Combining Six Sigma Tools with Lean Performance Measurement to Sustain Continuous Improvement Activities

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Abstract
Sustaining the results of any continuous improvement effort can be challenging. With Lean improvement, constant monitoring, coaching and tweaking is often required to keep the "old ways" from creeping back into the process. With Six Sigma process improvement, the challenge is to create ownership in the improved process; without this ownership the changes often disappear overnight. Two companies, both contract electronic manufacturers, have adopted methodology from both Lean and Six Sigma that has proven successful by placing the ownership in the workforce's hands and demonstrating results-based support from leadership. Both companies were searching for ways to improve quality and customer satisfaction when they began utilizing Lean Manufacturing concepts and then quickly integrated Six Sigma concepts to strengthen their outcomes.

As Lean began to produce results, it was apparent that there needed to be metrics in place to sustain the results and allow employees to manage the processes through the concepts of an empowered workforce. Finding that the traditional metrics that had been used for years were not sustaining the gains or providing adequate guidance to employees, these two companies turned to a fundamental Six Sigma Green Belt measurement tool and the concept of "Measurements with Meaning". Not needing to overwhelm their employees, Process Behavior Chart (PBC); AKA control chart software, was introduced to the manufacturing floor. Being able to measure the way processes normally behave and investigating signals to find root cause greatly enhanced daily production results, and gave the employees the ability and authority to identify and act upon problems as they occurred.

Relying on the concepts of Measurements with meaning to help identify the metrics necessary for success, fully engaged workforces evolved at both companies very quickly. Employees had no problem identifying what they valued both within their processes and as a company, and they wanted a way to show management that they were doing everything possible to succeed. Instead of "chasing" every minor change in productivity, each work center simply focused on total parts produced and work orders "left on deck" (due but not complete at end of day). All signals which now appear on the Process Behavior Charts are investigated initially for assignable (special) cause. Focusing on the right issues and items, through employee ownership of the processes, has created significant and lasting results for both companies.

Introduction
Two electronics contract manufacturing companies: one providing prototype development, high mix – low volume production, SMT, and through hole assembly; and, the other a custom switch and sensor manufacturer, historically searched for solutions to ongoing process problems by reacting to quality and customer satisfaction issues after they were brought to the attention of management; these were usually in the form of complaints from customers. This "reactive" method of problem resolution was a continual source of pain and concern, but was accepted as "business as usual" for more than 20 years within each company.

With exposure to Lean Manufacturing concepts through participation in conferences and professional organization participation, both companies made conscious decisions to adopt Lean Manufacturing as the methodology of choice for continuous improvement. Extensive training, followed by mentored kaizen event (five-day Lean project) facilitation, provided impressive initial results by improving quality, throughput, and the bottom line.

However, even as the management and quality teams of both companies reported out these improvements and hailed them as substantial steps in the right direction, over time the processes reverted back to pre-Lean conditions and results. Over a three plus year period, there was much discussion as to the cause of the "failures" as several managers described them. Both companies had fallen back into their traditional model of problem solving by gathering managers together, discussing the problem and finding solutions based upon opinion.

Some managers involved in the discussions used it as an opportunity to say that Lean does not work. Others blamed employees for not following Standard Operating Procedures (SOPs). While most of the participants believed that a primary factor was lack of employee ownership in the new processes, there were a few that blamed each other for failing to support the Lean Manufacturing efforts or for failing to properly train the workforce. Even though there was a considerable amount

of conflict surrounding these theories, the management teams of both companies agreed that a lack of the right metrics was the biggest failure for the lack of process sustainment.

Lean efforts came to a complete standstill until management discussions at both companies escalated to "What do we replace Lean with?" *Company A*'s approach was to hold team meetings and ask all employees for ideas and suggestions about the approach they had been using for continuous improvement. *Company B's approach was to* ask a Lean consulting service provider to sit in on a management team meeting to listen to the discussion and make recommendations.

The answers in both instances were similar. Employees at *Company A* said that they did not believe that employees on the manufacturing floor truly had ownership in the process changes and that they felt that while symptoms were being treated often times root cause was not being identified and addressed. After listening to management at Company B, the service provider stated that it appeared as though there were defect and variation problems that Lean Manufacturing was not addressing. Additionally, it was pointed out that trying to solve these issues in the conference room, and not on the manufacturing floor with the employees involved, was violating a major tenet of Lean.

These "aw-ha" moments for the management teams resulted in a three-fold continuous improvement approach for both companies. First, additional Lean manufacturing training and outside mentoring was utilized to ensure that experts were being developed internally. This helped to ensure that the employees not only owned the process changes made, but also were also capable of facilitating kaizen events elsewhere in the organization. Secondly, a small group of key employees, with the correct skills and abilities, were selected to participate in Six Sigma green belt training. These green belts were then assigned to study selected problem processes, find and then eliminate the root cause of the complex defects and variation problems that Lean was not addressing.

The final piece of the methodology change was accomplished through outside consultation and mentoring for both companies as they adopted a new strategy for measuring and monitoring the results of their continuous improvement efforts. By combining the concept of Lean Performance Measurement[i][1], with a Six Sigma tool known as process behavior charts (control charts) and the methodology of Measurements With Meaning[ii] [2], these companies provided visibility and understanding to the workforce as to expectations and results achieved within measured processes in real time.

Methodology

Lean Manufacturing Training

The first step in the recovery of Lean Manufacturing success was a renewed and dedicated effort to train all full-time employees in the basics of Lean Manufacturing.

For *Company A*, with a total of just over 80 employees, this meant first ensuring that all members of management had attended a one-day Lean 101 class (introduction to Lean Manufacturing)[iii] [3], second that all full-time employees had attended the same class, and finally that each new employee hired attended this training within their first 90 days on the payroll. The topics covered during this one-day class are outlined in *Table 1*.

Table 1 - Course Outline for Introduction to Lean Training

Lean 101: Introduction to Lean Manufacturing	
● 5S System	● SMED
● Standard Work	● Point Of Use Storage
● Teams	●Quality at the Source
● Visual Controls	● Pull Systems
● Layout	● Cellular Flow
● Batch Reduction	● Total Productive Maintenance
● Value Stream Mapping	

A second smaller group of employees, selected as the future leaders of the company by the management team, was then asked to participate in a series of Lean workshops and attend a Lean facilitator class to become the floor leaders of the Lean movement. The curriculum these selected employees participated in is outlined in *Table 2*. These Lean facilitators, working first with an outside mentor and then on their own as their confidence and skill level grew, conducted kaizen events in each manufacturing cell that had been previously worked on to regain the improvements that had been lost over time. Additionally, the facilitators identified issues and problems that were still in need of root cause analysis.

