2016

Adjusting Production Processes for Use in Engineering and Testing Environments

Jordan Proctor
University of Northern Iowa

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Abstract

The goal of this research was to find examples of traditionally production-oriented systems, particularly Continuous Improvement methods, being applied in engineering environments. On top of finding examples of CI tools being used outside of production, there was heavy focus on finding out how the systems were tweaked to reach the goals of different environments. A literature review was done to identify 5S and Six Sigma basics and cite examples of their use outside of traditional manufacturing. Examples of two separate projects done at the engineering center of a large Midwest manufacturer were evaluated for their effectiveness and the adjustments that were made to suit the specific environment were recorded. Separate conclusions were drawn for each project and then a final analysis of the overall study was done. Both the 5S and Six Sigma projects were deemed productive. The 5S project had been completed by the time this paper was finished and an expansion of 5S to adopt similar projects has begun. The Six Sigma project is still underway, but the process has helped lead the project in the right direction. This study has concluded that traditionally production-oriented CI tools can be used successfully in an engineering environment.

Adjusting Production Processes for Use in
Engineering and Testing Environments

A Research Paper for Presentation
To the Graduate Faculty of
The Department of Technology
University of Northern Iowa

In Partial Fulfillment of the Requirements for the
Non-Thesis Master of Science Degree

By
Jordan Proctor
March 11, 2016

Approved by:

____ 4-07-2016

Signature of Advisor Date

Julie Zhang

____ 4/07/2016

Signature of Second Faculty Professor Date

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Keywords: Continuous Improvement, 5S, Six Sigma, Kaizen, Engineering, Testing

Introduction

Continuous Improvement (CI) has transcended its status as a buzzword into the permanent consciousness of nearly every area of business. Within this hugely vague term lie a multitude of tools, processes, and philosophies. Familiar names like Lean, Six Sigma, 5S, and Total Quality Management (TQM) are among the systems that fall under the vast umbrella that is CI. Often, making these tools work together is essential to reaching improvement goals. In some cases, an entire Six Sigma project may not be warranted, but some tools from within the Six Sigma toolbox can be applied to reach a goal. A strong 5S program will likely be part of an overall Lean approach. Total Productive Maintenance (TPM) may be used to reduce the use of worn tools to reach a Six Sigma goal. Although these are separate systems, they can work quite well when used in conjunction or by fitting different pieces together to meet the individual needs of the current goal.

The goals of this research are to look into how CI tools have been used successfully in different environments and to apply that knowledge to real world projects. Much of the time, CI tools are presented through a manufacturing point of view. This is not all that surprising, considering how well these tools can work in a factory environment. However, it is important to realize that their benefits are not limited to manufacturing. Six Sigma, for example, has been applied in medical and office environments. With a little tweaking, these tools can be used in almost any environment. Within this writing, multiple examples will be included of how tools were adapted for use in an engineering environment.

Literature Review

A literature review was done to establish the basic principals of the CI tools used in the projects this research is based on. It also reviews examples of CI tools being used outside of their traditional environments.

Basics of 5S

The Five S's, or 5S, is a program designed to inspire and maintain improvement in the work place. Though it is often thought of as a manufacturing program, it has been used in many industries, including hospitals and accounting firms. The 5 S's come from five Japanese words that describe the various steps. These have been translated to English for ease of use in the U.S (Nicholas, 2010):

- Seiri (Sort): Proper arrangement (all items in the area are sorted and any unnecessary items are eliminated)
- Sedition (Set in Order): Orderliness (everything that is needed is given a specific place and coded if necessary; a place for everything and everything in its place)
- Seiso (Shine): Cleanliness (clean the area and make sure everything looks good; this could mean making repairs or painting.)
- Seiketsu (Standardize): Neatness (a procedure is put in place to keep up on the first three S's)
- Shitsuke (Sustain): Self-discipline (keeping things up to the 5S expectations)

The cycle is shown in Figure 1.

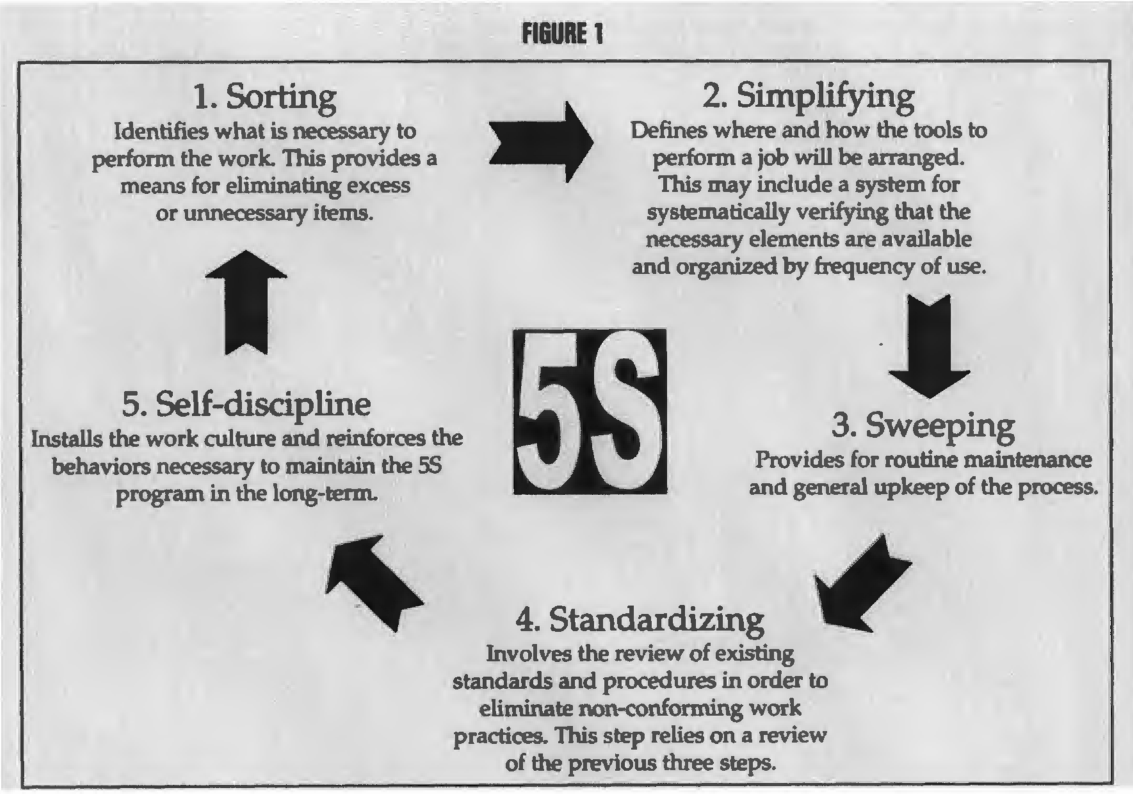

Figure 1. 5S Cycle. This figure shows the common 5S cycle. (Becker, 2001, p. 31)

There are several benefits a 5S program can provide. One benefit is safety, which is always a big concern for companies. A clean and organized work place eliminates hazards and provides a safer working environment. In fact, some companies include "Safety" as a sixth S. Another benefit is increased quality due to recognition of problems. A neat, clean, and organized work area makes it easier to spot problems and inconsistencies. When 5S is combined with something like a TPM program, time for maintenance is scheduled so there is no guesswork. This can help reduce machinery problems, as well. 5S can also increase productivity. Movement about a properly organized work area is quicker and more efficient. The last thing to note is the possibility of increased employee morale. People often feel better being in a clean and organized environment than when they are in a cluttered or dirty environment. They are also involved in the process and can take pride in knowing that they are having a positive effect.

A study by Michalska and Szewieczek (2007) took this a step further and broke down the positive effects each individual S:

1 S:

- Process improvement by cost reduction
- Stock decreasing
- Better usage of the working area
- Prevention of losing tools

2 S:

- Process improvement (increasing of effectiveness and efficiency)
- Shortening of the time of seeking necessary things
- Safety improvement

3 S:

- Increasing of machines' efficiency
- Maintains the cleanliness of devices
- Maintenance and improvement of the machines' efficiency
- Maintaining the clean workplace (easy to check)
- Quick informing about damage (potential sources of damages)
- Improvement of the work environment
- Elimination of the accidents

4 S:

- Safety increase and reduction of the industry pollution
- Working out the procedures defining the course of processes

5 S:

- Increased awareness and morale
- Decreased mistake quantity resulting from lack of attention
- Proceedings according to decisions
- Improvement of the internal communication process
- Improvement of human relations (p. 214)

Where 5S has been used. The 5S process has been used in a multitude of different industries. Hodge, Ross, Joines, and Thoney (2010) did a study that implemented Lean Manufacturing tools, including 5S, into a few different companies. The end results were a reduction in the number of unnecessary setups by 50 percent and a reduction of the setup time from 15 to 5 minutes. The first company studied was a cloth manufacturer that made things like denim and draperies. They were able to gradually reduce waste over six months and were also happy with the raised awareness of waste by employees and increased effort to reduce it. The second company was a yarn producer. The owner reported that, "the money his company had invested in the 5S system was in the hundreds of dollars, while the savings were in the hundred thousands" (p. 242)

Six Sigma Definitions and Origins

Six Sigma is defined as a "statistical concept that measures a process in terms of defects" (Brue, 2002, p. 2). A *sigma* (**σ**) is the Greek symbol for the mathematic calculation of a standard deviation. A standard deviation is a measure of how spread out numbers are and is calculated by taking the square root of the variance of a given data set (Pierce, 2014). It is used in this case to measure quality or the number of acceptable units of output per total units output. When a process is operating at the six sigma level, it will have 3.4 defects or less per one million opportunities.

