Introduction

In prior Special Publications, the topic of Statistical Thinking has been created in alignment with the goals of the ASQ Statistics Division. Discussions of statistical thinking regarding “data sanity”, its power, and regarding measurement systems have been explored. In this Spring 2004 edition, the world of Six Sigma and Lean Manufacturing will be explored. We are all familiar with the lineage of Six Sigma from its Motorola, AlliedSignal, and General Electric roots, to name a few. We are also familiar with Lean Manufacturing’s birthplace at Toyota. As more statistical professionals become users of the Six Sigma and Lean concepts, we see a maturity of toolsets and another generation of applications.

Many companies now appreciate that Six Sigma and Lean concepts need to be run together to optimize each toolset’s unique values. In Combining Lean and Six Sigma Methodologies, Joe Ficalora, Joe Costello, and Julien Renaud, give insight into tool usage, case studies and program organization. In Beyond Six Sigma/Lean: Methods to Ensure your Organization’s Health, Forrest Breyfogle III offers a methodology that aligns corporate goals with improvement projects using statistical measurement and the Lean “pull” concept. Mark Spearman and Edward Pound in Productivity, Quality and Measures: Using Factory Physics® Principle to Resolve Conflict and Improve Profitability, discuss how to manage solutions around competing corporate objectives using fundamentals of operations based upon a Six Sigma/Lean framework.

Each of these articles has a common thread of understanding process variation and understanding the customer’s voice. Whether it is the variation of a measurement system or process cycle time, the amount of variation is critical in establishing the look of our future processes. Six Sigma and Lean practitioners need to continuously apply Statistical Thinking to improve their processes and use these next generation and mature toolsets synergistically.
COMBINING LEAN AND SIX SIGMA METHODOLOGIES

JOE FICALORA
JOE COSTELLO
JULIEN RENAUD

Abstract
This paper will discuss the synergies between Lean methods and Six Sigma techniques. Specifically, the use of a combined roadmap will be used to illustrate in two examples how adding either one to the other can accelerate or amplify the results achieved. Lean manufacturing techniques generally aim to identify and eliminate waste in the production or service delivery system, while Six Sigma techniques were built around identifying and eliminating process variation and defects in delivered products or services. Both approaches have been independently and jointly elevated to full enterprise wide deployments with pre-defined roles and responsibilities organization wide. Those aspects have been documented elsewhere and are outside the scope of this paper.

Lean or Six Sigma?
Many people have contended that one of these methodologies should be deployed prior to the counterpart. In our experiences, either may be deployed first, depending upon business needs and circumstances. In the Art of War, Tzu (513 B.C.) counsels us on the need for Strategic Adaptation. In many ways charging forward with a change effort can be thought of as a war, with complacency and poorly executed change efforts viewed as the enemy. Hopefully, our change efforts are accomplished with passion but without any violence! The areas of understanding advantages and disadvantages for adaptation were especially emphasized in this early reference on strategy.

So it is with Lean and Six Sigma, as each can benefit from the other if you understand the objectives, benefits, and limitations of these two approaches. Dr. Steve Zinkgraf has recently spoken about this topic in his paper on Matching Methodologies, albeit from a design perspective. Each may be deployed separately for certain organizational needs and goals, again depending upon the environment. If deployed separately, they should not be set up as competitors: rather, they should be introduced as having clear and complimentary goals. In the race for doing more with less, combining these two may be a good solution for your organization.

Most readers already know that the objectives of Lean methods are primarily to drive out waste and increase efficiency. There are many variants of implementing the tools and techniques of Lean. Many readers are also familiar with different variants of Six Sigma, though most process implementations follow five defined phases, usually along the DMAIC roadmap popularized at companies such as Honeywell and General Electric.

Many Lean implementations initially focus on rapid results and fast turn around, usually through a series of Kaizen events. These are very useful when efficiency needs improvement and when roadblocks exist that prevent delivering value smoothly to customers. The variability in flow of product, service and information
may be rapidly improved. These events rely upon involving the right people, with the right knowledge of the processes to make these rapid changes. However, for low-yield processes one should note that the right level of process knowledge may not exist, thus the need for Six Sigma projects to more fully develop $Y=f(x)$ type knowledge. Kaizen practitioners should have as a goal, the identification of low-yield processes and technical barriers that create pull for Six Sigma projects and practitioners. Potential opportunities for process clean up include: processes with non-effective measurement systems, processes surrounding information flow and product and service, and initial Black Belt training class projects.

**Benefits and Limitations**

Many valuable and rapid improvements can occur quickly by implementing Lean methods. Most associates in value delivery chains can learn to use these techniques and then replicate the approach in follow-up events without a lot of support and mentoring. However, complex problems that have persisted for a long time with unknown causes will usually require more detailed roadmaps, process-focused tools, and a numerical problem-solving methodology. Leadership is still required to demonstrate knowledge, passion and proficiency to sustain Lean implementations.

Large projects associated with complex problems will typically achieve significant breakthrough results when implementing Six Sigma methods alone, albeit over a longer time period than a series of Kaizen events would take to complete. However, the statistical methods involved and the sophistication of the tools and techniques used, require an intermediate level knowledge of mathematics, process literacy, some computer proficiency and the ability to internalize these advanced methods quickly. Not all associates have these capabilities; some selection and screening is necessary from a personnel perspective.

Many organizations do not have appropriate technical and managerial mentors in place at the start of Six Sigma. Training of some key individuals as Master Black Belts and Champions is usually required to implement Six Sigma. Again, leadership is still required to demonstrate knowledge, passion and proficiency to sustain the gains of Six Sigma.

When Six Sigma projects uncover processes that are neither stable nor ready for improvement, some initial efforts to remove waste and non-value added activity offer leveraged opportunities for the project. Implementing a short, 2-day Kaizen event can often pull together a team and quickly eliminate obvious non-value-added activities, resources and space. This will only serve to accelerate the Six Sigma projects that employ such efforts.

Many Six Sigma projects identify and correct “low-hanging fruit” or items that are easily fixed along the way. If left to the practitioner, their knowledge of Lean methods may strongly influence how these are corrected, and how long these changes may last. Specifically, the understanding of bottlenecks and buffers for specific variability issues is crucial towards achievement of long-term success. Under-educated practitioners in these areas may attempt to reduce buffer sizes without removal of the underlying variability that drives them. If you are not managing your bottleneck, then it is most likely managing you! Knowledge of lean tools and methods can bring tremendous leverage to Six Sigma project work.

When working in the Improvement Phase, there are times when the flow of product, service, and/or information is identified as a root or contributing cause to the variability experienced at the end of the
targeted process. At this point, Kaizen events may be utilized to make the necessary improvements to correct these flow issues.

Two primary advantages of combining the tools of Lean and Six Sigma include faster Six Sigma project completion and improved process efficiencies in those projects. Using a Kaizen up front and a full Kaizen during the improvement phase will achieve these results. Shortening the overall cycle time to 13 weeks requires full time Black Belts, but yields large, fast results.