Table 2 - Company A Advanced Lean Curriculum

Advanced Training Curriculum	
• Value Stream Mapping Workshop (2-day)	• Pull System Workshop (2-day)
• 5S Workshop (2-day)	• Lean Facilitator Academy (9-day)
• Setup Reduction Workshop (2-day)	

At the beginning of each event, the facilitator and a champion from the management team would conduct a quick review of the concepts learned in the Lean 101 class and discuss the Lean strategy being used by the company. This discussion included a review of the "Typical Lean Methodology Strategy" chart (see *Figure 1*) that had been presented to the entire workforce during a series of one-hour Lean overviews prior to the original Lean implementation several years before. Using this chart as a focal point to encourage open and honest conversation about the company's earlier Lean shortcomings, management came forth and admitted their failure to adequately maintain Stages 1 through 3 and the complete failure to implement Stage 4 in their previous efforts.

Company B used a much more organic approach to training, even though they were more than three times the size of *Company A* with nearly 260 employees. Selected top level managers attended a Lean 101 class using the same curriculum as that of *Company A*. This was followed by a second small wave of managers and supervisors from the manufacturing floor participating in the same class. Once all participants had finished the training, a meeting was held to discuss what had gone right and what had gone wrong during the first attempt at Lean implementation.

From this meeting, *Company B* developed a story to explain the evolution of Lean within the company and what the future vision was including the use of Six Sigma as a way of attacking the difficult problems that had so many employees frustrated during the first attempt. The story and vision were presented to the workforce on the manufacturing floor in a series of four town hall meetings which were all conducted in a single day to ensure that management was telling the same story each time. Company B, at the encouragement of the outside mentor, also used the chart shown in *Figure 1* as a way to explain how Six Sigma tied into their strategy in Stages 3 and 4. At the conclusion of the meeting, employees were asked for suggestions of where the work could start immediately in order to get Lean back on track. Several informal floor leaders quickly took advantage of the opportunity to point out several extremely difficult problems that they had faced on their manufacturing lines and stated that kaizen events or Six Sigma projects would be welcomed with open arms if the problems could be addressed.

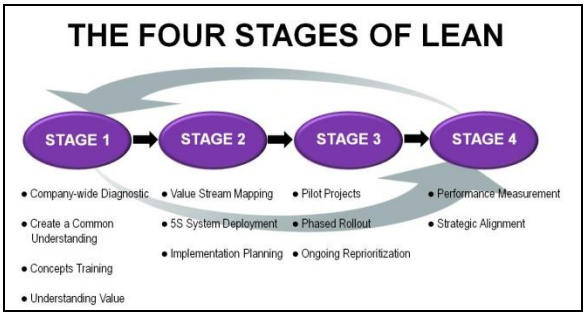

Figure 1 - A Typical Lean Methodology Strategy[iv] [4]

This retraining accomplished its goals for both companies. However, *Company B* required considerably more time to regain the trust, buy-in and ownership necessary for Lean success. For both companies, the addition of Lean concepts reviews during each kaizen event as mini-training sessions helped to refresh or give new insight into the power of Lean Manufacturing. This small change became a critical component of the training as management recognized the value of the exercise when employees became enthusiastically engaged. As a part of the concepts review with each kaizen event, team members were invited to list particularly tough problems that were not being solved on a parking lot flipchart, so that these issues could be addressed utilizing Six Sigma.

Six Sigma Training

Company A selected two employees (one engineer and one quality technician) to participate in Six Sigma training to obtain their Green Belt certification. *Company B* selected six employees for Six Sigma training (one engineering manager, one quality manager, two process engineers and two maintenance engineers). Both companies required the participating

employees to work as teams to solve a problem during the training by working a project. While *Company A* was able to quickly demonstrate the power of Six Sigma on a single problem during their two and one-half months of training, *Company B* was able to demonstrate the power of Six Sigma in three different areas of the manufacturing floor during the same training period.

Both companies selected a Six Sigma training program through their state's career technology (vo-tech) education system that was focused on teaching participants how to use statistical process control tools to solve problems as opposed to many of the Six Sigma offerings available today that present a large amount of theory and methodology that creates structure but not necessarily results. The course curriculum from this session is outlined in *Table 4*. As an outcome of the program, both companies were able to solve some problems that had been frustrating many employees. Additionally, it also created a strengthened relationship between employees and management by showing support through problem solving for those people on the floor that in the past had felt abandoned with no solutions to chronic problems in sight.

Table 4 - Six Sigma Green Belt Curriculum

Five by 2-Day Six Sigma Course Curriculum	
● Project Charters	● Root Cause Analysis
● SIPOC	● Introduction to Design Of Experiments
● Value Stream Mapping	● Simple Experiments
● Collecting & Summarizing Data	● Lean Concepts
● Process Behavior Charts	● FMEA
● Gage R&R	● Control Plans
● Process Capability	● Using Control Charts to Manage Process

Measuring the Process in a Meaningful Way

While the emphasis on training, or more appropriately phrased "retraining", brought a significant amount of attention to the processes and problems being experienced on the manufacturing floor, it also brought management, for both companies, into the continuous improvement loop in an unexpected manner. The mid-level managers (frontline supervisors and their managers for these smaller organizations) began to become engaged. As results were delivered, where once human roadblocks existed, these managers were slowly becoming champions in their own rights. They also became the very employees pushing for a better long-term outcome.

Recognizing that something different must be done was a critical turning point for both companies. As management began to see processes start to revert once more, a group of managers and supervisors at *Company B* began to ask their outside mentor how he thought they could maintain the improvements long-term. In complete opposition to *Company B's* inquisitive approach relying on the knowledge of their service provider, *Company A* found the answer in a proactive manner through their Six Sigma green belts. In the green belts' control plans (associated with two early Six Sigma projects), the monitoring process included a single statement in both projects. This statement recommended that the employees working in the value stream (process) be included in discussions to find the right metrics that could be captured on a process behavior chart. This chart could then be used to gain insight into the process allowing employees working within the process to take corrective action if necessary.

Company A management recognized the power of their green belts' statements as they reviewed the actual results of process changes implemented and the employees' knowledge of how each improved process should function. The challenge that accompanied this recognition was how to identify the correct metrics that could use process behavior charts for monitoring and control for all continuous improvement activities. Trying to keep Lean and Six Sigma activities completely separated was actually hindering the ability to see how to use both disciplines in a synchronized manner. Once it was understood that they could "blend" the methodologies, the only challenge became how to "get the metrics right".

Through research, and multiple conversations with their outside mentor, both companies made deliberate decisions to utilize the concept of Measurements With Meaning in conjunction with Lean Performance Measurement and Process Behavior Charts. To implement this new measurement system required the addition of deliberate action during Kaizen Events and Six Sigma project meetings to first identify what was valued organizationally within the value stream and then to find a simple way to measure it long-term.

An explanation of the Measurements With Meaning (MWM) methodology and how it supports Lean Performance Measurement was required, as was a high level explanation of Process Behavior Charts. A single slide (see *Figure 2*) showing the Value-Measure Life Cycle was used to explain MWM. This slide was used to walk both Kaizen/Six Sigma team members, as well as all employees in the affected value streams, through the concept of MWM.