Six Sigma was originally developed at Motorola in the mid 1980s. Pyzdek mentions that Motorola received the Malcolm Aldridge National Quality Award in 1988, which led to an increased interest of Six Sigma in other organizations (as cited in Anderson, Eriksson, and Tortensson, 2006). Six Sigma has since been successfully applied in other manufacturing organizations such as General Electric, Boeing, DuPont, Toshiba, Seagate, Allied Signal, Kodak, Honeywell, Texas Instruments, Sony, etc. (Kwak & Anbari, 2006).

The original basic idea of Six Sigma was more of a quality system focused on reducing errors in production parts or assemblies, but it has developed into an overall business strategy. This is supported by another definition of Six Sigma as, "a business process that allows companies to drastically improve their bottom line by designing and monitoring everyday business activities in ways that minimize waste and resources while increasing customer satisfaction" (Harry & Shroeder, 2005, p. vii). Anderson, Eriksson, and Tortensson (2006) support this definition with a review of the company, Ericsson's, successful Six Sigma program.

Ericsson started their program in 1997 and has adjusted its view of the program since. In describing this view, the researches state, "Six Sigma was first defined as a methodology for solving problems. Today, they rather see six sigma as a business excellence model for concrete areas and as a methodology in order to reach business goals" (Anderson, et al., 2006, p. 287). Ericsson has stated that they estimate savings from about 250 Six Sigma projects to be between 200 million and 300 million Euro from 1997 to 2003. Anderson et al. (2006) also note that "Volvo Cars in Sweden claims that the six sigma program has contributed with over 55 million euro to the bottom line during 2000 and 2002" (as cited in Magnusson et al., 2003) (p. 287).

Six Sigma's goal is to reduce variation. This could include process or product variation. The result of a reduction in variation will often be a cost savings and/or increased quality. The largest component of this is the DMAIC/DMADV system. The acronyms DMAIC and DMADV stand for practices that are used to improve existing processes and come up with new ones, respectively. DMAIC stands for Define, Measure, Analyze, Improve, and Control. DMADV stands for Define, Measure, Analyze, Design, and Verify. The difference being that an already existing process can simply be adjusted and improved, while a process that does not exist will need to be developed and verified (Anderson et al., 2006).

Six Sigma throughout business. The most obvious placement for a Six Sigma program is in manufacturing, but it can be successfully used in many other areas. Education, health care, supply chain management, and even government are a few examples of sectors where it has been successfully applied. Six Sigma can also be used successfully in service type organizations. Often service-oriented companies do not use Six Sigma, because it is seen as a manufacturing solution. Antony, Antony, Kumar, & Cho (2007) reported, "One of the major hurdles service-oriented organizations must overcome is the notion that, because their company is human-driven, there are no defects to measure" (pp. 296-297). Defects, however, could be clerical errors, not sending something out on time, unreliable timing estimates, or anything else. It does not have to be a physical measurement.

Ford Motor Company created a program called "Customer-Driven Six Sigma." They use this not just in their manufacturing areas, but also in every other area of their business. Al Ver, Ford's vice president of manufacturing and engineering, makes it quite clear that "Six Sigma is not simply something else we do, it's the way we must execute everything we do" (as cited in Christopher & Rutherford, 2004, p. 27).

An obvious traditional Six Sigma use in manufacturing would be the reduction of variation in a mass produced product or even a portion of that product. A company may have a product that is made up of many parts and a high percentage of defects are caused by one part. That would be the best part to focus on, because a quality improvement there would improve overall product quality. In a case study by Banuelas, Antony, and Brace (2005), a Six Sigma project was done to reduce waste on a film coating production line. They state that, "As a result, significant financial benefit was achieved in a relatively short period of time. This allowed material waste to be reduced by nearly 50,000 per year" (p. 569). They also maintain that other side benefits, like employee involvement and interest in successive projects came about.

On the medical side, a study reviewed some successful medical implementations of Six Sigma. Revere & Black (2003) state,

> Froedtert Memorial Lutheran Hospital in Milwaukee, Wisconsin, Six Sigma resulted in a tremendous decrease of clinically significant IV-infusion discrepancies. NAMM-Cal cut costs and increased revenue by undertaking almost a dozen Six Sigma projects. Scottsdale Healthcare in Scottsdale, Arizona, was able to reduce the amount of time its staff spent on finding a bed and transferring a patient out of the emergency room, creating increased capacity for the emergency department. Wellmark, Inc. in Des Moines, Iowa, used Six Sigma to save administrative expenses by $3 million per year. All of the healthcare organizations implementing Six Sigma have noticed improvements in their profitability, either directly or indirectly, through a reduction in length of stay. (p. 382)

These are great examples of using Six Sigma in a different environment. While medical facilities are not producing any tangible products to sell, they are using processes every day. By reducing the time it takes to do those processes or improving the manner in which they apply them, they may be able to literally save lives.

Immaneni, McCombs, Cheatham, and Andrews (2007) did a review on Capital One Banks' large overhaul of its business in 2004, which included implementing a Six Sigma program. They used DMAIC to go over *all* business processes. They decided to put emphasis on risk, cost, and customer experience, because these were determined to be the most critical areas to business improvement. By 2007, all three of these areas had significant improvements thanks, in part, to Six Sigma projects. On the cost reduction side, "the business was able to reduce the unit cost associated with opening an account to 61 percent of the cost in 2004. Likewise, the 2007 unit cost of servicing an account was only 46 percent of the cost in 2004" (Immaneni et al., 2007, p. 50). Customer experience was improved as well. Complaint rates dropped from about 6,000 per million opportunities to about 200. This is an increase from operating at approximately 3 to 4 sigma to about 5 sigma. Risk factors made "measurable, statistically significant improvements on all risk dimensions" (Immaneni et al., 2007 p. 51).

Ford used their Customer-Driven Six Sigma method mentioned previously to make a large saving by fixing a supply-chain issue. They had a 20 percent variability of inventory levels at one of their plants. They traced the issue back to the plant docks being inefficiently and inconsistently unloaded. Upon this discovery they determined that, "Taking steps to improve dock utilization and thus driving out process variability led to annual savings of more than $3.7 million due to inventory reduction, reduced overtime for unscheduled materials handling and other savings" (Christopher & Rutherford, 2004, p. 27).

Research Methods

Two separate CI initiatives were started at the engineering center of a large Midwest manufacturer and this research paper shows how they were adapted for an engineering environment. The first was a 5S program. In this project, two areas of Drivetrain Test went through a full 5S reboot and the department as a whole was set on a path of implementing proper 5S techniques. After the two areas had gone through the 5S procedure a survey was given to all technicians in Department 034. The survey results were used to judge the level of satisfaction that technicians had with this program.

The second was a large Continuous Improvement project that focused on internal parts procurement. This involved mapping the process, benchmarking another unit, and making and implementing recommendations. This project was proposed by management, because of the potential for improvement and frequent complaints about the current state of parts procurement. The metrics for this program were recorded from beginning to current stages and have been used to drive decision-making.

Department 034 5S Project

The plan to reintroduce 5S was to start small and try to focus on areas that could help make the biggest impact on the business. The experimental shop of the engineering center is divided into three departments: 028 Vehicle Test, 033 Component Test, and 034 Drivetrain Test. Drivetrain Test was chosen to pilot the new programs mostly because of the team's familiarity with this department.

Almost all testing is for prototype equipment or continuous improvement on existing products. Tests are not standardized, so measuring productivity is not easy. It is not like a factory where the same thing is built over and over. Doing things like trying to test the same platform in a particular bay as much as possible is ideal, but it all comes down to demand. So, in an environment that is constantly changing, it is very difficult to put a number on productivity. This is why survey results were selected as a measuring device. In the future comparing tooling year-to-year tooling costs could be another good way to judge the success. The areas of focus that were chosen to start with were the tool room and the technician machining area.

Tool Room

The tool room was chosen because technicians were complaining frequently about not being able to find the tools that they need to perform their jobs. The team thought this could be a big area of improvement. The Hodge, et al. (2011) study of one organization that did a tool room 5S program found that,

> The 5S project in the tool room in this case study has eliminated the waste of ordering a part already in stock, because all the parts and tools can now be easily found . . . project would save his company over 40,000 dollars over the next year in tool and part replacement costs. (p. 242)

Technicians at the engineering center have their own personal toolboxes with the essential general hand tools for their most common needs. This includes things like wrenches, sockets, screwdrivers, etc. However, special tools are often needed. Specialty tools, tools that are not needed on a daily basis, and tools that are too expensive to expect technicians to purchase are provided by the company and stored in the department tool room.

At the onset of the project, the room was a mess. Many tools were just piled in drawers. There were a lot of missing and obsolete items. The decision was made to first decide what needed to be there and what did not. This is the "Sort" stage. Every drawer was gone through; excess items were put into storage, items that were deemed obsolete were scrapped, and items that had a more appropriate place were moved. Next, items were given "homes." This is the "Set in Order" stage. Before, drawers and shelves were loosely labeled and poorly organized. To help organize, pegboard was added and shadow-tape was used on the board to show where tools should be (Figure 2). Double-layered foam was also purchased for the drawers. One layer was cut out of the foam to give tools a specifically sized and shaped "pocket" to sit in (Figure 3). This way, everything has a place and it is easy for technicians to see where tools go. Larger mobile items that are stored in the tool room, such as magnetic drill carts and portable hydraulic presses, were given permanent markings on the floor with labels to ensure they get back to the proper location. Next was the "Shine" stage. Old labels were removed and everything was cleaned up. The space looks much better visually and the layout makes much more sense now. The last two Ss' are ongoing. To "Standardize," several of the techniques used in the tool room project, including the shadow boarding, are being incorporated around the department. "Sustainment" is, of course, always an ongoing process.