The use of Special-K™ upfront and Full Kaizen in combining Lean and Six Sigma have recently been implemented by SBTI in their K-Sigma™ program and discussed by Ficalora., see China BB Program.

Combining the tools of Lean and Six Sigma

These tools may be organized along the traditional DMAIC roadmap, and taught together along the same lines to simultaneous Lean and Six Sigma practitioners. The summation goals for tool usage would be as follows:

Sources of Variation and Waste can be:
- Identified
- Quantified & Prioritized
- Eliminated or Greatly Reduced.

Along with these goals for tool usage is the fact that all variation will be buffered or passed on to the next part of the value chain. The major buffers are inventory, time, and resources or capacity. A fast look at the three major components of inventory reveals some variation contributors:

<table>
<thead>
<tr>
<th>Inventory Type</th>
<th>Variation Contributor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Materials</td>
<td>Additional needed to cover process yields, unexpected orders, schedule variance</td>
</tr>
<tr>
<td>Work-In Process</td>
<td>Process variance, cycle times</td>
</tr>
<tr>
<td>Finished Goods</td>
<td>Demand Variance, Forecast Error, Cycle times, Process Yields</td>
</tr>
</tbody>
</table>

Many Lean and Six Sigma tools can be used throughout the five DMAIC phases. However, it is the introduction of the tool to new practitioners in the right phase when needed that is of particular importance. Specific links between the tools are outside the scope of this paper. However, these links are of critical importance and should not be overlooked. Practitioners experienced in the deployment of both methodologies are required to transfer their knowledge to new practitioners and coach them through first, and sometimes second, projects.

Accordingly the tools align as follows in the five operational DMAIC phases. Not all tools may be listed for both methodologies, but the following is a sampling of the major tools. See table 1.
<table>
<thead>
<tr>
<th>Define Phase Tools</th>
<th>Define Phase Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Charter</td>
<td>Set project objectives, team members, scope</td>
</tr>
<tr>
<td>SIPOC Map</td>
<td>Identify Customers, Suppliers, and Top Inputs and Outputs</td>
</tr>
<tr>
<td>Process Map</td>
<td>Identify and classify independent and dependent variables</td>
</tr>
<tr>
<td>Value Stream Map</td>
<td>Understand value flow through the process</td>
</tr>
<tr>
<td>Spaghetti Map</td>
<td>Trace product, service, and information throughout the business</td>
</tr>
<tr>
<td>Process Step Filter</td>
<td>Prioritize process steps for focused activities</td>
</tr>
<tr>
<td>Performance Assessment</td>
<td>Identify value and non-value added work</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Measure Phase Tools</th>
<th>Measure Phase Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process Variable Filter</td>
<td>Prioritize variable for further activity</td>
</tr>
<tr>
<td>Statistical Process Control</td>
<td>Baseline variation and stability on key variables</td>
</tr>
<tr>
<td>Capability</td>
<td>Compare customer and process voices</td>
</tr>
<tr>
<td>Measurement Systems Analysis</td>
<td>Evaluate measurement systems</td>
</tr>
<tr>
<td>Overall Equipment Effectiveness</td>
<td>Evaluate critical equipment</td>
</tr>
<tr>
<td>Takt Assessment</td>
<td>Evaluate product velocity versus customer needs</td>
</tr>
<tr>
<td>Kaizen</td>
<td>Removal of obvious non-value added items</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Analyze Phase Tools</th>
<th>Analyze Phase Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voice of Customer</td>
<td>Obtain and analyze customer needs</td>
</tr>
<tr>
<td>Multi-vari studies</td>
<td>Passive data collection and evaluation</td>
</tr>
<tr>
<td>Hypothesis testing</td>
<td>Statistical evaluation of key inputs and outputs</td>
</tr>
<tr>
<td>Process Flow Analysis</td>
<td>Identification of bottlenecks, buffers, and the use of Little’s Law</td>
</tr>
<tr>
<td>Failure Mode and Effect Analysis</td>
<td>Analysis and correction of high risk items</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Improve Phase Tools</th>
<th>Improve Phase Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production Simulation</td>
<td>Simulate and analyze product flow options</td>
</tr>
<tr>
<td>Design of Experiments</td>
<td>Experimentation to determine Y=f(x)</td>
</tr>
<tr>
<td>Kanban</td>
<td>Replenishment analysis</td>
</tr>
<tr>
<td>Pull Systems</td>
<td>Reduced batch sizes, and increased flexibility</td>
</tr>
<tr>
<td>Cell design</td>
<td>Improved flow and higher efficiency</td>
</tr>
<tr>
<td>SMED</td>
<td>Reduced set-up time</td>
</tr>
<tr>
<td>Monument Management</td>
<td>Use of large capital investments</td>
</tr>
<tr>
<td>Total Preventive Maintenance</td>
<td>Optimizing uptime while minimizing downtime</td>
</tr>
<tr>
<td>5S</td>
<td>Efficiency in work area functions</td>
</tr>
<tr>
<td>Kaizen and Kaizen planning</td>
<td>Removal of non-value-added items</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Control Phase Tools</th>
<th>Control Phase Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Plan</td>
<td>Implement changes in sustainable ways</td>
</tr>
<tr>
<td>Statistical Process Control</td>
<td>Control key independent variables</td>
</tr>
<tr>
<td>Visual Management</td>
<td>Identification and correction of problems as they arrive</td>
</tr>
<tr>
<td>Audit Planning</td>
<td>Verification of new processes and procedures</td>
</tr>
</tbody>
</table>

Table 1: Tools Overview
**Case Studies:**
The first case study is about work that was conducted by Mr. Todd Smith of Sylvania, who is credited for his hard work and contributions at integrating Lean and Six Sigma. The forecast for a potential increased demand is one business consideration, while lower-cost foreign competition is another consideration that may impact the first.

This example involves a 3-step chemical manufacturing process as depicted in diagram 1. By evaluating the quantity produced and the cycle times, it became clear that step 2 is the bottleneck of the process (“constraint”). This was one initial focus as it is the pacing item in flow of the entire process.

Focusing on the bottleneck revealed some additional aspects of this step in the process. There were 3 furnaces, with a theoretical capacity of 7000 kg per day of materials processing. However, the uptime for this step was 71%. The scrap rate was 9.2%, but rework of out-of-spec batches is possible.

Since this is a bottleneck, increasing the uptime would be beneficial to the entire process. Utilizing the toolset of Total Predictive Maintenance (TPM) and some Six Sigma tools reduced the guesswork at maintenance schedules and improved the predictability of uptime.