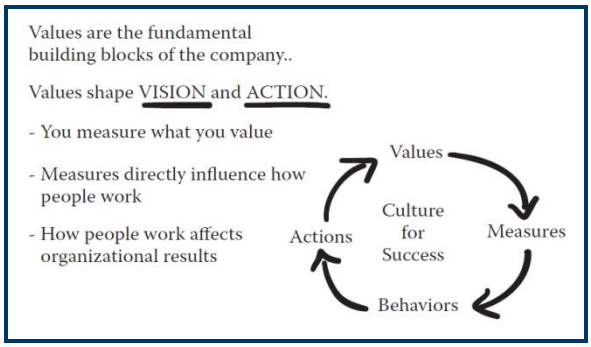

Figure 2 - The Value-Measure Life Cycle[v][5]

Getting employees to understand the relationship between values and measurements is critical to the success of any organization. Changing the focus from financial and/or arbitrary measurements to value-based measurements is a challenge for management, but the saving grace for employees. When an employee is asked what they value, or simply stated as what is important to the success of the task they do in relationship to the company as a whole, most employees will focus their answers on quality and on production based upon time available as opposed to arbitrary production goals or financial metrics they do not even understand.

Acknowledging that measurements do have a direct correlation with behavior, and that over time the desire to "beat the goal" has an impact on actions, allows employees to see that over time values change if you focus your efforts on the wrong things. To be successful, a company must keep values in plain sight to avoid one of the major concerns that Lean Manufacturing addresses; island mentality[vi][6] - focusing only on your individual success at the expense of the company.

The shift to MWM style metrics on the manufacturing floor was made somewhat easier when discussions about selected metrics began to focus on placing the reported results on a process behavior chart. Just as MWM was taught using a single slide, the complexity of process behavior charts was greatly simplified through a single slide (see *Figure 3*) explained on a level all employees could understand.

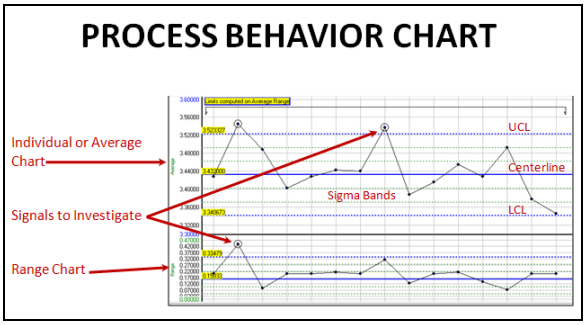

Figure 3 - Process Behavior Chart Explanation

By providing a simple explanation of process behavior charts showing what the chart looks like and what each part is, without burdening the audience with mathematical formulas and theories, acceptance of the tool was nearly universal. When employees see that if results stay between the upper and lower control limits there is generally no reason to ask what is going on, they begin to trust in the tool. To simplify the recording of data and calculation of limits, as well as to quickly display signals for investigation[vii][7], a software package is being used to track daily activity on the charts.

The metrics selected for display on process behavior charts were developed through team meetings with employees. Employees were asked what they value. Then they were asked how they would measure that. The goal was to find measurements that truly had meaning to the employees and were reflective of the process team's values. Some outside facilitation and mentoring was required to ensure that these new metrics (for the most part) fed into and supported the overall goals and organizational values of the company. Over time, key employees from both companies were able to carry out these discussions and metrics development on their own.

Perhaps the most compelling result for both companies was the overwhelming standardization in metrics that occurred. It was extremely easy for the key employees facilitating these discussions when without exception the answers of what was valued zeroed in on *quality product completed on time*. Supervisors and managers involved in the discussions almost always said "number of pieces produced is the only way to ensure that our employees are working hard." Over a six month time

frame at *Company A* and approximately ten month time frame at *Company B*, manufacturing cells standardized to two very simple yet powerful metrics: **Number of Pieces Produced**; and **Work Orders Not Completed On Time**. *Company A* labeled their work orders not completed on time metric as **Orders Left On Deck** after the shipping department adopted similar metrics and began referring to late orders using this term in daily production meetings. *Company B* simply labeled this metric on metric boards in each cell as **Late Orders**.

Another similarity between the two companies occurred as employees in one manufacturing cell would see the process behavior charts in other cells, they would invariably ask, "Why are we not being measured that way?" When these questions would arise, whether or not any Lean or Six Sigma work had been conducted in the area, upper management at *Company A* first encouraged and then supported the production manager and quality manager in changing all cells' metrics over to this simple system. A few supervisors at *Company B* resisted this standardization for more than six months; continuing to explain to their peers that what they did in their areas was unique. It took the president of the company mandating the change, in response to employee comments, to finally overcome this resistance.

Today, as long as the daily numbers posted are within the control limits, management does not burden the employees with things they cannot change. After process changes are made through continuous improvement efforts, the new process is typically allowed to run for two to four weeks (depending on demand), then the control limits are recalculated, and the monitoring process begins once more using these new control limits. When this limit change occurs, team meetings are held at both companies. These meetings are intended to explain the changes in the process and the limits, and to create a safe environment for employees to express concerns and fears about the changes made.

For both companies, any time a process behavior chart shows a signal, the employees in the value stream are empowered to investigate the cause—investigate, not correct without proper consultation. The root cause must be explained and the recommended corrective action approved by management prior to implementation. This is intended to eliminate the fiddle factor of making unnecessary adjustments (over or under) to a process when a single signal of assignable cause could be self correcting on the floor.

To ensure that this process is followed, management at Company B has a standardized process in place when interacting with employees in a value stream investigating a signal. *Figure 4* lists the question and answer methodology used once management is aware that a signal exists on a process behavior chart.

PBC SIGNAL MANAGEMENT QUESTIONS
● When did the signal appear? ● Who first noticed the signal? ● Have you investigated for assignable cause and is there assignable cause with this signal? ● If there is assignable cause, do we need to do anything within the value stream as corrective action? ● If there is assignable cause, does management need to ensure anything outside of the value stream is addressed as corrective action? ● If no assignable cause was found, who should be involved in the investigation for root cause?

Figure 4 - Process Behavior Chart Signal Investigation

This structured and standardized approach has allowed the workforce to take ownership in the corrective action process and yet ensures that opinion does not supersede facts and data. Employees are routinely encouraged to report any situation to upper management or the quality team when this Q&A process is not followed.

Data

Company A

The methodology used for metrics by *Company A* prior to this change in practice and philosophy was singularly focused. Each cell on the manufacturing floor posted two to three metrics on boards in the cell. A Production board was in every cell. However, the information on this board was limited (see *Table 5*).

Table 5 - Previous Production Board

Production	
Month	February
Goal	12,000
Last Week	**Month**
2,622	11,788

Additionally, at least one other metrics board appeared in most of the other cells. A Defects board was a common sight (see *Table 6*), as was a board showing on-time completion percentages for top ten customers. And in the Shipping Department, two boards focused on late shipments and errors made was prominently displayed (see *Table 7*) in such a way that not only did those employees in Shipping see the boards, but also employees in four manufacturing cells could see the numbers from their workstations.

Table 6 - Example of Previous Defects Board

Defects	
Month	February
Goal	< 3.0%
# of Defects	**% Defective**
613	5.20%

Table 7 - Previous Shipping Metrics Boards

Late Shipments		Shipping Errors	
Month	February	**Month**	February
Goal	0	**Goal**	0
Last Week	**Month**	**Last Week**	**Month**
21	115	4	31

The lack of information in these metrics was not recognized by management until the conversations began with the workforce concerning how to sustain progress during the second push at using Lean Manufacturing as the continuous improvement engine. Employees were surprisingly straightforward with their comments; mostly centered around the statement that these number don't tell us if we are getting better or worse.

