How Constraints Management Enhances Lean and Six Sigma

Lean and Six Sigma are two of the most effective business-improvement techniques available today. However, many companies still struggle to harness one or both disciplines to achieve the desired results. One solution is to combine lean/Six Sigma with a third business-improvement approach—constraints management. By bringing constraints management into the equation, companies can identify where to focus the lean and Six Sigma efforts for maximum success.

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Companies that have embraced lean and Six Sigma have had some impressive initial results. However, these popular business-improvement disciplines have not always worked for everyone—even when they have been combined. A number of companies have either not achieved the touted benefits or, after initial success, have seen their improvement efforts grind to a halt.

Recently, a few leading companies have used another business improvement approach, namely constraints management, to focus their lean and Six Sigma efforts and amplify their results. Constraints management looks at the business as chains of dependent events and focuses improvement efforts on the weak links in the chains. On the face of it, the inclusion of yet another sophisticated business process might seem to lead to excessive complexity. But in practice, this new layered approach actually can simplify management's job by providing a focusing mechanism for improvement initiatives.

This article will discuss the benefits of the new approach, beginning with a refresher on lean and Six Sigma in an effort to clarify how the application of constraints management techniques can help to jump-start stalled lean and Six Sigma implementations. To aid understanding, we refer to the example of an automotive parts plant (real but unnamed). This company had a relatively straightforward production process in which steel rolls were received, cut and shaped, plated, assembled, painted, and then shipped to the customer. Market demand on the parts plant calls for 30 parts an hour. Before the new blended process disciplines were applied, the stamping area had a throughput of 35 parts per hour. The plating and painting operations handled ten and 40 parts an hour, respectively, with final assembly running at 20 parts hourly. Unfortunately, the plant frequently suffered from missed due dates, poor quality, shortages of the right parts (with plenty of the wrong parts), and low morale. Piles of work-in-process (WIP) were seen everywhere in the plant. And, expediting was the norm.

We will look later at how the new business disciplines made a difference to this plant's operations. (Exhibit 1, on page 44, depicts the main activities at the plant, omitting inspection areas for simplicity.) First, though, it's helpful to revisit some of the fundamentals.

A Closer Look at Lean

Lean focuses on the elimination of waste, defined as anything unnecessary to produce a product or service. Seven wastes are particular targets: excessive motion, waiting time, overproduction, unnecessary processing time, defects, excessive inventory, and unnecessary transportation.

The lean approach is a natural outgrowth of just-in-time practices and the Toyota Production System. The term was coined by James Womack after his groundbreaking study of automotive manufacturing detailed in the book, *The Machine that Changed the World*. In the 1950s, lean manufacturing was pioneered and first applied effectively by Toyota, and today the automaker is the global leader in implementing organization-wide lean.

Lean aims to eliminate waste in every area of the business, including customer relations, product design, supplier networks, and factory management. The objectives are to use less human effort, less inventory, less space, and less time to produce high-quality products as efficiently and economically as possible while being highly responsive to customer demand. Lean is directly opposed to traditional manufacturing approaches that are characterized by economic order quantities, high-capacity utilization, and high inventories. In lean terms, high inventories diminish a company's competitive advantage; instead, it should strive to produce only what it knows it can sell.

The lean implementation approach is as follows:

1. Define value from the end customer's perspective. Value is defined by customer needs and expectations.

2. Identify the entire value stream for each service, product, or product family and eliminate waste. A value stream consists of all the actions required to bring a product through manufacturing and assembly. Tools such as value-stream mapping are used to determine which actions do not add value and, thus, can be eliminated.
3. Make the remaining value-creating steps flow. Here the focus is on maximizing value by producing only what's needed in the shortest time possible with the fewest resources.
4. Pull to customer demand. Everything is produced at the rate of customer demand only.
5. Pursue perfection. Empower employees with waste elimination tools and create a culture of continuous improvement.