Key items that were discovered to have synergy between Six Sigma tools and TPM can be seen in Table 2.
COMBINING LEAN AND SIX SIGMA METHODOLOGIES

<table>
<thead>
<tr>
<th>TPM item</th>
<th>Six Sigma Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiate Downtime tracking</td>
<td>Failure Mode Pareto, Time Series analysis</td>
</tr>
<tr>
<td>Operator Based Maintenance</td>
<td>Process FMEA</td>
</tr>
<tr>
<td>Preventative Maintenance Plan</td>
<td>Process FMEA</td>
</tr>
<tr>
<td>Cleaning and Inspection</td>
<td>Process FMEA</td>
</tr>
<tr>
<td>Wear Part replacement frequencies</td>
<td>CpK &gt; 1.5</td>
</tr>
<tr>
<td>SPC on key parameters</td>
<td>Variable Priority Filter, Multi-vari Analysis</td>
</tr>
<tr>
<td>Process Control Plan</td>
<td>Process FMEA</td>
</tr>
</tbody>
</table>

Table 2. Six Sigma and TPM

After applying these tools together, the uptime increased to 91%, with a 6300 kg/day average output. Time series analysis revealed that start up and shut down were major sources of inefficiency, so a 7 day schedule was implemented. Maintenance costs were reduced by over $10k per month. Additionally, the scrap rate was reduced to 5.1%, and breakage of a key handling item was reduced by 66%, for a net annualized savings in this step over $250k.

Returning to Step 1, it was discovered that while rework is possible, it takes 4 days to rework a faulty batch. The first pass yield in this step was 92%, with corresponding subjective criteria for the rework decision. A measurement systems analysis (MSA) revealed that the measurement system contribution was 56% of total variation in the data. Correction of measurement system deficiencies resulted in a first pass yield of over 99%. Additionally, a second shift employee was able to run another process due to the lack of rework. The net annualized savings at this step was over $150K.

The final effort was to look at Step 3, which had been ignored previously because it followed the bottleneck. The total output initially was only 5100kg/day. This step had a utilization of 41%, meaning that one shift too many existed. This buffer was unnecessary and was costing money. The third shift was then staffed with only 1 operator to build ahead for shifts 2 and 3. The second issue in Step 3 was an unknown scrap cause. This work followed the traditional Six Sigma roadmap. Work on a faulty measurement system followed by a multi-vari study of key factors resulted in over $500K of additional savings.

Case Summary
3 additional projects generated from measurement phase of this project, which eventually netted $600K annually. None of the savings in this project required moving past the analyze phase of the MAIC roadmap. Over 50% of the savings in this project were realized just by correcting poor measurement systems. The total project time was 4 months. This is just one portion of the Lean & Six-Sigma effort in this area. The total analysis resulted in a 26% reduction in labor cost with no loss of production capacity and much greater flexibility with which to serve the customer. The total savings annualized were projected at $2900K.
Case Study 2:
The second case study is about shop floor deployment and comes from Julien Renaud and Joe Costello.

Shop Floor Deployment Roadmap, the Operational Assessment

The business assessment process set the direction for operation improvement. One of the key elements of the assessment is to dissect the plant into value propositions, basically determining the key processes in the operations that can be the focal points of operational improvement. The assessment was designed to determine the level of activities in each of these focus areas, the target level of improvement that could be expected and an estimate of the timeline for improving the business area.

The elements of the assessment included focused interviews. The objective of these interviews is to get an idea of the different number of tasks that were completed during a typical day. The tasks are then categorized into several groupings such as administrative, scheduling, traveling, meetings, expediting and other. The amount of time spent on each of the categories of activities was then compared to what his or her supervisor believed to be the case and then finally these times were compared to what the whole group believed was the ideal case. The differences in the time spent between observed time and ideal time was then evaluated for improvement options. This was the beginning of the project selection process. An example of what we found can be seen in the following graphs:

Figure 2. Production Scheduler’s Time
Reactive management vs. proactive management is the key finding in this area. Obviously there are a lot of possible reasons for the high level of reactive management, include possible instability in the process capability, suspect raw materials quality that may be causing inconsistent available goods for shipping, disconnects between the forecast and actual demand for the finished goods. All of these potential root cause reasons would need further investigation before an actual project could (or should) be launched but the assessment allows us to look in the right direction.

Other observations during the assessment process included: Shift startup processes. How well were the shifts prepared to make the first few minutes of each shift as effective as possible? Did the operators have to go and look for production plans? Look for materials? Look for tools? Did they know if the previous shift hit their daily targets? Were there daily targets to know about?

We also assess the inventory management system with critical questions such as; what is the purpose for the inventory on hand? Is the current inventory level driven by a demand analysis? Is the inventory segregated by demand behavior of the products? Does a majority of work-in-process inventory sit at the least mature level possibly? Is there an inventory improvement objective in place?

Most of these questions are typically very hard to answer in the average production operation of today. In a World-Class operation there is an ongoing inventory reduction program in place. In some of the most sophisticated operations we see inventories that are shared by multiple customers. For example, in one company that provides large horsepower electric motors to industry we have installed the shared inventory concept. This is where more than one customer actually owns the same motor sitting in finished goods. These motors are inventoried for the specific purpose of emergency breakdowns. These three or four customers would need this motor sent with as little as one hour notice in order to keep critical processes running.

The motor company could never have stocked these motors just-in-case there was a breakdown; the holding costs would have been too high since the needed emergency replacement occurred as rarely as once a year or less. But if 3 or 4 customers all agreed to share the same motor, when one of them needed it there would be a replacement built and stocked in as little as one week. The probability of multiple emergencies within the same week was so low that the risk was deemed worthy. Each customer paid upfront of one-third or one-quarter of the value of the motor each to have the motor build. This allowed the motor company to have zero cash outlay (inventory that was already paid for) and each customer would be out only a fraction of the motor cost with a frozen price guarantee! The agreement was when one of these motors left the shelf all of the potential customers of this motor would be informed of the limited exposure for the following week.

Creative inventory management systems like this motor company’s can be used in various industries including: textiles, chemicals, mining equipment even after-market car parts.
The Organizational Structure
The organizational structure is, without a doubt, the most important consideration to any successful operational improvement initiative!
Who will be accountable for the project selection?
Who will be accountable for the project tracking?
Who will be accountable for the Black Belt selection?
Who will be accountable for the curriculum selection and training provider?

A proper organizational structure addresses all these questions and more. The organizational structure is typically made up of 4 levels:

The Executive Steering Committee,
In the case of multi-plant operations, this committee is made up of divisional representations in Operations, Finance, Human Resources and Distribution. Often the plant managers are members of this executive team and represent the operational leg of this committee. The purpose of this ESC team is very different than a divisional staff meeting and needs to have a specific and detailed agenda focused on the operation’s Lean Sigma deployment. The agenda for this steering team is to report on the progress of each plant’s Lean Sigma program, to share best practices and to get a roll-up of the improvement targets, planned vs. actual.

The executive team may sponsor (Champion) many of the Lean Leaders at the plant level. By having a direct link to the Executive Steering Team the Lean Leaders understand that their projects and they themselves have a very high profile in the organizational direction.

The Plant Steering Team,
Similar to the Executive team, the Plant Steering Team (PST) has the responsibility of setting the direction of each of the Project Teams, selection of the Lean Leaders and tracking the improvements, planned vs. actual, for each of the Kaizen events, Lean implementation plans and project teams. The most effective PST meetings occur weekly and last only about 45 minutes, focused on what was accomplished last week by the operations teams, kaizen events and other improvement initiatives and what is targeted to be completed this week to support the operational goals.