With the change to MWM, the metrics became visual and standard. Based completely upon the two things employees repeatedly said they valued - quality work and on-time completion - every cell was equipped with process behavior charts (PBC) for First Pass Yield and Work Orders Not Complete at Day End. In explaining the power of these charts, the green belts took four months of historical data (which had been saved on a daily basis but never shown except when a problem arose) and created a PBC first for daily defects (see *Figure 5*). This chart clearly showed multiple signals, data points circled on the chart, which needed explanation/investigation. During a team meeting with this cell, the quality team and the production manager admitted they had done nothing in most cases to understand the signals shown.

However, when the data was presented in the form of a First Pass Yield PBC, the story was quite different. *Figure 6* shows the same subset of data as First Pass Yield. Looking at what employees value, it can be seen that while there was a serious issue in need of investigation late in the period, the reality is that the process statistically delivers an FPY value 44% and 100% (this is a one-sided specification since FPY cannot exceed 100%). Any daily value greater than 44% is what the process delivers, therefore there is little reason to investigate unless FPY is less than 44% or another signal appears. What this means is that when managers got upset/excited about the three signals shown in *Figure 5*, there really were only two

signals that should have caught their attention (those less than 44%), and they appear to be related when looking at both charts together.

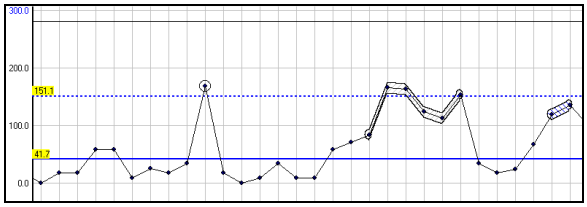

Figure 5 - Daily Defects from a Single Mfg. Cell

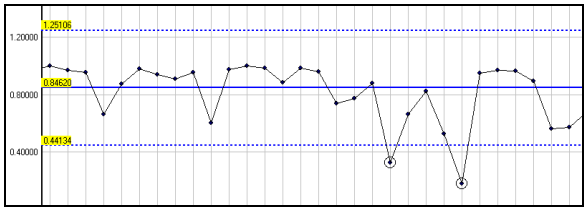

Figure 6 - Daily First Pass Yield for *Figure 5* Defects

This exercise, not only explained to employees how these new metrics would work, but it also showed the Quality Department and management that they might need to measure other things in conjunction with what employees were seeing and responding to. Additionally as the green belts worked their way through the education and training associated with these charts, they also learned that explaining only the measurement chart piece of the PBC, and teaching employees to focus their efforts on this as opposed to both the measurement side and moving range sides of the chart, created a much more receptive environment. Now managers, quality technicians and green belts study the entire chart for signals.

After having these charts in place for six months and addressing several newly found issues though kaizen, the numbers throughout the facility began to improve significantly. For the manufacturing cell discussed in Figure 5 and *Figure* 6, the lower control limit of the process improved from 44.1% to 97.2% and the mean improved from 84.6% FPY to 99.2% (see *Figure 7*). The employees in this particular cell were incredibly motivated to improve the process since profit sharing dollars were at stake. As the workforce began to understand the relationship between performance and profits, their ownership of the process increased as well. While not perfect, as is shown late in *Figure 7*, when a signal now appears, employees are both motivated and interested in finding the root cause and solution.

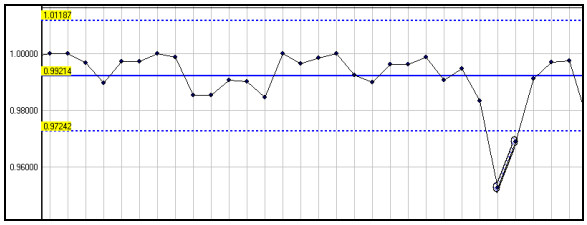

Figure 7 - Daily FPY after Metrics Change

Company B

In similar fashion to *Company A*, the implementation of MWM type metrics for Company B spread quickly once employees recognized the value. In a year-end town hall meeting shortly after PBCs showing **Pieces Produced** and **Late Orders** for most manufacturing cells, one employee commented "These new boards allow us to do our job and not worry about screwing up. Managers and the quality guys can help us figure it out when we have a bad day."

To understand the power of this employee statement, it is important to see what most manufacturing cells used previously as metrics boards. *Table 8* shows an example of a board used. Employees were overwhelmed with numbers; many of which they neither knew the source of the data, nor did they understand how it linked their work to the company as a whole.

Table 8 - Company B Previous Metric Board

Week	27
Production	1510
Scrap in Cell	185
Scrap at Inspect	231
Scrap at Packaging	12
FPY	72%
% ON TIME	63%

Company B, whose managers also acknowledged that there was no historical link to show progress or decline, now keeps old PBC charts, with limits shown, available for teams to review at any time. This allows the employees in their daily standup meetings to educate and discuss changes and progress made over time. This has become an invaluable tool when problems are discussed since anytime changes are made to a process, standard operating procedure dictates that a note be added to the PBC for **Pieces Produced** and **Late Orders**.

In an interesting twist, a conscious decision was made to shift from talking about **% On Time** to **Late Orders**. Management and employees alike believed that even though their outside mentor's recommendation was to focus on the positive, it was critically important for them to know when they were not meeting customer expectations. Therefore, instead of posting the good side of the equation (**% On-time**), they now post it in a very clear fashion: YOU ARE LATE (**Late Orders**).

The two standard charts used extensively at *Company B* are shown in *Figure 8* and *Figure 9*. The Pieces Produced PBC excludes defects produced and rework performed during the day and the employees understand this. In other words, quality is still being addressed even though it is somewhat more subtle than at *Company A*. Because the work order system at Company B is automated, the relationship in and impact on the process is very apparent. Supervisors see late orders at the top of their work order queues shaded in bright red all day long. At the end of the day, they count up the red orders in their queue and update the PBC so that it is ready for the next morning's standup meeting.

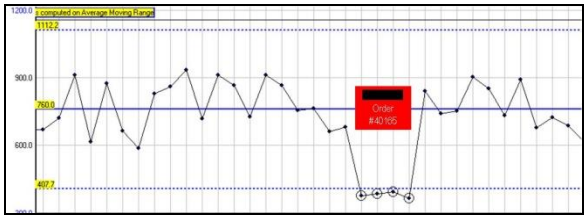

Figure 8 - Pieces Produced Board with Assignable Cause Noted

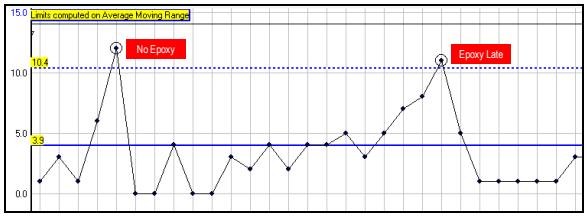

Figure 9 - Late Orders with Assignable Cause Noted

On both of these boards, the supervisor has added notes in red where assignable cause was found. This provides simple explanations that allow the employees to focus on the work at hand, and information available to management to solve problems outside of the line operators' control. An interesting item to note when comparing these two PBCs is the relationship, or lack thereof, when the production went down on the Pieces Produced board due to a highly complex order. An uneducated observer might instinctively want to react when seeing the late orders start to rise because of the apparent lack of production. However, the only signal in this run appears when the epoxy vendor is late with a delivery; totally unrelated to the drop in production.