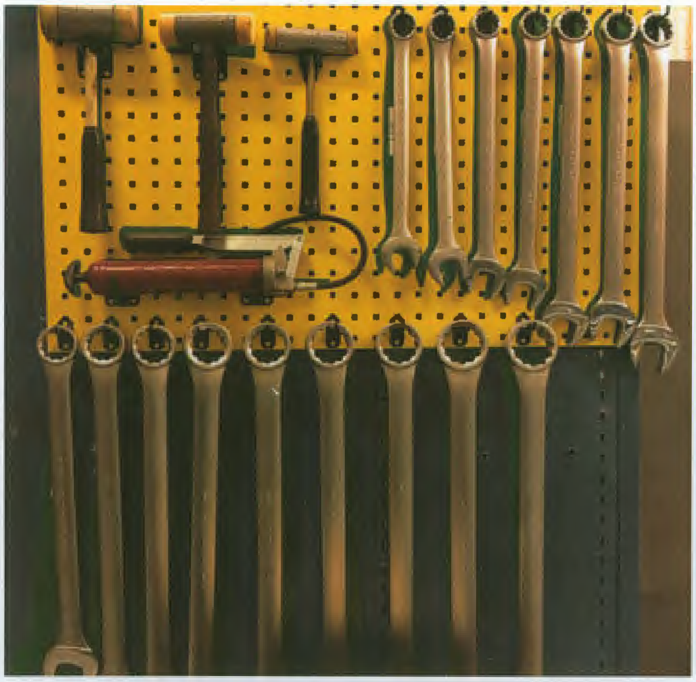

Figure 2. Photograph of a tool room pegboard with shadow tape and labels installed.

Figure 3. Photograph of double-layered foam providing "homes" for tools.

Another system that was put into place is a new checkout system. Tags were made up for each bay and hung on a pegboard (Figure 4). The technician grabs a tag marked specifically for their bay and replaces the tool they took with the tag. This way if someone else comes and needs to use the tool, they will know where to find it.

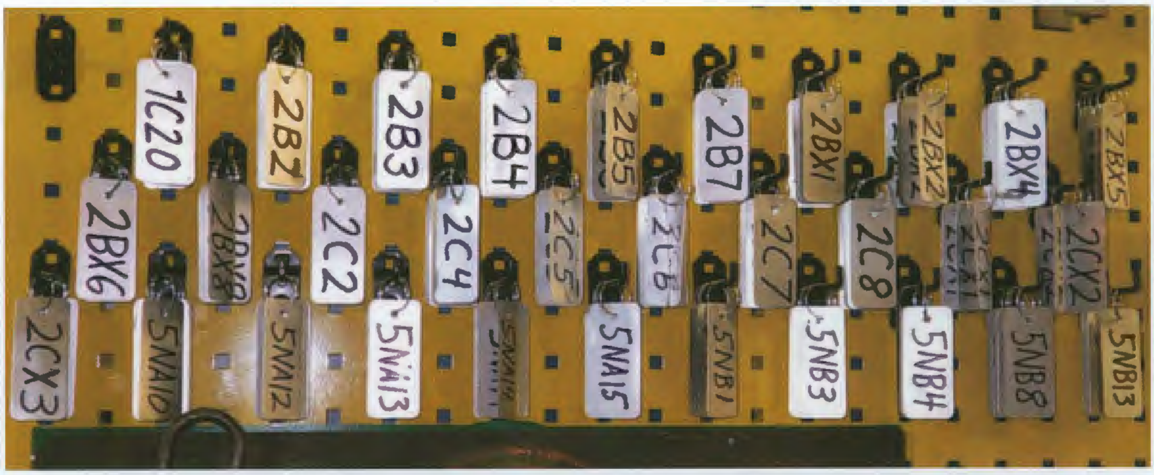

Figure 4. Photograph of the tool room checkout tags. These can also be seen in use in Figure 3.

Technician Machining Area

The machining area was quite a mess. Nobody really took ownership of it and it was very unorganized. There was an existing board that housed all of the most common drill bits and taps, however, it was missing nearly half of the items and there were containers full of loose random bits. Everything was gone through and broken, dull, and double bits were eliminated. All missing bits were ordered and replaced. The board was then brought back to function (Figure 5). A cabinet was then added and labeled to hold things like new blades, belts, hold-downs, vices, and other maintenance items. Everything was then cleaned. A sign was put up asking users to please put items back in their respective locations. A spot for a broom and a vacuum was also added to encourage technicians to clean up after themselves.

Figure 5. Photograph of the Machining Area board providing designated spots and labels for taps, drills, and other necessary items.

Results

Keeping a close eye on the newly 5S'd areas was essential to judgment of success. Over the past several months, the areas have stayed very much the way they were arranged. It seems that, because everything has a place and everything is clean and organized, technicians are keeping it that way. This is likely due to the fact that it helps them do their jobs better. A survey was sent out to ask about how they think the 5S'd areas have affected their jobs. Survey results indicate that technicians are happy with the new system and organization. They were first asked if they had used the tool room since it had been redone and if they thought it had maintained the new organization style and cleanliness. They were then asked to rate the questions on a 1-5 scale (1 - Much worse than before, 2 – Slightly worse than before, 3 – About the same as before, 4 – Slightly better than before, 5 – Much better than before): Do they think the layout is better, do they think the checkout system is better, do they think it will be easier to find tools, do they think this will help them save time. Figure 6 is a copy of the survey. The results were an average of 4.3, 4.5, 4.3, and 4.5 respectively (Figure 7). This shows that on all accounts, technicians think the system has improved and will save them time.

034 Tool Room Improvement Survey

Have you used the tool room in the last month?	Choose an item.

Do you think the tool room has maintained the new organization style and cleanliness?	Choose an item.

On a scale of 1-5 make selections based on

1 – Much Worse than before

2 – Slightly Worse than before

3 – About the same as before

4 – Slightly Better than before

5 – Much Better than before

Do you think the tool room layout is:	1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Do you think the new checkout system is:	1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Do you think the ease of finding tools will be:	1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Do you think this will help you save time:	1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Other Comments/Suggestions:

Please enter any comments or suggestions here:

Figure 6. The survey given out to technicians to gauge satisfaction and outlook on the tool room project.

	tool room in the last month?	maintained the new organization style and cleanliness?	Tool Room layout rating	Checkout system rating	Ease Rating	Time Saving Rating
	Yes	Yes	4	5	4	4
	Yes	Yes	3	3	4	4
	Yes	Yes	4	4	3	4
	Yes	Yes	5	5	5	5
	Yes	Yes	5	5	4	4
	Yes	Yes	5	5	4	5
	No	Yes	5	5	5	5
	Yes	Yes	5	5	5	5
	Yes	Yes	4	5	4	4
	No	Yes	4	4	4	4
	No	Yes	5	5	5	5
	Yes	Yes	4	5	4	4
	Yes	Yes	5	5	5	5
	Yes	Yes	5	5	5	5
	Yes	Yes	3	4	4	5
	Yes	Yes	4	4	4	4
	Yes	Yes	3	3	4	4
Ratio Yes:Nc	11:03	14:00				
Avg. Rating			4.29411765	4.52941176	4.29411765	4.47058824

Figure 7. Survey results spreadsheet.

Additional Efforts

On top of these two projects, an effort is being made to bring the departments up to company 5S standards. There was already a created document that included all of the standard colors and procedures for meeting the 5S standard. For example, trashcans and recycling bins were outlined in blue colored floor markings. Along with this was a catalog of common tools used throughout the facilities for 5S. The first step in bringing the engineering center to company local factory 5S standard was marking the floors, which has been started and is ongoing (Figure 8). The next thing was implementing 5Shine boards (Figure 9). Conveniently, the template had already been made, and these only had to be ordered. The boards were shadowed and included spots for a push broom, regular broom, hand broom, dustpan, duster, window cleaner, and rags. They also saved space over the current hanging systems that were being used. Not only did this help standardize, but it also helped save valuable wall space for technicians to hang other things like straps and tooling.

Figure 8. Photograph showing floor markings and labels to give items a "home."

Figure 9. Photograph of the 5Shine boards.

Conclusions and Recommendations

The pilot program was deemed successful. It is likely that this will be expanded to other areas. There are still a lot of areas that can be improved, including the test bays themselves, operator control rooms, and the instrumentation stock room. In further analysis, it would be best to find a better way to measure increased productivity and have a longer period of time for judgment.

Giving each technician a training overview of 5S, how it works, how it helps, and what his or her part in the process is will be a future project. Once this is done, asking for suggestions from the technicians will be another way to grow the program. One study's survey found that

> The most significant barriers identified are related to lack of communication and gap between the top management and shop floor employees and also the lack of training and consciousness of this activity amongst the staff. Poor communication will influence the poor results in managing the resources i.e. time, budget and materials with resultant lowered morale and motivation amongst employees. (Brahman, Khamis, Zain, Deros and Wan Mahmood, 2010, p. 1188)

Therefore, it is very important to provide education to team members.