One of the key agenda items in every PST meeting is the report of Kaizen event status. Each kaizen event will have a report to the PST approximately 10 days after the event itself has been completed. By setting the expectations that the Kaizen facilitators are accountable to the PST will drive completion and implementation of the Kaizen action items.

Another PST requirement is implementation benefits tracking. Best practice benefits tracking will have 3 levels of implementation being monitored. Level #1 is “Benefits Identified”; this is the amount of savings that will occur when all the action items from previous kaizen events are closed. Level #2 of benefits tracking is the “Benefits Implemented” by tracking the implemented actions we can start to identify risks of identifying more than we are following up with. As strange as it may seem, often times we see that we are doing Kaizen events simply because they tend to generate so much excitement in the target areas and we don’t want to loose momentum. As was said by a deployment expert

COMBINING LEAN AND SIX SIGMA METHODOLOGIES
COMBINING LEAN AND SIX SIGMA METHODOLOGIES

“It’s like we have only one tool, a hammer we call Kaizen and now everything is beginning to look like a nail”. Level #3 is “Benefits Realized”. These are the actual benefits that have hit the bottom line (the ones that pay the bills), validated by the plant controller.

If there is too much of a gap between any of these levels we can take a better look at what is really happening. Are we identifying a lot of savings but not pulling the trigger? Have we overstated the benefits during in the improvement stages? Are we not identifying an accountable person to “own” the implementation? Are we giving full credit to the savings?

**The Deployment Teams**

Work Stream Teams (WST) – Several teams per operations usually divided by specific targeted areas for improvement i.e.: Stamping, Molding, Assembly, Sub-assembly, Finishing, Administrative, Supply chain, Warehouse, Distribution, etc.

- Each team has a dedicated team leader. This person is trained and coached by a Lean consultant. The team leader is dedicated for the length of the project implementation phase as a minimum. The team leader is responsible for the development of a team charter, identifying improvement opportunities, identifying methodologies to implement improvement ideas (Blitzes, Mini projects, etc.), ensure that the team members meet the team objectives and report weekly to the PST on his teams progress to plan.
- Team members (no more than 7) are partially dedicated to the project (usually 20 – 25 % of their time) during the implementation phase of a project. They have the responsibility of making the physical improvement changes in the affected processes.
- The team has the responsibility to ensure the charter addresses the team’s goals and objectives. They also work together to ensure the opportunities are identified and priorities to maximize results and minimize resources to achieve those results. The team must also work together to raise issues that prevent them from achieving their goals and objectives as soon as possible in order to get help in removing roadblocks that may come up.
- The team must meet at least once a week to discuss strategy, update the overall status of specific team tasks and re-direct as required.
- Maintain an open action list to ensure that new issues are captured and followed up (what, who and when).

**The Lean Leaders**

One of the first activities was to develop the internal Lean skills of the client. This was conducted via Lean Leader™ training. A Lean Leader™ is a core, full time, improvement leader. Focused at driving the Lean philosophy into the fabric of the company the Lean Leaders are process improvement zealots that, once trained, will be the support system for the deployment team’s implementation plans, conductors of Kaizen events and Lean awareness trainers.

Lean Leader™ is a multi-week training course that includes at least 2 waves of Kaizen events. Lean Leaders will bring the lean tools to life in internal real-world applications. From multiple forms of detail process mapping, 5S, SMED, Visual Factory concepts, flow, project management and Lean management tools these
COMBINING LEAN AND SIX SIGMA METHODOLOGIES

Lean Leaders will be able to carry the ball forward thus reducing the dependency on external experts. Typical Lean Leader training is 6 weeks in duration including 2 kaizen weeks.

Traditionally there will be 3 waves of Lean Leader™ training before a client will be self-sustaining in Lean Leader™ deployment. During the 1st wave the Lean Leaders will trained in Lean tools, implementations techniques and Lean management concepts. This training will be totally facilitated by outside experts in Lean deployment. By the end of the Lean Leader™ training these Lean Leaders will also have identified their own Lean implementation project plans for their area if influence within the operations.

During the 2nd wave of Lean Leader training some of the previous Lean Leaders will be asked to support wave #2 rollout. Some of the training modules during this 2nd wave will be presented by wave #1 Lean Leaders. By conducting training elements the Lean Leaders will be able to drive home the concepts and give credibility to the tools as they have been deployed in the business.

Wave #3 Lean Leader training will be equally facilitated by previous Lean Leaders who have been successful in deployment practices and by the outside Lean experts. During this training cycle the internal facilitators will be coached on key concepts that must be driven to ensure successful Lean Leaders. By having the previous Lean Leaders facilitating the Lean training this will give visible career path examples of what opportunities may be in store for each new wave of Lean Leaders.

The Kaizen Events
Kaizen events are the most powerful and exciting of all the Lean tools! The origin of the word “Kaizen” actually comes from the Chinese. The concept of change or “kai” is combined with good or “zen” creating Kaizen, or “good-change”

Kaizen events are 4 or 5 days of precisely targeted improvements to an operational area. With half of the first day dedicated to Kaizen tool training, by the end of the first day the team will have mapped the current process and started to separate what is value added vs. non-value added steps in the process.

By the end of day 2 the team will have gone from concept design, through detailed design and defined the implementation plan for the desired process state.

Day 3 takes the plans to the process, implementation day for the Kaizen team means that the design steps have been validated and approved by the process owner. Any articles that may have been in the way of the team’s design should have been moved by maintenance the previous night and the new process is taking place today.

Day 4 stabilizes the improved state and full support from the Kaizen team is in place to help any of the operators with the transition into the new process. Today the control tools are put in place and all operational questions are fully supported by the kaizen team and the process owner. The team drafts their report to the executives and validates savings with the Controller.

Day 5 is simply the Kaizen report-out. A low tech report showing the improvements that the Kaizen team has put in place and any follow-up action items that will be reported to the PST in about 10 days time.
Combining these two methodologies can enhance many of the benefits of both Lean and Six Sigma efforts. With that combination comes the challenge of identifying personnel appropriate for the rigors or numerical analysis and rapid internalization of many process tools and techniques. In the efforts to integrate, one should not overlook the fact that many associates not suited for this can become Lean-Leaders™, with all the benefits of the Lean and Kaizen methodology change efforts. Keeping them separate can create confusion and strife unless there is clear explanation in both camps of the objectives, benefits and limitations of both methods.

Integrating them together makes great sense. However the integration requires great commitment to set-up the projects, implement the full-time personnel planning, and setting the expectations for breakthroughs and follow-up support resources. In addition it requires an integrated roadmap and tool linkages that must be
COMBINING LEAN AND SIX SIGMA METHODOLOGIES

clearly explained by experienced practitioners of both methods. Finally, like any successful change effort, Lean and Six Sigma integration requires leaders that are knowledgeable, passionate and proficient in the methodology. They do not need to be experts, but they must be able to speak about why, and how these methods are being deployed.

“The significant problems we face cannot be solved at the same level of thinking we were at when we created them.”