From the data presented in this section, while just a snapshot of the information broadcast companywide, it is possible to see how quickly employees begin to believe in the PBCs and what they represent. Understanding that on a certain chart, when the numbers are between the limits indicates all is well, is a powerful tool. Also knowing the difference between good and

bad when a signal appears, what is assignable cause and what needs investigation provides a strong basis of ownership for the workforce.

Results

For both companies, the results have been much better than expected. Process changes are being sustained; employee ownership of the processes is apparent with just a casual tour of each company's facilities. Employees are very open in their discussions about the value streams they live in on a daily basis. While there are still a few small pockets of resistance within both companies, for the most part employees will talk about both the good and bad that happen around them.

The buy-in with Lean Manufacturing and excitement about participating in Kaizen Events can be seen and heard daily. Employees want to be selected to be a member of these teams. Both management teams are making deliberate efforts at pushing the cultural change associated with Lean and the new way of measuring success. Areas of resistance are routinely included in the schedules of Kaizen Events, and the human roadblocks found in these areas are included on the teams. When the roadblock is a supervisor or manager, instead of being on the team, they are relegated to a position of observer, are coached by upper level managers, and are instructed to just stand back and observe the results. Many times this has resulted in positive change for a human roadblock. Other times, the human roadblocks have chosen to leave the company. But either way, both the company and the employees ultimately win.

Company A has shown substantial results though this journey. Order Lead Time to the customer has decreased by 38% over the last 24 months. Overall First Pass Yield has improved from 82.3% to 99.1%, a 20.4% increase. The goal in 2016 is for Overall FPY to improve to 99.5%. Employee satisfaction has also improved greatly as demonstrated through the employee turnover rate. For 2013, the turnover rate for manufacturing employees was 27.2%. The 12 month period ending September 2015 showed an annual turnover rate of just 14.6%. While it may be argued that this reduction is due to the current economic conditions, a sampling of employees suggests that it is largely due to a much more enjoyable work environment where they are actively participating in the success of the company. Overall, the Lean Manufacturing effort since late 2012, when this new emphasis began, has produced a one-time savings of just over $200,000 and annual savings of approximately $950,000.

Company B, while more than three times the size of *Company A*, has shown similar results when comparing dollars head to head—one-time savings of more than $350,000 and annual savings of $1.5 million. However, the biggest improvement is shown through an average order lead time reduction of more than four weeks. Cutting Process Lead Time by more than 50% has allowed the company to gain market share through improved responsiveness to customers. The average number of late orders left not completed at the day has decreased from 19.8 orders to 10.8; an improvement of 45%. This metric has become a rallying cry as nearly all cells on the manufacturing floor, including Shipping, have taken it upon themselves to do everything possible to reach the goal of ZERO.

Summary

Lean Manufacturing is an incredibly powerful tool in the continuous improvement journey. However, if metrics that have meaning to both the company ***and*** the employee are not integrated into the process, setbacks and failures in the process, as well as in the overall company goals and objectives, may occur. Changing to another process improvement methodology unfortunately conveys the message of "flavor of the month" and over time, Lean will also become a thing of the past.

To overcome this challenge many companies are beginning to synchronize their Lean efforts with Six Sigma. Taking advantage of a simple and easy to understand Six Sigma tool, Process Behavior Charts (PBCs), and combining it with the metrics development process known as Measurements With Meaning, can create a strong Lean System embraced by both employees and management.

Training and education on PBCs is a requirement. It does not have to be complex or greatly detailed; just providing a working knowledge of the concept is often all that is required. Putting the focus on what the team and the company values allows for the development of metrics that employees can embrace and be proud of. By walking a team through the Value-Measures Life Cycle, and then finding those values and metrics, begins the process of employee ownership.

Tying these three methodologies together has provided a means where employees can, and often do, take the lead role in success. Not just through their actions in producing a part, but also in their desire to become a piece of the investigative team that looks into problems and issues and then finds the solution and helps to take corrective action. When this occurs, employees can do the task they are paid to do and management can do what it is paid to do… think strategically and eliminate the roadblocks that hinder employees' success.

While both companies in this paper have now completed their second full year of this methodology, the management teams' understand that they cannot rest on these accomplishments. Continuous improvement is just that. Both companies recognize the need to continually look at ways to improve these measurements with meaning. And while much of management's efforts will focus on the remaining problems, much more of their time will be deferring to employees to solve these problems while they work on strategic issues and opportunities.

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Combining Six Sigma Tools with Lean Performance Measurement to Sustain Continuous Improvement Activities

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This is a Journey: 2 Companies' Stories

- Lean is a journey, not a program
- 2 ECM companies began this journey when Lean was "the hot continuous improvement" tool.
- This presentation is not about all the Lean tools used to make improvements; it's about how the companies sustained the changes.

Background: Company A

- Contract manufacturer providing various services to electronics industry:
  - prototype development
  - high mix – low volume production
  - SMT and through hole assembly
- Routinely ships between 4,000 and 5,000 units each week
- Approximately 80 employees.
- In business for more than 35 years .

Background: Company B

- Also a contract manufacturer focusing on custom switches and sensors.
- Does some wire harness assembly work for specialized cabling using sensors.
- Ships nearly 100,000 units per week.
- Approximately 260 employees.
- In business for more than 40 years.

Historical Path to Continuous Improvement

- Reactionary.
- Collectively search for solutions to quality and customer satisfaction issues.
- Over more than 20-year timeframe this became the norm.
  - Company A evolved under the leadership of founder.
  - Company B evolved under 2nd generation.
  - For both companies this was “business as usual”.
- Overall, very little process improvement was achieved.

Introduction to Lean Manufacturing

- Company A: 2nd generation assumed control of company leadership.
  - Wanted to stop fighting the same problems.
  - Needed a way to keep good employees.
  - Quality improvement critical to keeping customers.
- Company B: 3rd generation became actively involved in management of company.
  - Focused on growth and increased profits.
  - Recognized “insanity” of the past.

Introduction to Lean Manufacturing

- New leadership at both companies adopted Lean Manufacturing as their continuous improvement methodology.
- Training included introductory Lean class for key employees and engineers.
  - Lean 101
  - Value Stream Mapping
  - 5S
- Kaizen facilitated by outside experts produced exceptional results.