It should be noted that this project was very inexpensive. Most of the cost was in tools that were going to have to be replaced anyway and a small amount of cost in organizational items, like the foam and tape. There were actually items found in the wrong spot that had been replaced for no reason. It seems completely reasonable to assume that an overall cost savings will be seen because of the reduction in lost tools and wasted time.

Adjustments for the engineering center

It was not possible to just read a short section of a textbook to implement 5S at the engineering center. The dynamic environment requires special considerations. There were some things that could be ported directly from factory environments, such as the 5Shine boards and standard color-coding. However, due to the dynamic environment, it's impossible to do that with all aspects. In a factory setting, it is often possible to provide five minutes at the end of the shift to make sure everything is back in its place for the next shift. This is often not reasonable for technicians. The shifts are laid out to give them a half-hour over-lap to pass on information. There are often projects left in progress between shifts. This means benches may be stacked with disassembled parts or that lifting fixtures may be kept out of place. In assembly bays, things are often in need of being rearranged to accommodate different projects. This eliminates the possibility of marking permanent places for all of the equipment. Wherever possible, though, implementing 5S protocol is strongly encouraged. Audits can be performed to make sure there are no violations, like unmarked chemical containers or having things parked in front of fire extinguishers. Tool cabinets can also be organized and marked. Both of these things are in future plans. Small parts cabinets with often-used parts are kept organized and labeled. Seldom used parts are ordered in to avoid clutter. Because of the constant changes to prototypes, parts are often changed and eliminated part numbers are generally scrapped.

Parts Procurement Project

One of the major complaints among engineers at the engineering center is the time it takes to get parts. This was identified as one of Drivetrain Test department's top issues in its 4DX data. They were looking at top reasons test cells were not running, in order to improve utilization percentage and mean time between tests. Right at the top was "waiting on parts." For this reason, a project was put into place to improve the parts procurement process. It was hypothesized that reducing parts procurement time could help the business by reducing down time, reducing wasted resources because of idle test cells, and by expediting the time in which tests are completed and therefore increasing speed to market with new products, fixes, and updates.

Creating a Charter

Before beginning the project, it was important to get an idea of where it was heading. A project charter is a formal document that lays out project guidelines. This included goals, metrics, team members, scope, and other project guidelines. The charter is where a team can look back and see if they are still on track or if they have steered off-course.

Team Selection

The first thing to do when starting the project was to identify the key stakeholders. The part ordering process affects many areas of the business and several different roles. To identify the key stakeholders, the process had to first be mapped. A team of representatives from each functional area was assembled to accurately map the process. During this session, improvement opportunities, or kaizens, were identified as well. In order to properly map the process, a beginning and end point had to be determined. It was determined that the beginning would be once the order was requested, and the end was when the part was delivered to the end location. Once a solid Value Stream Map (VSM) was created and the key stakeholders were identified a team could be chosen.

The team members that were selected to lead the project going forward were as follows

- Sponsors: Operations Manager and Lab Manager
- Champions: Process Pro and Continuous Improvement Coordinator (Author)

- Team Members: Test Engineer, Assembly Engineer, Engineering Technician, three Material Coordinators, Planner, Material Specialist, and Receiving Supervisor

These team members encompassed representatives from every stop along the process. The goal was to provide fair representation from each group, while keeping the group small enough to stay focused.

Mapping the Process

The first step in deciding where the process needed to go was to establish exactly how the current process looked. To do this, the team was brought together for a three-hour meeting to simply map the current process. This helps the project leaders, who are generally not experts in the particular area, but are rather tasked with keeping the project on track and facilitating work. It is also crucial to identifying the potential improvements or "kaizens." The process essentially broke down as follows. (See Figure 10 for a picture of the finished map that came out of this meeting and Figure 11 for the digital version)

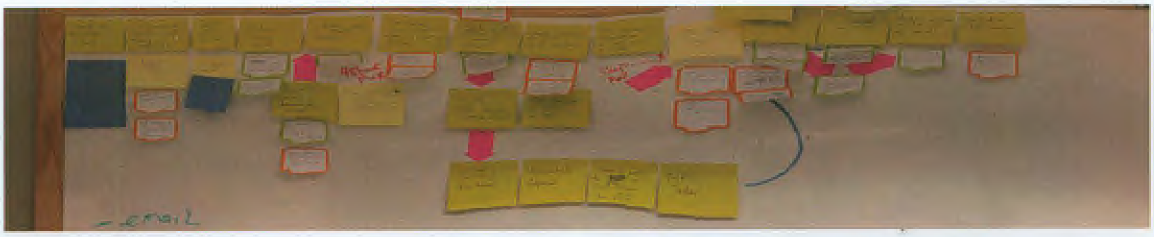

Figure 10. Photograph of the board at the end of the process-mapping meeting.

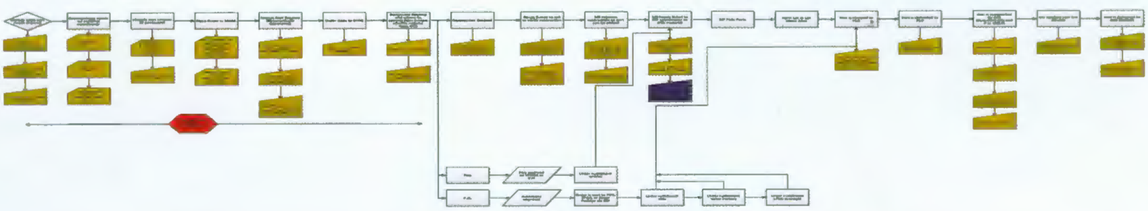

Figure 11. Digital representation of the final board results from the process-mapping meeting.

Phase one. The engineer or technician decides what parts they need. They then notify the Material Coordinator (MC) of the needed parts. The process then moves onto phase two.

Phases two and three. Once the MC gets the request they can decide whether to request the part from a specific location or not. Generally, this does not happen. It is only used for special circumstances and the source location will be chosen later in the process. The order is then placed in MaSA (Material and Service Acquisition), which is an SAP based software that is used to place part orders. Once the MaSA is submitted, a project plan is automatically created. The project plan is then sent to the Experimental Parts Procurement Group (EPPG). From here the EPPG personnel decide whether to create a reservation, pick, or purchase order (P.O.). This is dependent on the type of part, and this is where the process splits into three possible routes. An internal factory part, such as something from another local company site, would be processed as a reservation. A P.O. would be a request from an outside company, such as a one-off gear or custom clutch discs. A pick refers to an item already stored at the engineering center's contracted external warehouse.

Reservations. The EPPG personnel create reservations and then a manual e-mail is sent to the Material Specialist (MS) at the factory from which the part is coming. The Material Specialist either releases the reservation or notifies EPPG that the reservation cannot be fulfilled and explains why. Assuming the reservation can be fulfilled, it is released and the part can be picked. The parts are then pulled and brought to a parts set down area. From here the steps converge back together into phase four.

Picks. Picks are another type of order. The pick is sent to the warehouse and the order is then sent to stage four by them.

Purchase orders. Purchase Orders (P.O.s) are sent for approval and approved automatically. They are then sent to the appropriate source. The source then sends the parts to phase four.

Phase four. The part is then sent and delivered to the shipping and receiving department at the engineering center (Dept. 038). Reservation and P.O. orders are then in-reported by 038. Picks are not in-reported, because they have already been done at the warehouse. The Material Coordinator that ordered the part is then notified that their part has arrived. A Department 038 personnel then checks where the part is to be delivered and delivers it to the end location.

Map Creation

A virtual map was created in accordance to general Value Stream Map standards. The general breakdown is that the ovals are starting and stopping points, the squares are events, and the diamonds are decision. The entire process was broken down into four phases and these phases were put into swim lanes to help categorize the process and improve visibility. The entire map can be seen (Figure 12) along with larger individual crops of each phase (Figure 12.1-12.4).

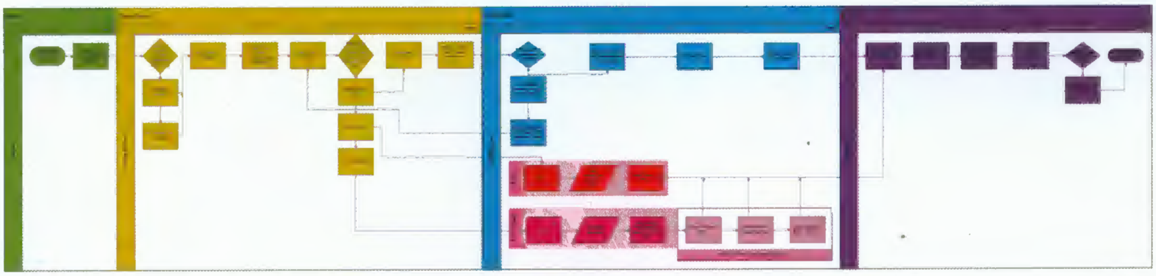

Figure 12. Process map broken down into phases and using proper VSM shapes.

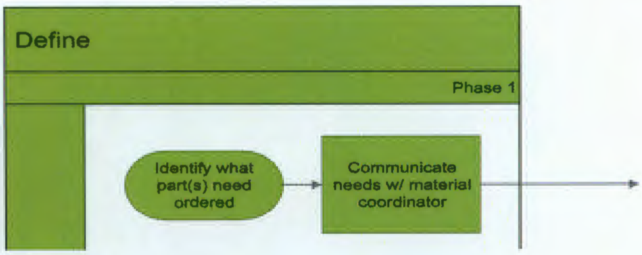

Figure 12.1. Close-up of the define stage of the process map.