Revisiting Six Sigma

Six Sigma was pioneered by Motorola Corp. in the mid-1980s to improve manufacturing yields. The discipline evolved from the quality programs of the 1980s (cost of quality, zero defects, and total quality management) utilizing the collective knowledge of management gurus W. Edwards Deming, J.M. Juran, Philip Crosby, and others. Its primary goal is the elimination of variation in products and service processes to such a degree that six sigmas of variation (99.9997 percent yield) will fit within the specification limits defined by customers. The Six Sigma performance target is virtually defect-free processes and products: 3.4 or fewer defective parts per one million opportunities. Defects may be related to any aspect of customer satisfaction: high product quality, schedule adherence, or cost minimization, for instance.[1]

The Six Sigma discipline includes the use of statistical tools and techniques to help analyze and reduce variation so the process can become more predictable and reliable. Once the process is under control, tools such as root-cause analysis can then be used to help reduce the average processing time. Here's an example of a typical Six Sigma project: reducing the variability of response times at a call center that has an average customer response time of 20 seconds. The calls are being answered in as little as 10 seconds and as long as 90 seconds—a wait time that quickly leads to irritated customers.

The Six Sigma drive for defect reduction, process improvement, and customer satisfaction is based on the concept that everything is a process and all processes have inherent variability. Data is used to understand the variability and drive process-improvement decisions. Six Sigma comprises the following key themes:

- **Customer-centric:** Stakeholder value is the starting point for all Six Sigma improvements.
- **Process-focused:** Mastering business processes is a way to build competitive advantage in delivering value to customers.
- **Data- and fact-driven:** Decisions are based on established data and facts.
- **Standardized and repeatable:** Customers value consistent business processes that deliver world-class levels of quality.
- **Collaboration without boundaries:** Six Sigma expands opportunities for collaboration as people learn how their roles fit into the "big picture" and as they recognize and measure the interdependence of all activities in a process.
- **Drive for perfection, tolerance for failure:** Understand that no company has ever achieved great results without some mistakes along the way.

The Emergence of Lean/Six Sigma

In the past five years, companies have begun to realize that using either lean or Six Sigma exclusively has serious limitations. Six Sigma will help eliminate defects and variation and, thus, increase the reliability of processes. But, it will not address the question of how to optimize process flow, and it does not address the competitive element of speed. Lean, for its part, will help reduce complexity, but it does not address reliability as Six Sigma does.

By combining these complementary approaches into what is now called lean/Six Sigma, companies can address the key competitive elements of speed and quality. For example, on a call center project, Six Sigma would help identify a customer requirement to answer calls within 19 seconds and then enable 95 percent of the calls to be answered in no less than 15 seconds and no more than 25 seconds. Meanwhile, lean would help reduce the length and volume of the calls, and help reduce the need for full-time staff and facilities. Or, on a supply chain project, Six Sigma could help identify the root causes of variation in schedule and production processes, while lean would contribute to lower manufacturing cycle times and inventory to meet market demand.

To further illustrate how lean/Six Sigma can be applied concurrently, let's take a look at the automotive parts company example. Exhibit 1 shows the old process with market demand of 30 parts an hour. The auto parts plant was operating in a "push" fashion—orders were pushed through the plant. But lean prescribes the use of a demand-pull system, with orders being pulled through the plant according to a final-assembly schedule that is synchronized to customer demand. In our example, the set-up time for the stamping press was measured in days and was highly unpredictable. By applying lean reduction techniques, set-up can be reduced first to a few hours and eventually to less than 10 minutes.

To enable the *kanban* logistics system—to pull material through the system to the customer—both lean and Six Sigma tools can help drive variation out of the process and eliminate nonvalue-added activities.

Exhibit 2 shows the new process after application of lean/Six Sigma. (Market demand is still 30 parts an hour.) Set-up reduction techniques have been applied at the press operations to cut set-up times. These techniques can also dramatically increase effective capacity as well as the ability to reduce batch sizes. Six Sigma problem-solving techniques have helped to increase the quality at the plating operation (previously experiencing a lot of rework) so that its effective yield is slightly more than market demand of 30 parts hourly. Lean concepts have been implemented at all operations to help reduce waste, and preventive maintenance is now being done to avoid machine and tool breakdowns, which has resulted in a significant boost in final-assembly throughput. Finally, a pull scheduling system has been implemented that pulls product through the system at the rate of market demand.

Dramatic improvements have been made. The process is now predictable and under control. Inventory, particularly WIP inventory, has been slashed by more than 70 percent. Cycle time has been halved, and customer service levels are now up 95 percent.