Reverting Back: Trying to Understand

- When Lean improvements began to falter at both companies….
- Surprising discussions searched for answers.
  - Obvious change in thought processes with “new generation” in charge.
  - Obvious blame game existed.
    - Lack of support from Management.
    - Employees not following new SOPs.
    - Supervisors not properly training employees.
- In the end, biggest factors were easily agreed upon.
  - Strong recognition existed that there was no ownership.
  - Lack of correct metrics weakened the overall efforts.

Back on Track: A Collaborative Effort

- Company A
  - Went to the workforce asking for thoughts and opinions.
  - If Lean was not the answer, what is?
  - In the end, the message was clear…. Get back to what was working!
- Company B
  - Asked Lean service provider for advice.
  - After listening to a management meeting discussing the topic and touring facility, the answers were not quite as expected.
  - It’s not Lean, it’s the approach.

Doubling Down on Lean

- Both companies made the decision to restart their Lean efforts addressing both management and employee concerns.
- Three-fold approach improved the chances of long-term success.
  1. Additional Lean training combined with outside mentoring to develop internal experts.
  2. Key employees selected for Six Sigma Green Belt training.
  3. Adoption of Measurements With Meaning to create “the right metrics”.

Company A's Path: Lean Training

- Step 1 – Lean 101 Training.
  a) All members of management attended first.
  b) All full-time employees completed same class.
  c) Each new full-time employee must attend within 90 days of employment.

Lean 101: Introduction to Lean Manufacturing		
• 5S System	• SMED	• Quality at the Source
• Standard Work	• Point Of Use Storage	• Pull Systems
• Teams	• Batch Reduction	• Cellular Flow
• Visual Controls	• Value Stream Mapping	• Total Productive Maintenance
• Layout		

Course Outline for Introduction to Lean Training

Company A's Path: Lean Training

- Step 1 continued.
  - Small group attended additional training.
  - Lean skills workshops
    - 5S System
    - Value Stream Mapping
    - Pull Systems
  - Lean Facilitator class
    - Focused on facilitation skills not specifically Lean tools.
    - Included facilitation of a Kaizen Event.
    - Developed Lean review process for all Kaizen events.

Advanced Training Curriculum	
• Value Stream Mapping Workshop (2-day)	• Pull System Workshop (2-day)
• 5S Workshop (2-day)	• Lean Facilitator Academy (9-day)
• Setup Reduction Workshop (2-day)	

Company A - Advanced Lean Curriculum

Company A's Path: Six Sigma

- Step 2 – Six Sigma Green Belt Training.
  - Two employees selected:
    - One engineer.
    - One quality technician.
  - Class was conducted in 5 two-day modules.
  - The two employees partnered on one project.
  - The project , worked throughout the training process, generated $220,000 in annualized savings.

Company A's Path: Six Sigma

- Step 2 continued.
  - Utilized the local career technology (vocational education) center to find a service provider that would customize and mentor throughout the certification process.
  - Partnered up with other companies and held sessions on-site on a rotating basis.
  - Focused on problem solving, not structure and software.

Five by 2-Day Six Sigma Course Curriculum	
• Project Charters	• Root Cause Analysis
• SIPOC	• Introduction to Design Of Experiments
• Value Stream Mapping	• Simple Experiments
• Collecting & Summarizing Data	• Lean Concepts
• Process Behavior Charts	• FMEA
• Gage R&R	• Control Plans
• Process Capability	• Using Control Charts to Manage Process

Figure 4 - Six Sigma Green Belt Curriculum

Company A's Path: Metrics

- Renewed results from Lean Kaizen and Six Sigma projects brought monetary results and renewed excitement.
- Managers who had once been passive or resistive began to change.
  - These same managers became unexpected champions.
  - Began asking for long-term solutions…. How can it stick?
- When the processes started reverting once more, it was these managers that pushed hard for answers.

Company A's Path: Metrics

- Green belts brought an idea to the table.
- Pulled from control plans of several projects.

  "Employees working in the value stream should be engaged in discussions to fund the right metrics for sustainment."

- The measurement(s) should be able to be displayed on a Process Behavior Chart.
- Management's response was how do we get this right each and every time?

Company A's Path: Metrics

- Adopted the ***Measurements With Meaning*** metrics development system.
- Focused on the values of the company.
- Key Metrics must not only reflect these values, but must also having meaning to each employee.
- Limited in number; do not overwhelm or confuse the workforce.

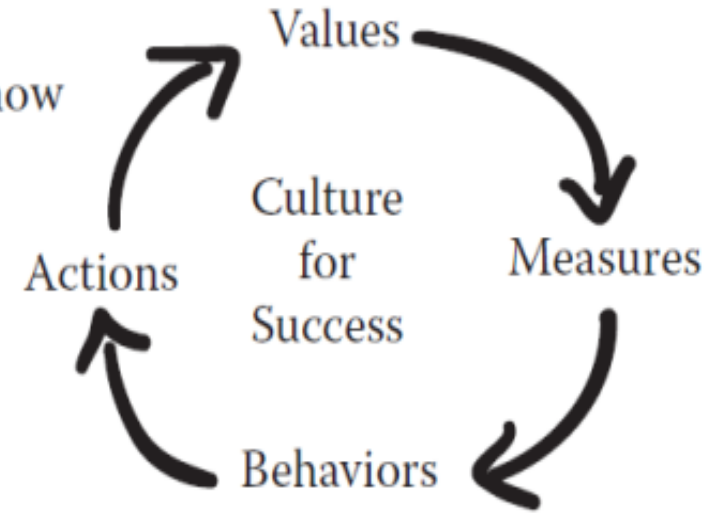
Company A's Path: Metrics

- The visual used by Company A to explain ***Measurements With Meaning***.

Values are the fundamental building blocks of the company..

Values shape VISION and ACTION.

- You measure what you value
- Measures directly influence how people work
- How people work affects organizational results