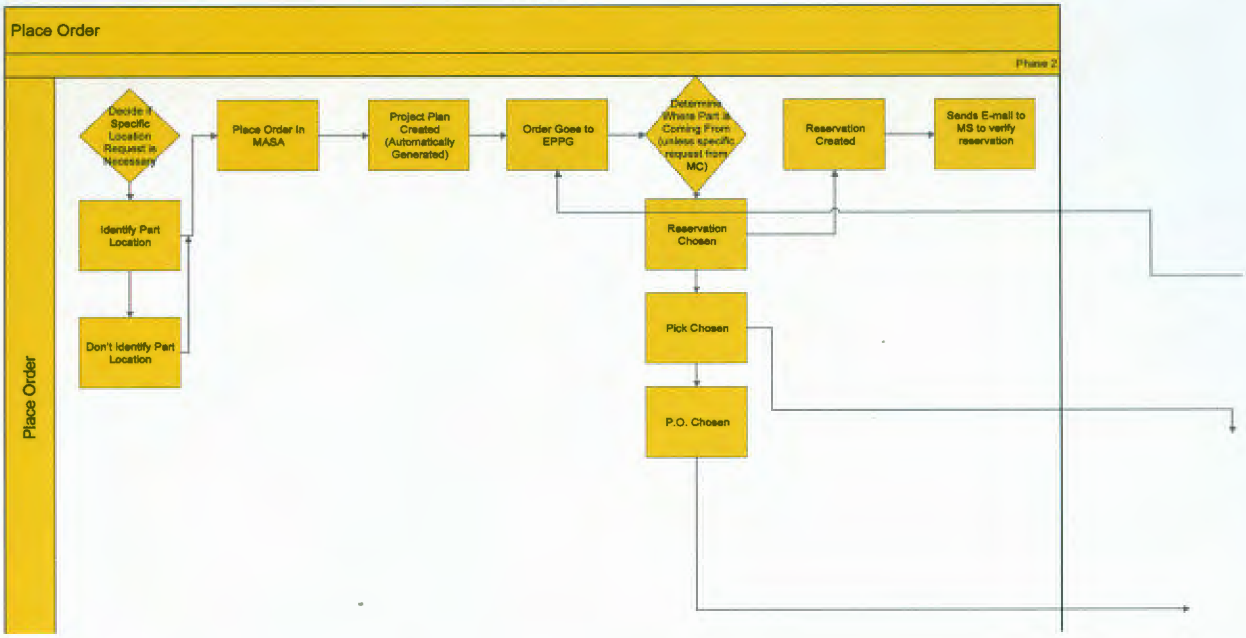

Figure 12.2. Close-up of the Place Order phase.

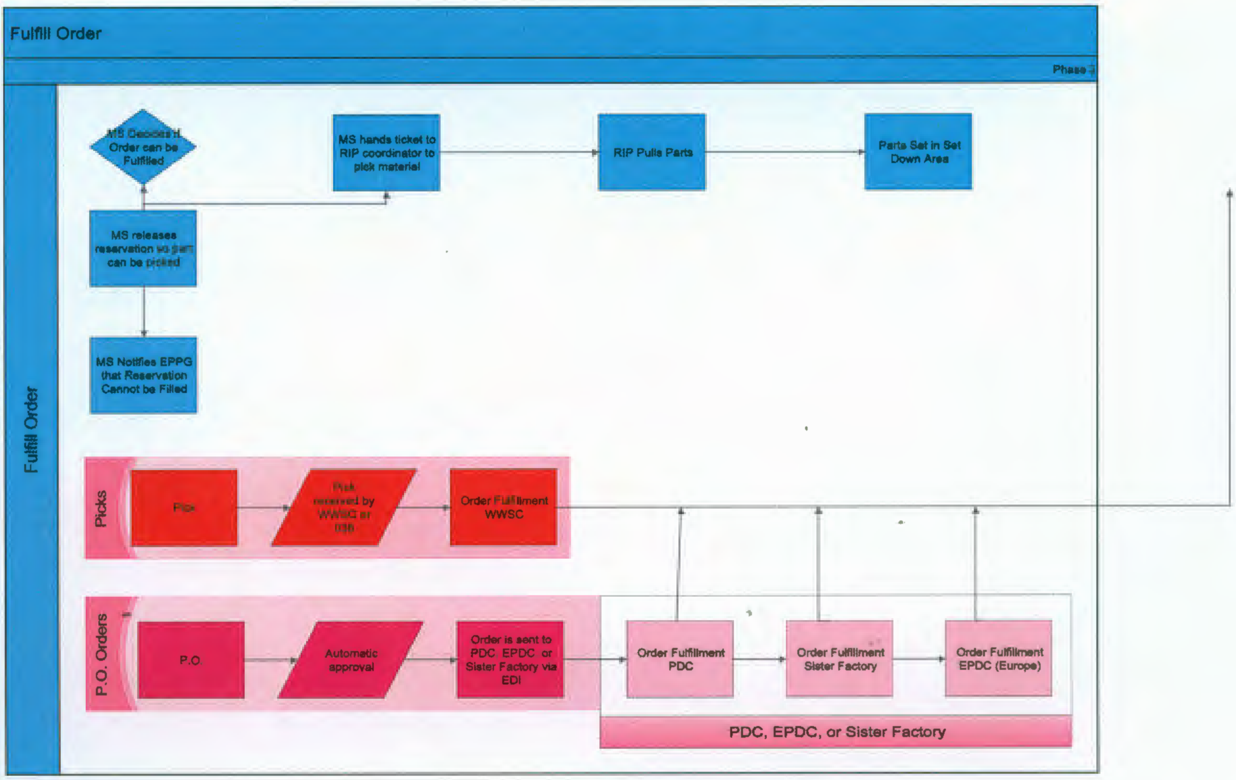

Figure 12.3. Close-up of the fulfill order stage.

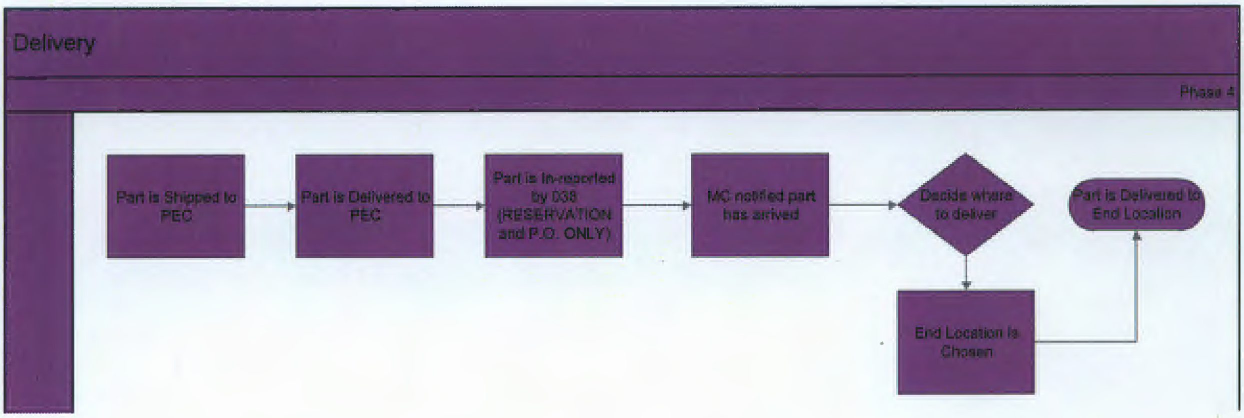

Figure 12.4. Close-up of the Delivery stage.

Establishing Time Standards

Once a process map was made, the time standards could be established. Process time is the maximum allowable time for each step in the overall process. Cycle time is how long the actual task takes for the employee or software to do it. The overall process time would be a sum of the allowable time for each step, and the overall cycle time would be a sum of the individual cycle times.

Establishing Goals

Once a good process map was developed and current time standards were known, goals had to be established. It is important to know what you are working towards in order to decide how to best affect it. The main goals were to reduce the current 12-day maximum process time to five days and reduce the average part procurement time from five days to three days

Deliverables

The key deliverables that were noted were as follows:

- Drive lab asset utilization from 50 to 57 percent by Fiscal Year (FY) end 2016. This is an ongoing facility-wide goal, which could be helped by improving the parts procurement process.

- Reduce mean time between tests from 21 days to 17 days by FY end 2016. This is a Drivetrain Test goal, which could again be assisted by reducing the parts procurement time.
- Reduce engineers non-value added time spent ordering and searching for parts to zero.
- Improve technicians and engineers' productivity time by reducing the idle time waiting for parts.
- Identify and resolve issues quicker within the parts process by providing a better flow of communication and feedback.
- Define a process map with clear roles and responsibilities.

First looking at the facilities overall goals and then looking into the main beneficiaries of improving this process identified these.