-Albert Einstein

Trademarks:
Six Sigma™ is a registered trademark of Motorola Corporation
Special-K™ is a trademark of SBTI
K-Sigma™ is a trademark of SBTI
Lean Leader™ is a trademark of SBTI
Lean-Design™ is a trademark of SBTI

References:
1. Leading Six Sigma – Snee and Hoerl, pp 182-185
3. The Art of War - Sun Tzu, Research and Reinterpretation by J.H. Huang
4. MBB Project - Todd Smith
6. Factory Physics – Hopp & Spearman
7. Lean Thinking – Womack and Jones

About the Authors
Joe Ficalora’s Industrial Experience comprises over twenty years of managerial, technical and Six-Sigma responsibilities. He holds a MS in Electrical Engineering, BS in Physics, is the author of several patents and is a certified BB and MBB. He is currently the SBTI Vice President of Technology, and has oversight of new methodology, services and tool integration for all of SBTI’s Six Sigma, Lean Sigma and Lean offerings. He may be reached at JFicalora@sbtimail.com.

Joe Costello is an Executive Director for Sigma Breakthrough Technologies, Inc. responsible for Lean and Lean Sigma deployments for SBTI. While with SBTI he has successfully developed and deployed SBTI’s Lean Leader™ curriculum and methodologies into some of SBTI’s largest clients yielding rapid, high impact savings. Previous to consulting Joe held the position of Engineering Manager at Kelsey Hayes’ automotive brake systems in Jackson, MI, leading the efforts of the prototype brake design operations for such automotive product launches as Chrysler’s Prowler and Viper platforms. Joe has been published in technology journals and a recently released Lean Manufacturing text. Joe can be reached at jcostello@sbtimail.com. He holds a B.S. in Mfg. Engineering and is a Certified Mfg. Engineer.

Julien Renaud is a Lean Specialist with SBTI and has successfully deployed Lean for several clients worldwide in the areas of manufacturing, business process improvement and change management. Prior to consulting, Mr. Renaud held various positions including Plant management and Industrial Engineering Director with a major tier 2 Automotive supplier leading all continuous improvement activities for their North American Electronics division. Julien’s experience includes more than 25 years in manufacturing and management. He holds a BS in Electronics Engineering. He may be reached at irenaud@sbtimail.com.
**BEYOND SIX SIGMA/LEAN: METHODS TO ENSURE YOUR ORGANIZATION’S HEALTH**

Forrest W. Breyfogle III  
CEO, President and Founder, Smarter Solutions, Inc.

**Abstract**

Which companies will be around in ten years? The certainty of any response to this question has probably changed over the last year. Will your company face problems similar to problems faced by Enron or K-Mart? Many companies need to readdress how they measure and make improvements within their organization. For survival companies need to replace the focus on fire-fighting activities with a focus on fire prevention. This paper describes a method that helps companies improve their competitiveness and bottom-line. Described is a statistical based cascading measurement methodology that tracks an organization as a system, which pulls for the creation of improvement Six Sigma/Lean projects that are in direct alignment with the needs of the business.

**Issues**

After visiting an American company that was implementing Six Sigma, Jim Womack, President and Founder of Lean Enterprise Institute, Inc., highlighted some problems.1 “Each manager has multiple value streams running through his or her departmentalized facility, but the metrics are at the department or facility level. Thus, natural conflicts have emerged between what’s best for the department or facility and what’s best for the product as its value stream flows from start to finish through many departments and facilities.” “They are committing three common sins the Lean Community should be getting beyond:

- They have no policy deployment process to prioritize the improvement initiatives and to de-select down to a short list that can reasonably be accomplished and stabilized each year.
- They have no value stream managers to look at the entire value stream for each product family, to optimize the whole rather than the parts.
- They have relied on multiple and sometimes conflicting metrics to get their facility and department managers to do the right thing, yet have not given them any useful training in how to actually improve performance.”

I agree with Mr. Womack that many companies are having problems with Six Sigma implementation. However, there have also been problems with Lean implementation. This paper addresses these issues by describing a method to wisely integrate Six Sigma with Lean activities.

**Smarter Six Sigma Solutions (S+)/Integrated Enterprise Excellence (IEE)**

In general organizations need to operate in a framework that leads to the right activities in their day-to-day operations. These activities involve doing the right things and then doing things right. However, management often unconsciously asks the wrong question of its employees. When this happens, employees can waste much resource answering the wrong question – perhaps to the third decimal place. If directives are not given appropriate focus, employees can be spending much of their time fire fighting day-to-day problems that just don’t seem to go away, instead of working on fire prevention activities that truly fix the system such that problems do not reoccur.
BEYOND SIX SIGMA/LEAN: METHODS TO ENSURE YOUR ORGANIZATION’S HEALTH

All managers within an organization need a system that helps them determine what questions to ask their employees. This system should also be able to help employees answer these questions for the business. A system needs to be created that not only uses data to make the right decisions for their organization, but they must also create the means where meaningful data are available in a useful form throughout the organization’s supply chain.

Organizations create strategic plans and policies. They also create goals that describe the intent of the organization. These goals should have measurable results, which are attained through defined action plans. The question of concern is how effective and aligned are these management system practices within your organization? Many organizations have an opportunity for improvement in this area, which can significantly improve their bottom-line. A Smarter Six Sigma Solutions (S4) or Integrated Enterprise Excellence (IEE) approach offers a solution to these challenges. The S4/IEE approach is similar but yet more powerful than a traditional Six Sigma on Lean approach.2

Within an S4/IEE management system, satellite-level and 30,000-foot-level Metrics3 are created and tracked. This approach leads to measuring the organization as a system at different levels as shown in Figure 1, which are aligned.

Long-term improvement opportunities to the overall system can then be easier identified and scoped as S4/IEE improvement projects. Trained practitioners then follow a structured roadmap for executing S4/IEE projects, which can involve not only quality improvements but also cycle time improvements that reduce waste within an organization.

Satellite-Level metrics are high-level business metrics. More information can be gleaned from data presented in this format, as opposed to examining quarterly numbers as a single entity in a tabular format or as a dashboard number. Data presented in this format can be useful for executives when creating their strategic plans and then tracking the results of these strategic plans. With an S4/IEE strategy, action plans to achieve organizational goals center around the creation and implementation of Six Sigma projects, as shown in Figure 2.
BEYOND SIX SIGMA/LEAN: METHODS TO ENSURE YOUR ORGANIZATION’S HEALTH

Metrics at the 30,000-foot-level are high level operational or Six Sigma/Lean project metrics. These metrics link Six Sigma activities to business strategies and goals. Use of the right metric drives the right activity. Also, these metrics can significantly reduce fire-fighting activities. In addition, this form of tracking is also useful for balanced scorecard metrics.

The S4/IEE strategy tracks an organization at a Satellite-Level using a statistical control chart. Metrics such as capital utilization, growth, revenue, profit, and customer satisfaction are tracked in this time-series format measuring the overall system output beyond the bounds of quarterly or fiscal accounting periods. A Satellite-Level chart is often compiled and tracked monthly.

