization that can achieve a competitive advantage that few companies can duplicate. Allowing operators to write their own standards and facilitating operators on waste elimination are powerful enablers towards this pursuit.

7.4 Standardization and Continuous Improvement is the Easy Part

Applying the various tools and methods to achieve standardization and continuous improvement is actually the easy part. The hard part is creating an organization that is deeply committed to these principles.

[8] Quote from lecture notes taken in Professor C. Fine's class at Massachusetts Institute of Technology, Operations Strategy, Spring 2005

7.5 Conclusion

A primary goal of this internship and thesis was to gain a deeper understanding about standardization and continuous improvement. I gained this deeper understanding by working with actual projects first hand. Although there are many articles and books based on these principles, there is no substitute for a hands-on experience. My hope is that this thesis conveys some of the key lessons from my experience and serves as a valuable reference for Mighty Motors and other readers.

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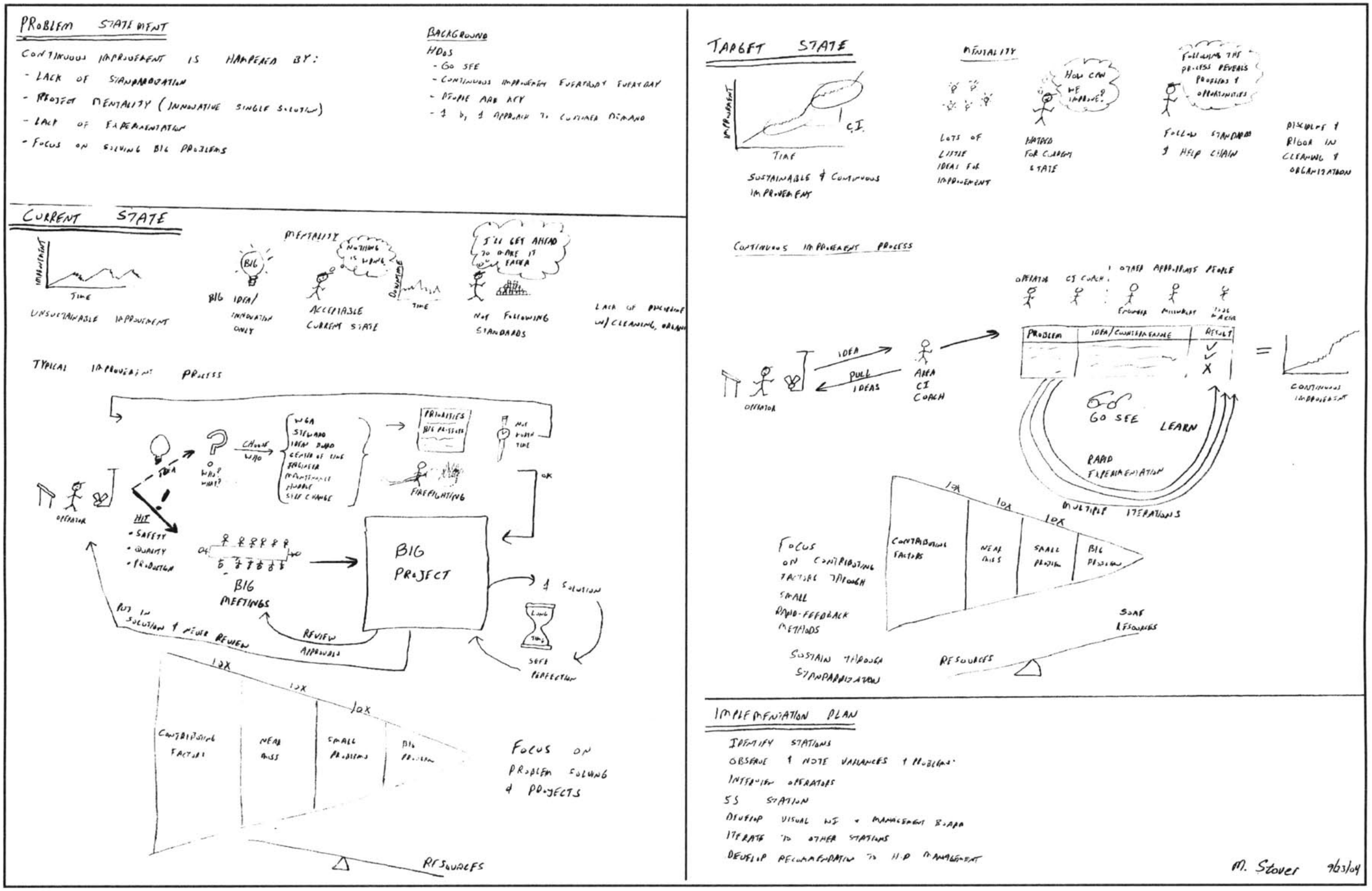
Appendix 1: A3 Diagram for Continuous Improvement



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