Project Scope

A very important factor in the success of a project is scope and avoiding scope creep. That is, deciding exactly what the boundaries of that project are and not letting the project drift beyond said boundaries. It is very easy to start with a small specific task and end up with a massive undertaking. This can easily derail a project that could have been successful. This is why it is necessary to spell out hard lines on the scope of a project. According to Dolan (2003),

> Once a team gets started, it may uncover additional problems that expand the scope of the project. The project leader should guard against "scope creep" and ensure the team stays focused on the main problem. Do not try to change things beyond the scope of your process. It is better to have success in one or two areas than to use a shotgun approach that does not yield good results. (p. 26)

After examining the collected data, the project scope was set. It was determined that since reservations were 40 percent of all orders and since they were dealing with local company factories, they should be the focus of this initial project. Reservations seemed to offer the most potential for time saving and seemed to garner the most complaints. If a P.O. for a make to order part is taking a long time, there is not a lot that can be done, but when it comes to moving production parts off of the assembly line to the engineering center, much more can be done to expedite that process, especially when the factory and engineering center are part of the same company. It was also decided, as was noted earlier, that the process would start with the Material Coordinator receiving a request and end with the part being delivered to the end location. Some very large-scale suggestions were also ruled out for the time being, as they would likely require an entire other project. This includes things like adding tracking systems. Also excluded was refinement of the "Hot" ordering process. A "Hot" order is a rushed order for emergency use in line-down situations or other high importance circumstances. While there was no denial that this process could use its own project, it was decided that for this project there would be too much additional work to include it. It was also hypothesized that if there was success in reducing the regular part procurement time, the need for "Hot" orders could be reduced.

Benchmarking

While preparing for the project, the leaders had been in contact with supply chain management mangers at a sister factory's engineering facility. The sister factory transitioned to using MaSA, the same system that the engineering center uses, three years ago. In fact, they received training on using the program from one of the members of the engineering center team. Upon implementing MaSA, they went through a similar project as the one being discussed here.

Given their three-year head start it was decided that this sister factory would make a great benchmarking opportunity for the engineering center team. The team arranged an entire day of tours, discussion, and collaboration. The following day the entire team met to debrief and discuss their feelings about the benchmark as well as work on recommendations going forward.

Metrics

The most difficult part of this project was likely determining metrics. In order to make data driven decisions, it was first necessary to collect valuable data. Initial data was taken, as stated before, to compare cycle to process times. This also made it possible to identify which steps provided the most room for improvement. This data was put into several different visual formats, including Pareto Charts broken down into steps and work area (Figure 13 & 14), comparison charts by step between process and cycle time (Figure 15), and a cause-and-effect (fishbone) diagram relating each problem to a focus area (Figure 16).

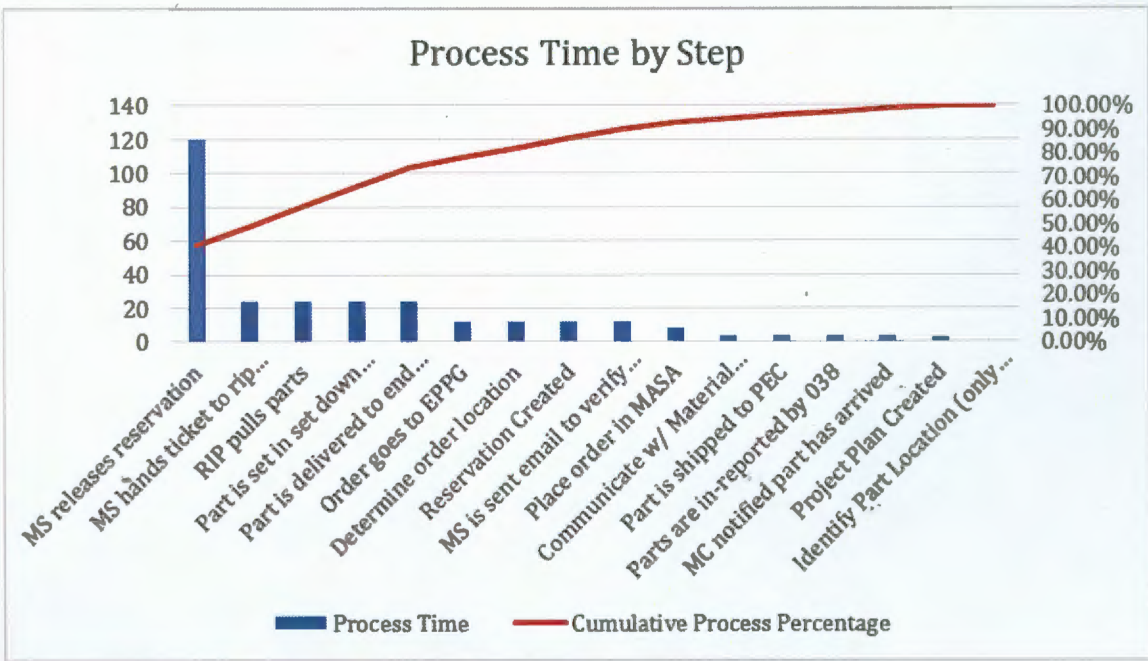

Figure 13. Pareto chart showing process time per step.

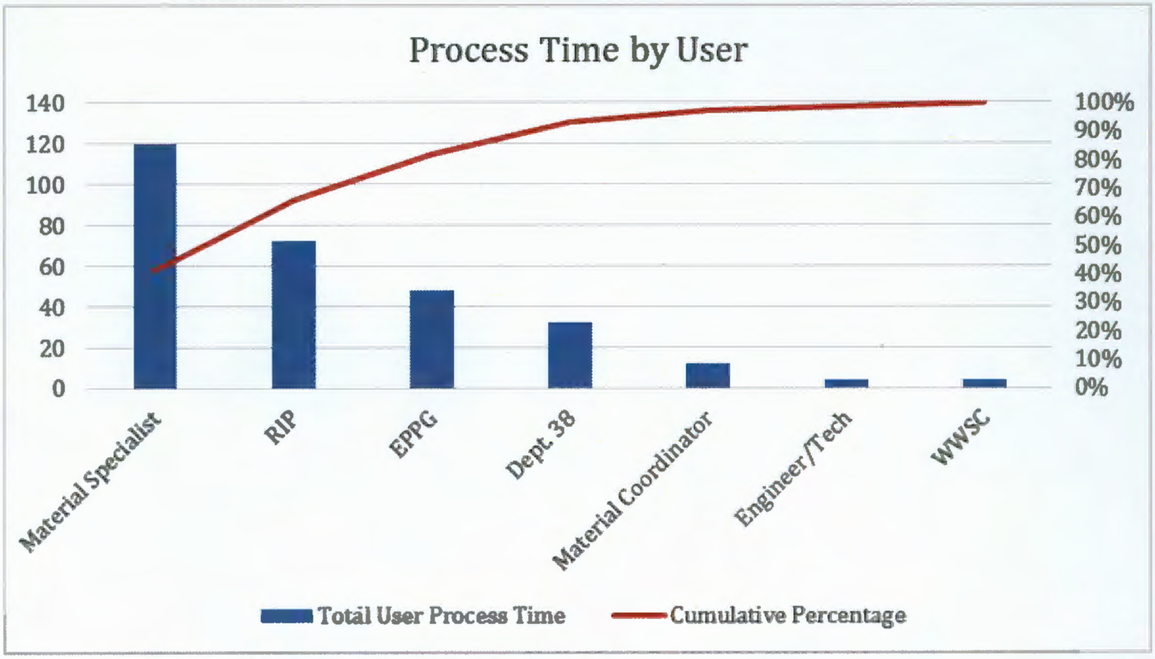

Figure 14. Pareto chart showing process time per user.

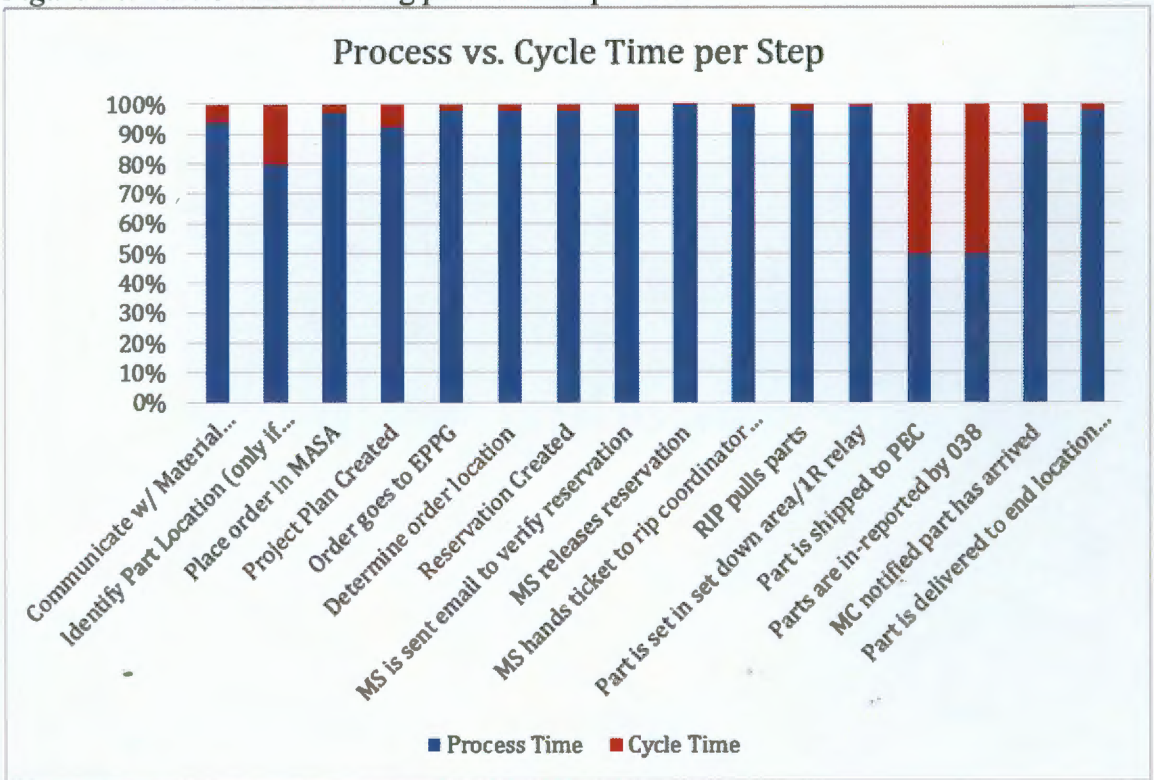

Figure 15. Chart showing process time vs. cycle time.