The control chart format for this presentation separates special cause events from common cause variability. This simple presentation of data can lead to the dissemination of questions throughout the organization, which encourage the execution of projects that improve the overall system, as opposed to fire-fighting the up and down variability excursions of the system as though they were special cause. Using lean terminology we could say that the measurement systems pulls for the creation of projects.

The alignment of 30,000-foot-level metrics to satellite-level metrics is critical. Traditional operational metrics that can be tracked at the 30,000-foot-level are defective/defect rates, cycle time, waste, days sales outstanding, customer satisfaction, on-time delivery, number of days from promise date, number of days from customer requested date, dimension, inventory, and head count. Metrics at the 30,000-foot-level are also tracked on a statistical control chart that has infrequent subgrouping/sampling, e.g., daily or weekly. This charting approach separates common cause occurrence from special cause events. Reacting to out-of-specification conditions when a process is not capable of consistently meeting these requirements is fire-fighting, i.e., treating common cause issues as though they were special cause issues. Typically, fire-fighting activities require much resources and address only short-term fixes.

An S4/IEE business strategy helps organizations understand and improve the key drivers that affect the metrics and scorecards of their enterprise. Tracking the overall system at this level can be a stimulus to the creation of long-lasting change. For example, retribution by executive management for missing arbitrarily
quarterly objectives can change to more timely questions about the status of S/IEE projects that are addressing the improvement of key processes, which are aligned to the overall business metrics.

**S/IEE Project Execution**

Figure 3 shows how projects within S/IEE follow a 9-step Define-Measure-Analyze-Improve-Control (DMAIC) roadmap. Improvements to the process will then be demonstrated in the 30,000-foot-level metric. The financial impact from this change can then be determined.

Voice of the customer (VOC) issues need to be addressed both at the satellite-level and the 30,000-foot-level project level. At the satellite-level we need to have a system that captures and tracks the true voice of the customer. This involves more than just sending out survey forms that people may or not answer. It involves the creation of a meaningful customer feedback process, which encourages activities that are aligned with the needs of both internal and external customers. The S/IEE business execution strategy has the steps noted in Figure 4 within the VOC sub-process.
BEYOND SIX SIGMA/LEAN: METHODS TO ENSURE YOUR ORGANIZATION’S HEALTH

After the customer is defined, their wants, needs, and desires need to be determined. This information can come from several sources, which can lead to the formulation of improvement projects, as illustrated in Figure 5.

Creating an effective system to track the effectiveness of meeting customer needs at the satellite-level and 30,000-foot-level is not easy. However, after this VOC system is established, systems can be created to help tracking and report these metrics along with other meaningful metrics that area aligned with the needs of the business enterprise as a whole.

References

About the Author
Forrest W. Breyfogle III is CEO and president of Smarter Solutions, Inc., which he founded in 1992. Smarter Solutions is an international company that integrates Six Sigma, Lean, and Theory of Constraints, helping customers improve both their bottom-line and customer satisfaction. Breyfogle was the Subject Matter Expert (SME) for a Six Sigma benchmarking study conducted by APQC. He is an ASQ Fellow. He can be reached at forrest@smartersolutions.com and 512-996-8288.

© 2002 Smarter Solutions, Inc. All rights reserved.

Smarter Solutions and satellite-level are registered service marks of Smarter Solutions Inc. Smarter Six Sigma Solutions, S4, and 30,000-foot-level are service marks of Smarter Solutions, Inc.
PRODUCTIVITY, QUALITY AND MEASURES: USING FACTORY PHYSICS® PRINCIPLES TO RESOLVE CONFLICT AND IMPROVE PROFITABILITY

EDWARD S. POUND
MARK L. SPEARMAN

Introduction
From the advent of Frederick Taylor’s time studies in the early 1900s, business owners, managers and executives have tried to understand and control operations and improve productivity using a scientific framework. It’s been over a hundred years since those first attempts at a scientific approach to productivity improvements. According to the American Society of Quality (ASQ), “Taylor’s new approach led to remarkable rises in productivity, but it had significant drawbacks. Workers were once again stripped of their dwindling power, and the new emphasis on productivity had a negative effect on quality. To remedy the quality decline, factory managers created inspection departments to keep defective products from reaching customers. If defective product did reach the customer, it was more common for upper managers to ask the inspector, ‘Why did we let this get out?’ than to ask the production manager, ‘Why did we make it this way to begin with?’”

Fast forward to the 21st century where operations managers and executives have a plethora of choices for the “latest” productivity initiatives. Lean, Six Sigma, and Theory of Constraints are some of the most popular. In addition, there are a myriad of software packages claiming to provide an information system solution to a company’s productivity ills. Enterprise Requirements Planning (ERP), Advanced Planning Systems (APS), Warehouse Management Systems (WMS) and Supply Chain Management (SCM) packages are major players in the industrial software market. Operations managers and executives have their work cut out for them just keeping up with all the TLAs (Three Letter Acronyms). Yet, the basic tenets of operations management and improvement have not changed.

On the quality front, the emphasis has shifted from a product focus to a process focus. This evolution of process-oriented quality was accelerated during the 1960s and 1970s by the remarkable success of Japanese companies in gaining market penetration and market share through implementation of Total Quality Management (TQM) practices. In the 1980’s and 1990’s, American industry responded with Six Sigma programs based on Motorola’s highly successful quality improvement program. Today we have a confluence of quality and productivity approaches with the advent of “Lean Six Sigma.”
PRODUCTIVITY, QUALITY AND MEASURES: USING FACTORY PHYSICS® PRINCIPLES TO RESOLVE CONFLICT AND IMPROVE PROFITABILITY

As industry has struggled to reconcile the various approaches to quality and productivity, there has been a basic oversight: There are fundamental relationships between inventory, cycle time, capacity, WIP, utilization, and variability that govern how all businesses operate. Too often decisions are made without a good understanding of these relationships or the tradeoffs inherent in decisions involving these relationships. Trying to decrease cycle time while increasing machine utilization can be a recipe for disaster. Reducing WIP levels while trying to increase throughput can cause serious performance problems. At the same time, the effect of variability on capacity is typically not well understood by many managers. So while everyone agrees that high profitability is good, the tradeoffs encountered in achieving high profitability are much less well understood.

As a response to this lack of a comprehensive framework for understanding, controlling and improving operations, Factory Physics® principles were developed at Northwestern University by Dr. Wallace Hopp and Dr. Mark Spearman. Factory Physics principles provide the knowledge to tie together all the relationships governing operations environments. Dr. Spearman’s work with Factory Physics, Inc.’s clients has demonstrated the tools and techniques of Factory Physics applications to be powerful improvements for today’s productivity initiatives.

Competing Objectives
Welcome to the real world. A company wants high throughput and low inventory, high utilization and high customer service or short cycle times and high product variety. The fact is that there are tradeoffs between these objectives. Until the discovery of the Factory Physics framework, there was no well-defined method for helping managers understand these tradeoffs.