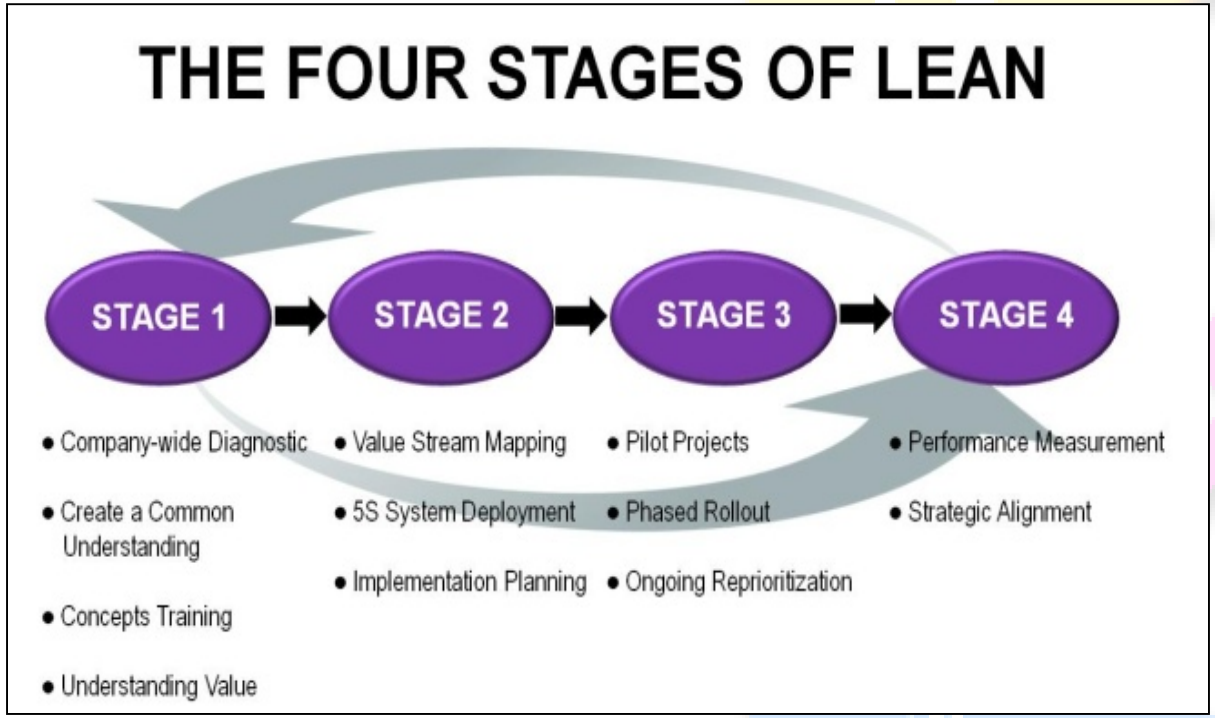


SOURCE: Mark A. Nash and Sheila R. Poling, The Right Measures (Boca Raton, FL: CRC Press, 2012) 154

Company B: Similar Yet Different Path

- Top Level managers attended Lean 101; followed by a group of mid-level managers and supervisors from the manufacturing floor.
- These attendees met to discuss earlier successes and failures.
- Crafted a story to explain to all employees what worked and what didn't.
- Developed a game plan to follow for the renewed Lean effort.

Company B: Similar Yet Different Path



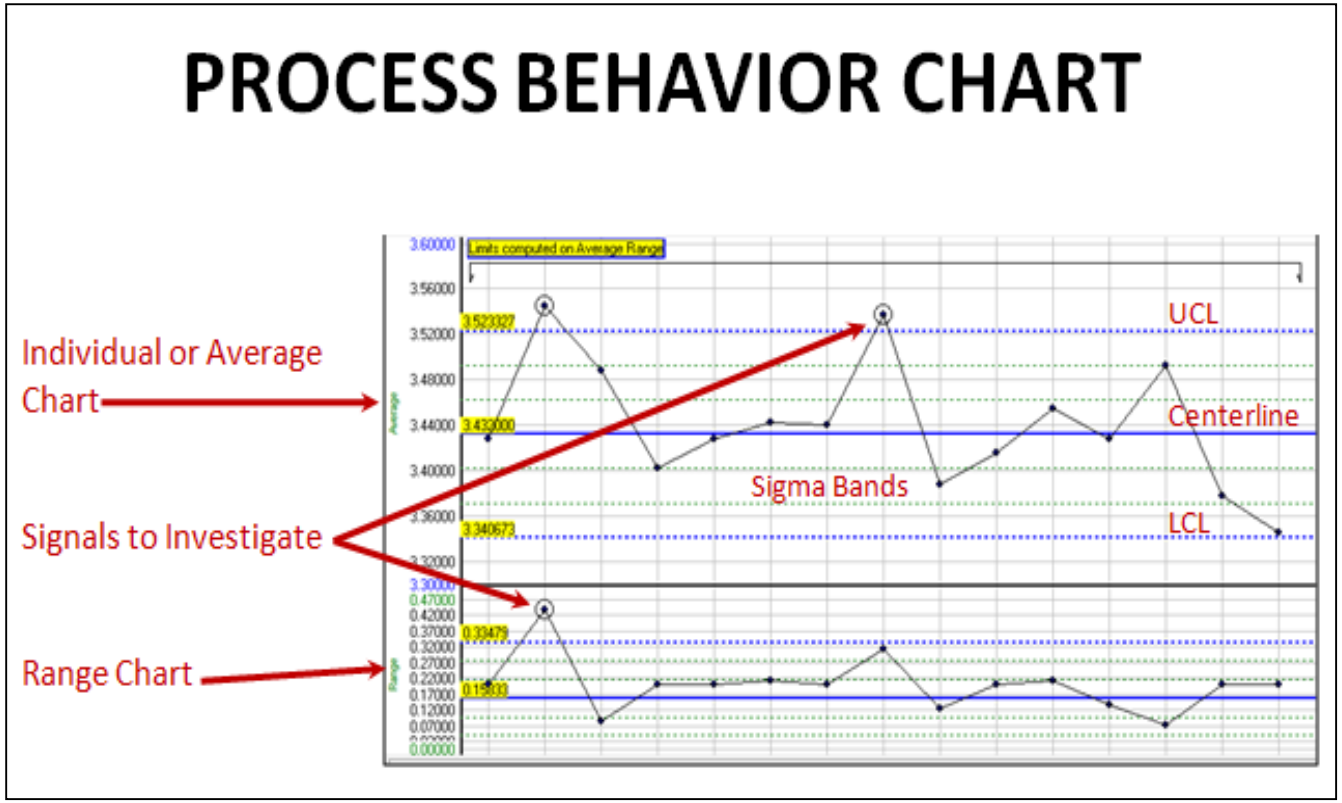
- Held town hall meetings and presented the story with a chart used in the first attempt.
- Explained where management had failed to do their part, and what must be done to succeed at the next level.
- Developed a plan to review Lean with each Kaizen event.

Company B: Similar Yet Different Path

- Sent six employees to green belt training.
  - Same curriculum as Company A.
  - Worked on four projects.
- Took Lean mentor's advice about ***Measurements With Meaning*** when similar concerns and discussions started as results began to slip some.

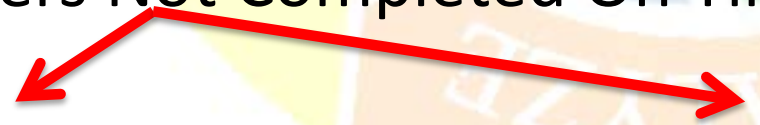
Company B: Similar Yet Different Path

- Company B used a simple explanation of Process Behavior Charts to ensure that employees understood what the metrics meant.



Managing the Change

- Both companies found simple metrics that had great meaning to employees and showed if the company was successful.
  - These Key Metrics supported the values of the company.
  - The Key Metrics were easily understood by all.
  - Every single Key Metric was placed on a Process Behavior Chart (PBC).
- Both standardized to a few similar metrics.
  - Number of Pieces Produced.
  - Work Orders Not Completed On Time.



Co. A = Orders Left on Deck **Co. B = Late Orders**

Managing the Change

- Examples of previous metrics and their Lean metrics boards.