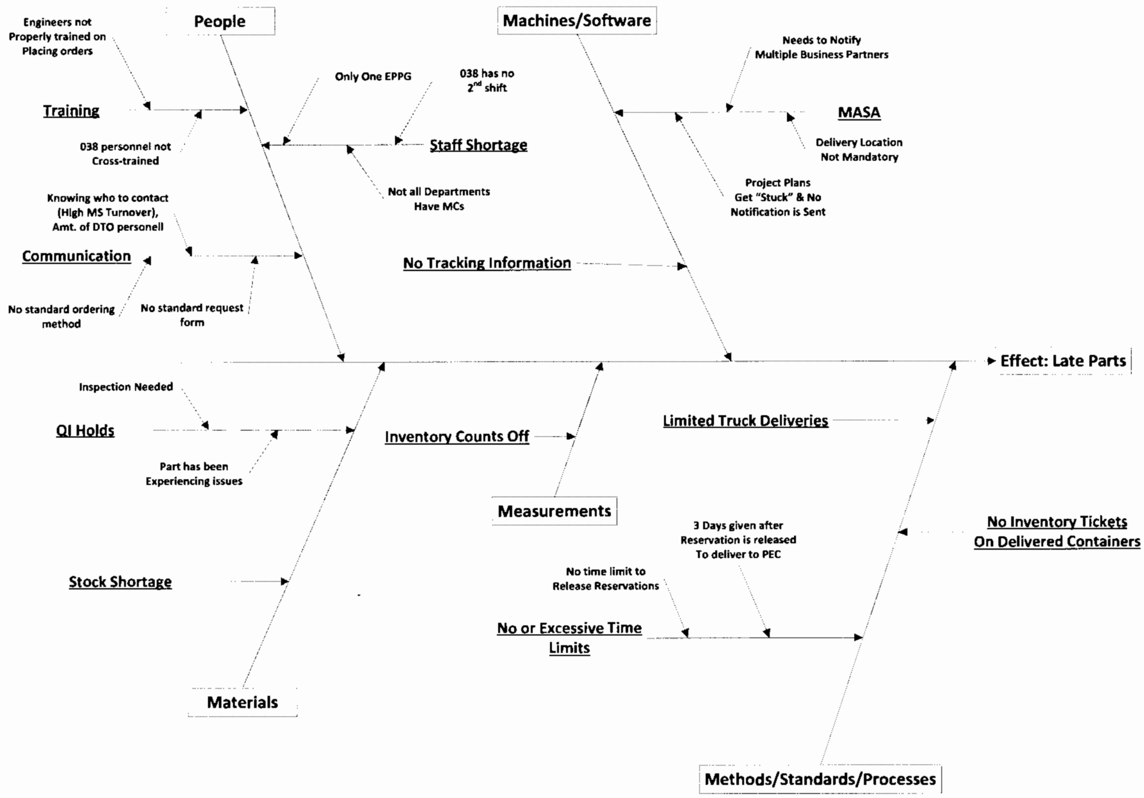

Figure 16. Cause and effect (Fishbone) diagram based off of VSM and kaizens.

There were hopes that by combining information from several reports created throughout the ordering process there would be a way to get a historic view of average delivery time for reservation orders. Unfortunately, after hitting dead ends at every turn and finding out from the sister factory team during benchmarking that they had also pursued this to no avail, it was abandoned. Fortunately, however, a few employees that place MaSA orders had been extremely organized and kept data for themselves. It was determined that, although there was not a comprehensive average for the facility, there was some significant sample data that could be used. It turned out the estimate of five days was rather accurate (Figure 17 & 18). At the onset of the project, Material Specialists and Engineers that ordered frequently were given a template to track their orders manually. The form included the request date and delivery date to calculate the desired metric of delivery time, along with other variables like whether the part was ordered

HOT or if an explanation was given for delinquency (Figure 19). Gaining this data was very important, because it makes it possible to view trends once fixes are put in place. When each kaizen is implemented it can be dated and then watched to see if the delivery time decreases. This helps validate the changes and prove that the changes are driving metrics towards goals.

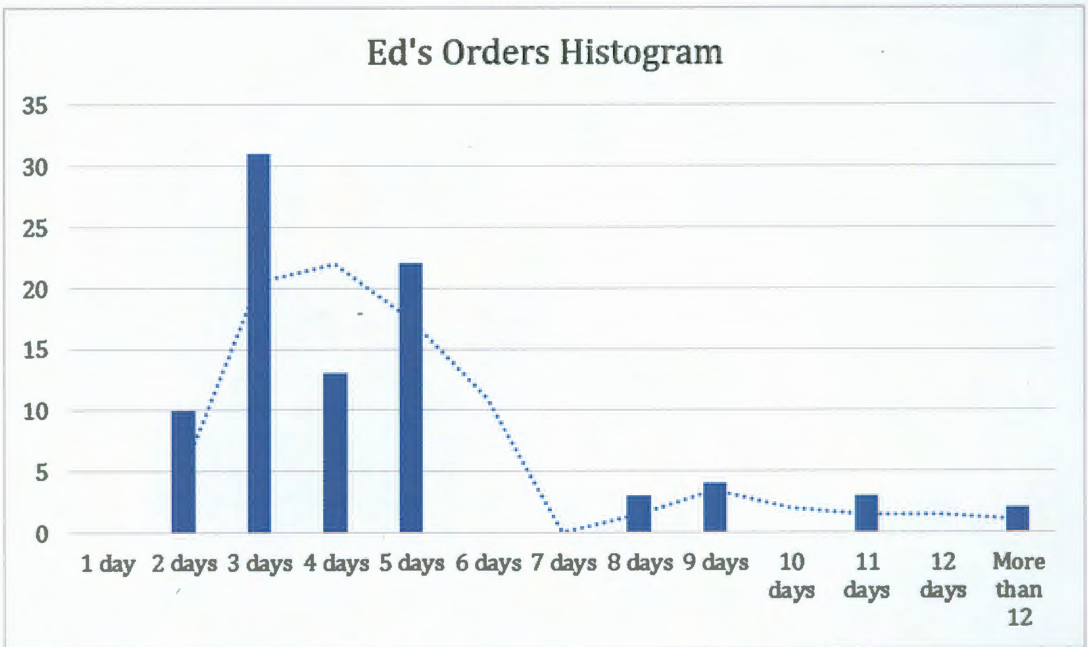

Figure 17. Graph showing Ed's MaSA order delivery times broken into bins of one to twelve days.

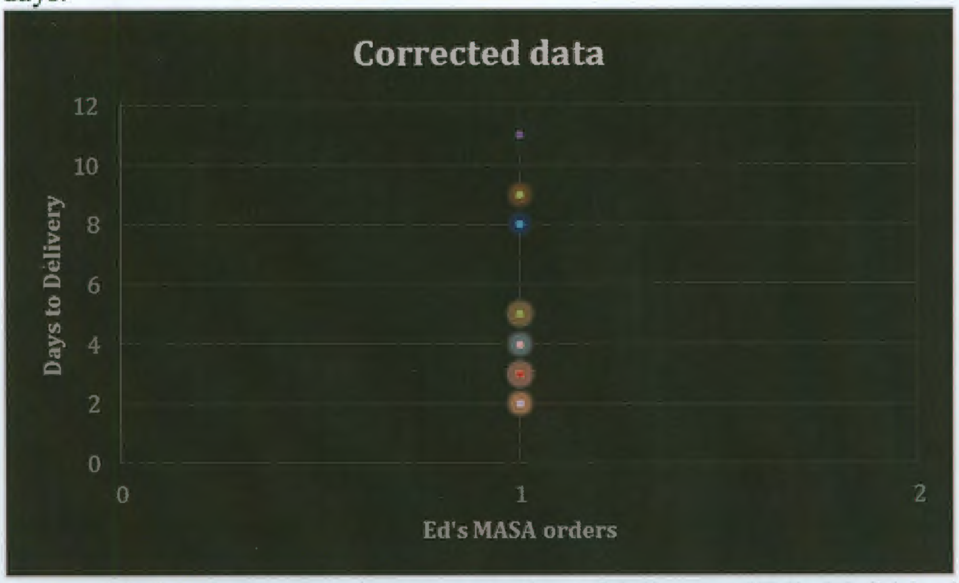

Figure 18. Graph showing the concentration of delivery of Ed's MaSA orders.

Figure 19. Image of the tracking sheet given to Material Coordinators.

Kaizens

Once the team had an appropriate VSM and got to experience the benchmarking opportunity, it was time to brainstorm for improvement ideas. The VSM was laid out on the wall of a conference room and step-by-step, team members voiced problems with that step and possible solutions. These were pinned below the step and later converted to a digital file using Visio. Once all of the ideas were out in the open they were looked at individually to see if they were in scope. The ideas that were determined to be in scope were then discussed by the group and categorized into four types of initiatives:

- Quick Kills – Initiatives that can be done quickly and with relative ease among team members
- Major Programs – Larger projects that could require additional resources, such as capital, management support, or further time commitment
- Future Possibilities – Projects that may be good ideas, but are not going to be the current focus of this project, mostly due to size or timing
- Possible RCI's – Rapid Continuous Improvements are smaller standalone projects that can be knocked out in a short time period among a small team

Goals Going Forward

Management was presented with the plan the team had decided to go forward with after selecting kaizens. These included the Major Programs, Quick Kills, a brief overview of possible future projects and RCI's, and a general review of the project thus far including the benchmarking event.