The Factory Physics framework illustrates these tradeoffs through a table of Hierarchical Objectives:

![Hierarchical Objectives Diagram]

Figure 1: Hierarchical Objectives
PRODUCTIVITY, QUALITY AND MEASURES: USING FACTORY PHYSICS® PRINCIPLES TO RESOLVE CONFLICT AND IMPROVE PROFITABILITY

One example illustrated here is that companies want low unit cost that typically means high equipment utilization. At the same time, customers want fast response, which typically requires low equipment utilization (consider the utilization of a fire truck or an ambulance).

The tradeoffs in these fundamental parameters affect companies daily. Ignoring the relationships or not understanding them is like not paying attention to the Law of Gravity. Companies will be affected whether they pay attention or not.

Factory Physics® Principles And Evaluation Of Competing Initiatives

Owners, managers and executives immediately recognize the legitimacy and applicability of Factory Physics principles when properly introduced, but sometimes have a hard time understanding how Factory Physics principles will work in their organizations. This cognitive dissonance is especially acute if organizations have pre-existing productivity improvement initiatives such as Lean Manufacturing or Six Sigma. These programs have been successful and the Factory Physics approach does not jettison these efforts—a further complication because organizations typically take the position that the previous programs have been flawed and need replacing. The application of Factory Physics principles clarifies and energizes existing efforts. Factory Physics knowledge and tools provide the foundation for evaluating and implementing productivity efforts.

Figure 2: Six Sigma, Lean, and Factory Physics Tools

Building Blocks of Profitability

Six Sigma (Quality Focus)
- Process Mapping
- Measurement System Evaluation
- Design of Experiments
- Statistical Process Control
- Failure Modes and Effects Analysis

Lean (Productivity Focus)
- 5S
- Value Stream Mapping
- Plus
- Standardized Work
- Set-Up Reduction
- Kaizen Events
- Factory Layout

Factory Physics Knowledge and Tools (Fundamental Relationships)
- Factory Dynamics
- Variability Basics
- Batching
- Push and Pull
- Inventory
- Measurement Alignment

- Absolute Benchmarking
- Demand Analyzer
- Flow Analyzer
- Stocksetter
- CONWIP
- Custom Software

Figure 2: Six Sigma, Lean, and Factory Physics Tools
The Factory Physics approach is a complete framework for the description and control of operations environments and supply chains. Lean Manufacturing and Six Sigma are initiatives by imitation. Lean Manufacturing was developed in attempts to emulate the success of the Toyota Production System. Six Sigma was developed in a similar attempt to gain the benefits of Motorola’s Six Sigma quality program. There is nothing inherently wrong with initiative by imitation and much has been gained through such efforts. All too often though, these efforts degenerate into management by slogan. “We must get Lean!” says management. The company charges off on Lean or Six Sigma implementation efforts and gets good initial success. The efforts continue but once the obvious low-hanging fruit is picked, the efforts begin to lose traction. Management reinvigorates the cry, “We must get Lean!” or “We must reduce variability!” Though now the troops are saying, “We’ve reduced waste. We have many Black Belts working on Six Sigma projects, what do you want to do next?” The typical reply from consultants or management is something like, “Lean is a journey. Trust me. This company must get Lean!” The implication is that the initiative worked elsewhere and the company must work harder at working smarter to get continued benefit from the initiative. In reality, the company might have already achieved the highest payback possible from trying to work like Toyota or Motorola or GE. To continue improving, a company needs an understanding of what works well for its own environment. While manufacturing is not simple, it is comprehensible. No one would think of building microchips without knowledge of semiconductor physics. Yet for some reason, many managers think that manufacturing logistics is something that can be learned through osmosis and there is no special knowledge needed to understand and control operations. Nothing could be further from the truth. Factory Physics principles provide the knowledge to tie together all the relationships governing operations environments.

**Measures and Buffers**

There are only four basic measures that are needed to understand and control logistics performance: capacity, time, inventory and variability. Factory Physics principles describe the relationships between these parameters. Factory Physics principles provide good news and bad news for managers: The good news is that there is a comprehensive framework for understanding and controlling operations environments and there are only four basic parameters to worry about. The bad news is that there are only four basic parameters for you to worry about! Those managers looking for a miracle solution are out of luck. Many of the initiatives of the past received much of their support from those managers who believed that if they just had the right initiative and slogan i.e. “focus on the bottleneck” or “eliminate waste” or “eliminate variability”, their problems would be solved. At Factory Physics, Inc., we call the single solution approach “Factory Magic” and it doesn’t work.

In deciding what measures are appropriate for your company, you must consider the relationships between the parameters of capacity, time, inventory and variability. One fundamental relationship between three of these parameters is Little’s Law:

\[
\text{WIP} = \text{(Cycle Time)} \times \text{(Throughput)}
\]
In a simple interpretation, this says that if you keep throughput constant and you increase WIP, cycle time will increase. Conversely, if throughput is constant and WIP is decreased, cycle time has to come down. This relationship lies at the core of the success of pull systems such as CONWIP and kanban.

In determining performance measures, companies often ignore Little’s Law and other fundamental relationships to their detriment. For instance, holding people accountable solely for machine utilization will invariably increase cycle time. Why? High machine utilization requires lots of WIP to keep the machines running. High WIP means high cycle time.

So how do you get your mind around the tradeoffs and how they should be measured? Starting simply, every value stream is composed of only three elements: demand, transformation (flow), and buffers. Remember also that only four parameters are needed to provide a complete mathematical description of a value stream’s performance: capacity, time, inventory, and variability – a simple basic framework to start.

For over 100 years, companies and consultants have worked on reducing different elements of this framework without a good understanding of how it all works together. Measurements have focused on reducing inventory or reducing cycle time or reducing variability or improving throughput in isolation from one another. At best there have been admissions of relationships between the four parameters only by implication. Some examples from the Internet:

- “Reduced process variability results in increased operating efficiency, improved product quality and reduced operating costs.”
- “As processes are improved cycle time is reduced.”
- “When you fix the business processes that caused the excess inventory buffers to exist in the first place, you will very likely shorten cycle times, decrease costs, increase quality, and improve customer service.”
A deeper understanding of the relationships governing operations requires an understanding of buffers. While the figure above shows the classic inventory buffer, there are two other buffers that are less well understood: capacity and time. Before going further, it is important to note all buffers exist to buffer variability. In some cases variability is good. For example different sizes of shoes and different colors of cars are required for competing in those markets. Bad variability means things like variation in processing times (e.g., long setups), variation in material quality, and the like. From a Factory Physics perspective, the question is “What level of variability can you profitably live with?” or “What is it worth to reduce variability?” A corollary to these questions is “What options do you have for buffering variability?” It may be that buffering with some extra inventory, as an aerospace manufacturer did, is a good alternative for increasing profitability. On the other hand, a major semiconductor manufacturer drove down cycle times using extensive capacity buffering (read, “very low utilization”) at non-bottleneck resources—in their case, an effective way to reduce cycle times but a serious drain on profits when the market turned down.