Production	
Month	February
Goal	12,000
Last Week	**Month**
2,622	11,788

Defects	
Month	February
Goal	< 3.0%
# of Defects	**% Defective**
613	5.20%

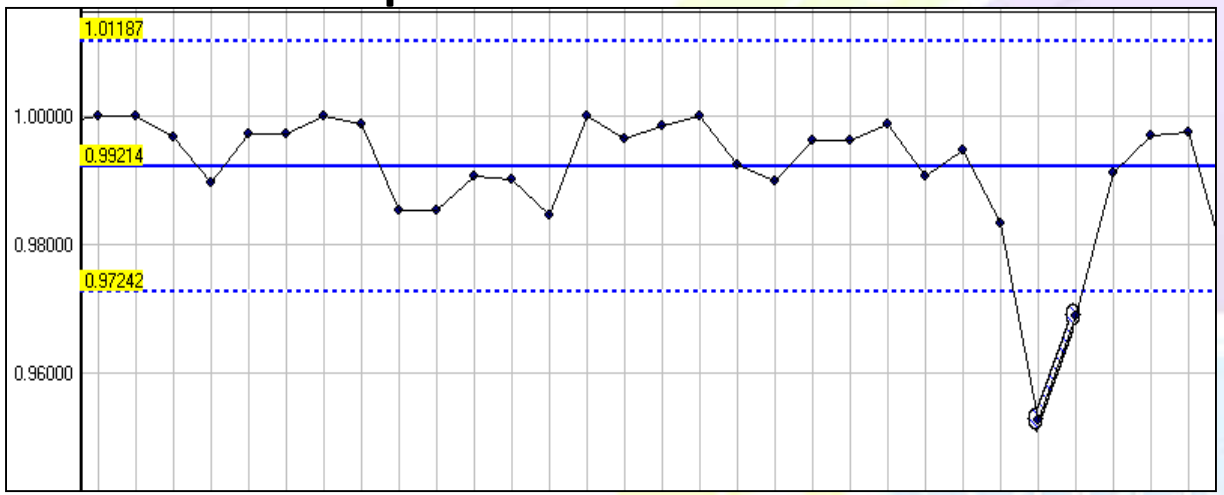
Week	27
Production	1510
Scrap in Cell	185
Scrap at Inspect	231
Scrap at Packaging	12
FPY	72%
% ON TIME	63%

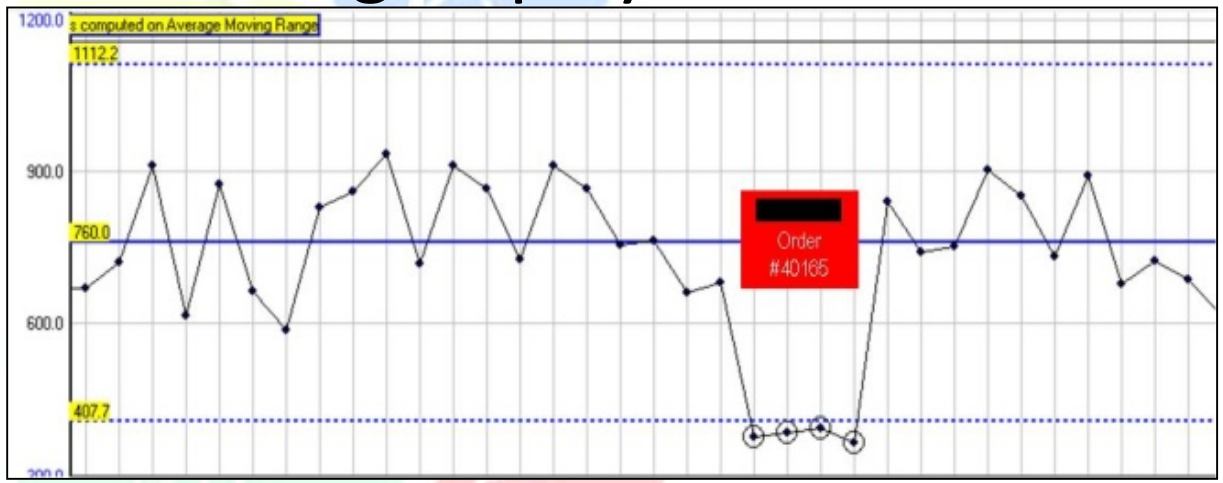
Late Shipments	
Month	February
Goal	0
Last Week	**Month**
21	115

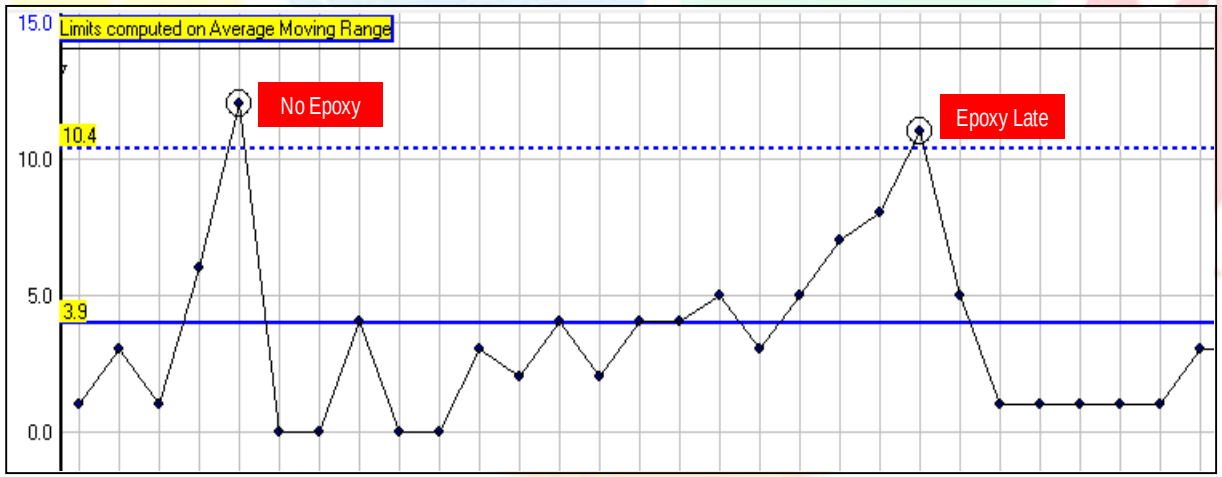
Shipping Errors	
Month	February
Goal	0
Last Week	**Month**
4	31

Managing the Change

- Examples of Measurements With Meaning displayed on PBCs.







The Results

- **Company A**
  - Order Lead Time to customer has decreased by 38% over the past 24 months.
  - First Pass Yield has improved from 82.3% to 99.1% (20.4% improvement).
  - The FPY goal for 2016 is 99.5%.
  - Employee Turnover Rate for 2013 was 27.2%; down to 14.6% as of September 2015.
  - Since 2012, annualized savings is $950,000 plus one-time savings of $200,000.

The Results

- **Company B**
  - Order Lead Time to customer has decreased by four weeks since January 2012 (50% improvement).
  - Late Orders not completed at day's end (in Shipping) has decreased from average of 19.8 per day to 10.8 (45% improvement).
  - The Late Order goal (and rallying cry for the production team) is ***ZERO!***
  - Since 2012, annualized savings is $1,500,000 plus one-time savings of $350,000.

Questions & Closing Comments

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