Major programs. Some of the kaizens were determined to need more attention than others. These required a larger amount of time and some help in removing roadblocks from management. They were identified as Major Programs and included reorganization, implementing a reservation release time limit, and making SAP updates.

Reorganization. Reorganizing the Material Coordinators and EPPG personnel under Supply Chain Management was the first recommendation. Currently each MS is under separate engineering department organizational charts. This creates several problems. First, it limits their ability to work together and backfill for each other's vacancies. It also leads to a knowledge loss with position turnover. Having a common manager should help with this. The engineering managers that are currently serving as their bosses do not have any expertise in ordering parts. Working under Supply Chain Management should open up that network to help make improvements. Also under this category was a more immediate request for a part-time employee to help take on some of the EPPG load. Historically there were three EPPG people fulfilling orders, but this has now been reduced to one and the workload is quite heavy. Showing how the sister factory had chosen to organize its team after going through this process also supported this reorganization. The model created was very similar to their organizational chart (Figure 20). In response to this request, management has asked that a business case with roles and responsibilities be presented to the Supply Chain Management leaders. This is currently in progress. They were also very willing to get EPPG help and are currently working on it.

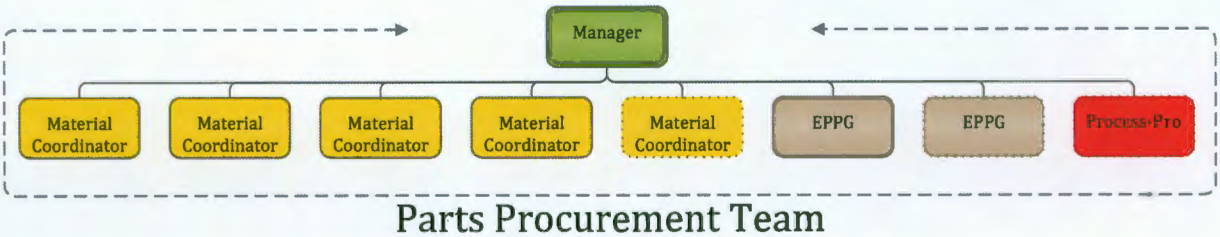

Figure 20. Potential organizational chart presented to management.

Reservation release limit. Cutting reservation release time was the next major goal. Putting a dedicated reservation release time in place and cutting the delivery time from local factories to the engineering center to two days was suggested. This would drop the total process time from a maximum of eight days to a maximum of three days. This is the largest time saver in the entire project. The factory representative on the team (the Material Specialist from DTO) agreed that this was very doable. The next steps are just for management to make this a formal agreement and find a way to track and enforce the policy.

SAP updates. SAP limitations were another problem. Several time delays seemed to revolve around software glitches and limitations. There is a standard process that needs to be followed to implement SAP changes. SAP is what MaSA is based on, so this would include MaSA changes as well. Once the charter is submitted to the SAP team, they decide what they can do, and changes are rolled out twice per year. A smaller team, made up of a few current team members, will be put together to complete the SAP charter. One issue was making "delivery location" a required field. This would eliminate ordered parts being delivered to receiving and receiving not knowing where to send them. Another change is to make it possible to input multiple business partners. This way, both the requestor of the order and the person that inputs the order will be notified when the parts have arrived. The biggest issue is with a software glitch. Randomly, orders will be placed and the "automatically created project plan" will not create. It gets stuck and does not notify the person that had placed the order. The preference would be to fix this glitch, but at least being able to add some sort of automatic notification that a project plan has not been created would certainly save time.

Quick Kills. Along with the Major Programs there were also many kaizen opportunities that were more easily fulfilled. Anything that was simple or required little time, influence, or capital was deemed a "Quick Kill." During the presentation to management, permission was granted to immediately begin work to implement any Quick Kills that were deemed worthy. They are making a standard ordering template and staffing the receiving dock.

Standard ordering template. Standardizing an ordering template for engineers was a fast and easy step. The goal was to only have a bare minimum of required fields, but still be able to cover everything the MC needs, so that no back and forth is necessary. Shortly after the management meeting a smaller group consisting of group members got together and made a plan for the template. The template is now finished and will be distributed for use very soon (Figure 21).

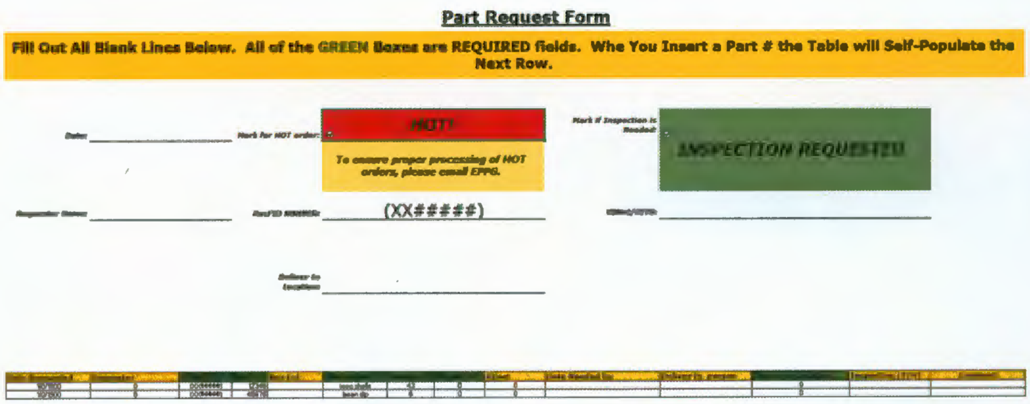

Figure 21. Image of the standardized parts request form.

Staffing the receiving dock. Flex personnel for the receiving department could be very beneficial. Currently the receiving dock is open until 6:00 P.M., but it is only staffed until 4:30 P.M. It seems quite obvious to have at least one person staying until the dock closes to in-report and deliver late orders. This could quite possibly save an entire day on some projects by getting parts to second shift technicians that would otherwise have to wait until the next morning.

RCI's and future projects. Along with the immediately requested Major Programs and Quick Kills came an array of future possibilities. These are ideas that did not necessarily fit the scope of the project or were too large in scale to be included, but they may warrant a project of their own. On the benchmarking tour, the sister factory had shown many supplemental programs for SAP that they had created or chartered. In the world of very slow SAP responses it had been found necessary to use their programming resources to create several tools to help track their desired metrics. Fortunately, they have already done this and it's likely that the engineering center can take what they have and find a way to implement it without starting from scratch. Some other ideas, like redoing the HOT process, have been slated for future RCI events. Though not every idea was used in this particular project, it is still beneficial to have the ideas on the shelf and the fact that all of the problems have been identified is helpful.

Project Conclusions and Recommendations

This project is currently ongoing. Unfortunately the business world did not move fast enough to see the fruition of this project by the time this paper needed to be finished. As stated above, many of the recommendations are currently being put into place. It would be beneficial to see how these changes have effected the delivery time of parts, but fortunately the main point was to see how the process was used in the engineering environment and the project not being finished did not prevent that.

Adjustments for the engineering center

Had this project been for a factory environment, a more straightforward Six Sigma approach likely would've been feasible. In all likelihood some sort of "pull system" would be put in place to make the process as lean as possible and automatic order generation would be the overall goal. Unfortunately, the engineering center does not order a standard set of parts constantly and it does not order at regular intervals. It is anyone's guess as to when programs are going to ramp up or problems are going to occur. One week the engineering center may request

100 of one particular bearing or ten of a particular casting and then might never order them again. This is part of the reason the factory keeps buffer stock. Plans for big builds are made as much as possible ahead of time, but as was stated before, often times part changes are made. So, implementing an existing factory style plan does not work. Using Six Sigma for this particular project, the way a factory would, would not really work either. Part of the problem was being limited on metrics. It is difficult to analyze an issue without having a good amount of data behind it. This project was not about making sure that 99.99966 percent of all deliveries were made within five days. Six Sigma level quality was not a necessary, or frankly, a realistic goal. But, the use of Six Sigma tools has helped steer the project into the right direction to meet the goals it set out to achieve.

Conclusions and Recommendations

This paper has shown that Continuous Improvement processes and tools can be successfully used in engineering/experimental shop environments. The two specific processes analyzed here were 5S and Six Sigma, however within the latter, some Value-Stream Mapping was included. These processes have been tweaked accordingly to warrant a successful use within the engineering center to help achieve business goals. These processes have proven their flexibility over time through use in manufacturing, healthcare, and other forms of business. This paper has laid out how each process was used in a real world project, step-by-step, and discussed the results and deviations from the standard manufacturing style processes. Given the promising early results of the 5S project, it will almost certainly be expanded throughout the facility. The Parts Procurement CI project, though not finished, has yielded some very high potential for time and cost savings. Assuming the potential improvements are followed through and the process makes the suggested improvements, it is likely that additional similar projects will be started.

These programs may have built their reputations in factories, but they are certainly just as useful in other environments with a few alterations.

In the future, it would be recommended that some other processes be studied. For example, using TQM in an experimental machine shop where tooling is not used on as regular of a basis as it would be in a factory setting. More Six Sigma studies could be done as well, considering it can be used for such a broad spectrum of projects. There are always new tools being developed to improve productivity and new environments to test them in.

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