Toyota, the benchmark for Lean Manufacturing, made extensive use of capacity buffers—a fact not well understood (and seldom mentioned!) by many Lean practitioners in their drive to establish one piece flow. Toyota started out with an extra capacity buffer (10 hours of work scheduled in a 12 hour shift) and then used classic Lean techniques (Kanban, one-piece flow) to reduce inventory and time buffers. Only after the processes were improved did Toyota reduce its capacity buffer. But by this time, variability was down so they could have low buffers in both inventory and capacity. Again, this is not a simple strategy to execute but it is comprehensible. Regrettably, it doesn’t lend itself well to one-line slogans. The use of buffers is at the heart of good manufacturing practice. Unfortunately, the concept of buffering variability is generally not well understood.

In the Factory Physics framework, variability occurs when there is an imperfect alignment between demand and transformation (flow). This might be necessary (e.g., seasonal demand) or unnecessary (e.g., too much inventory). Necessary misalignment results in a “strategic buffer” (e.g., buffering random customer demand). Unnecessary misalignment results in a “surplus buffer” (e.g., buffering for extremely long setups). “Waste” occurs when you have surplus buffers. However, it is not wasteful to use strategic buffers. Focusing on reduction of surplus buffers can only go so far—this is the “low hanging fruit” picked during typical Lean Manufacturing applications. To fully understand, control and improve your operations a thorough understanding of buffer optimization is required. This should strike a chord with anyone who has seen big corporate initiatives implemented, good initial results achieved and the initiative then descend into wheel-spinning and back-biting in trying to determine how to address the nuances left once the obvious opportunities have been harvested.

**Inventory Buffer Optimization**

An example of buffer optimization is the efficient frontier curve technique used in the Factory Physics, Inc. Stocksetter. Through the application of Factory Physics principles, FPI has developed an effective approach to managing crib and finished goods inventory (any inventory at the end of a transformation process) through the use of Efficient Frontier Curves. Do you know what your set-up costs, order costs, and
inventory carrying costs are for all your parts? If you don’t, you’re not alone. Fortunately, you don’t have to know these parameters and therein lays the fundamental benefit of the Stocksetter. The Stocksetter considers policy parameters of Replenishment Quantity and Reorder Point, the basic cost and demand data for your parts, as well as supply data (mean and variability in lead time). Using this information, a company can create an efficient frontier curve (see figure below) that contrasts the fill rate against total inventory investment for a host of optimal policies. You can then compare your current performance with where you would like to be with respect to customer service and inventory investment and obtain an optimal policy. There is no need to estimate these costs—estimates that always result in huge arguments between departments. Choosing a point on the curve provides all the reorder points and reorder quantities for the optimal policy. By doing so, you have implicitly specified the inventory carrying costs, the set-up costs, and the backorder costs that you are incurring. Why continually rehash the old arguments with Accounting on what costs to use for set-ups and inventory carrying costs? The Efficient Frontier Curve provides a measure of peak inventory management performance tailored specifically to your company’s unique situation. The Stocksetter is just one application of Factory Physics principles to optimization of buffers and it provides a fundamental advantage over typical productivity improvement approaches: the efficient frontier is a measure of the best possible performance for your company.

Choose where you want to be on the graph, then click that point to see the optimal policy.

![Figure 4. Stocksetter Example](Image)
You simply cannot get any better performance than that represented by the efficient frontier curve. Your company doesn’t have to guess at a “stretch goal”, it can quickly determine its performance limits and make informed decisions about allocation of resources and options for using strategic buffers. In the Factory Physics framework, this is called Absolute Benchmarking. You are benchmarking against your best possible performance potential and measuring against customer requirements. This is in place of classic benchmarking where you are looking at your competitors and trying to understand if you should be performing as well or better than they are performing—a lagging indicator at best. Other benchmarking and optimization methods have been developed for cycle time, capacity, WIP, and lot sizing.

A fundamental Factory Physics law is that \textit{Variability in a production system will be buffered by some combination of inventory, capacity and time}. Note the law does not state that variability is good or bad. The challenge for companies establishing their measures, quality programs and productivity initiatives is determining what combination of variability, inventory, capacity and time is most profitable. This brings us full circle back to Fredrick Taylor’s efforts to establish a comprehensive, scientific framework for understanding, controlling and improving operations. Fortunately we now have over a hundred years of progress on the topic, powerful tools in the form of Lean and Six Sigma combined with the definitive Factory Physics framework and powerful Factory Physics applications to enable complete understanding and control of operations environments for achieving companies’ goals.

About the Authors

Mark L. Spearman is President and Chief Executive Officer of Factory Physics, Inc and Head of the Department of Industrial Engineering at Texas A&M University. For over 15 years, his research and teaching has dealt with manufacturing enterprise integration and supply chain management. He is co-author, with Wallace J. Hopp, of the book, \textit{Factory Physics: The Foundations of Manufacturing Management}. Dr. Spearman has worked with numerous companies over the last twenty years, applying the principles of factory physics to improve operations by increasing productivity and by reducing cycle times and inventories, developing integrated supply chain approaches that are both simple and effective. He holds a PhD in Industrial Engineering, is a senior member of IIE, a full member of INFORMS, and is certified in production and inventory management by APICS.

Edward S. Pound is Chief Operating Officer for Factory Physics, Inc. His career spans over fourteen years in manufacturing with diverse general management, operations, purchasing, and product development experience with top national and international manufacturing companies and in entrepreneurial ventures. He has applied the Factory Physics principles successfully in many different settings from tight tolerance aerospace machining to production control for consumer products manufacturing. Mr. Pound has a BS and MS in Mechanical Engineering from the University of Alabama, an MBA from the Kellogg Graduate School of Management at Northwestern University and a Master of Engineering Management from the McCormick Institute of Technology at Northwestern University.

\textit{Factory Physics, Inc. is a full service operations consulting company offering the best tools and implementation services available for understanding, controlling and improving operations. Find more information go to \url{www.factoryphysics.com} or \url{www.leanphysics.com}}
The ASQ Statistics Division Newsletter is published quarterly by the Statistics Division of the American Society for Quality.

All communications regarding this publication, EXCLUDING CHANGE OF ADDRESS, should be addressed to:

Bill Rodebaugh, Editor
ASQ Statistics Division Special Publication Newsletter
Phone: (215) 439-1547
Fax: (215) 743-0406
Email: Bill.Rodebaugh@Grace.com

Other communications relating to the Statistics Division of ASQ should be addressed to:

Bob Mitchell
Bldg. 223-03-S-03, 3M Center
3M Company
Maplewood, MN 55144-1000
rhmitche@mmm.com

Communications regarding change of address should be sent to ASQ at:
American Society for Quality
P.O. Box 3005
Milwaukee, WI 53201-3005

This will change the address for all publications you receive from ASQ including the newsletter. You can also handle this by phone (414) 272-8575 or (800) 248-1946.

VISIT THE STATISTICS DIVISION WEBSITE:
www.asqstatdiv.org

Other Periodicals for Applied Statistics
http://www.asq.org/pub/jqt/

UPCOMING SPECIAL PUBLICATIONS NEWSLETTER

<table>
<thead>
<tr>
<th>Issue</th>
<th>Vol. No.</th>
<th>Due Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td>22-1</td>
<td>Summer 2006</td>
</tr>
</tbody>
</table>