Problems with Implementation

Yet while there have been examples of dramatic results, lean manufacturing programs at many manufacturing companies have had trouble staying on track, according to a recent article by the ARC Advisory Group. "Many lean programs are in trouble," says Ralph Rio, research director of ARC's lean manufacturing practice.[2] In the Lean Enterprise Institute's recent survey, 36 percent of lean practitioners viewed their companies' "backsliding to the old ways of working" as a major obstacle.

The same phenomenon has been observed with companies that have implemented Six Sigma. Even those that have had great initial results with their implementations are now encountering difficulty maintaining their programs' momentum. In some cases, the programs have actually ground to a halt.

Why is this happening? Part of the problem is that many of the companies that have effectively implemented lean and/or Six Sigma have too many such projects. Managers have been heard complaining that that they've reached a point of saturation where they don't know which projects are "important" and which aren't. This problem can arise from the core assumptions behind these disciplines. Lean's central assumption—that waste reduction will automatically result in a rise in business performance—is not valid in all circumstances; nor is the Six Sigma assumption that reducing variability everywhere will automatically lead to an overall systems improvement.

It is difficult to argue against the underlying philosophy of improvement. The economic reality, however, is that companies seek the most improvement for the least investment. Trying to improve all of a company's individual processes at the same time requires tremendous time commitments by many people throughout the company. In truth, wringing variation out of processes and eliminating waste everywhere does not necessarily lead to decreased spending or increased throughput. How do managers determine which projects are important and which aren't? If everything is a priority, then nothing is a priority.

There is also the common issue of viewing these improvement projects only in terms of local optimization without looking at the "big picture." In one notable case, a manufacturer's purchasing department launched an initiative to lower the cost of raw materials. The conclusion: The company could save money on a particular component by purchasing the part from China. Although the raw-material cost savings were real, they came at a huge price. The new delivery times were long and unreliable—as long as six weeks—yet cycle time was a key competitive factor in the company's marketplace. The band-aid measure: large warehouses full of component inventory. The company came close to going out of business.

This was a classic case of local improvements quickly compromising the entire system. Companies that have begun enterprise-wide lean/Six Sigma efforts—with many improvement projects running at the same time—are very susceptible to this type of problem.

So how can managers understand the effects of local initiatives on the whole company? The answer is to combine lean/Six Sigma with the systems focus of constraints management.

A Refresher on Constraints Management

Constraints management (CM) is based on the Theory of Constraints developed by Eli Goldratt, an Israeli physicist.[3] CM looks at companies as systems. A system can be defined generally as a collection of interrelated, interdependent components or processes that act in concert to turn inputs into defined outputs in pursuit of a particular goal. Likening systems to chains, CM defines the weakest link as the constraint—the system's limiting factor. (See Exhibit 3.)

A common theme in the success stories of CM implementations is how quickly results are attained. That's because the focus on constraints is, *de facto*, a focus on the areas where there's the most potential for improvement.

There are essentially two different types of constraints: physical and policy. A physical constraint is usually a capacity-constrained resource, such as a machine or person. It can also be the market itself: excess capacity can result if demand dries up. A policy constraint, which is the dominant type of constraint, can be any business rule that conflicts with the goal of making more money. An example: the prescribed use of large batch sizes in order to be "efficient" but at the expense of longer lead times.

Thinking of a business as a money-making machine—with money entering the machine and money captured inside—helps explain the value of the CM approach. The money produced by the machine is called "throughput," defined as "the rate the machine generates money through sales." Note the word "sales"; if something is produced but is not sold, it's not throughput. Nor is throughput the same as gross revenue. Some revenue generated by the machine is produced by vendors, and this revenue element simply flows through the machine. So throughput equals gross revenue minus all variable expenses (raw material costs, sales commissions, and so forth).

The money captured in the machine is called "inventory." (In this case it includes not only the materials and parts made but also all assets, including buildings and equipment.) And, the money the machine uses to turn inventory into throughput is called "operating expense." This definition includes all direct and indirect labor and all overhead. Consider these as the unavoidable costs of doing business. They are short-term, non-variable costs; over the next financial period, it doesn't matter how many units are sold—the employees must still be paid.

Throughput, inventory, and operating expense can be easily tied to the bottom-line financial measures of net profit and return on investment (ROI).

Constraints management argues that the greatest improvements come from addressing issues at the weakest links in the chain. Improvements at non-constraints have very little positive impact on the overall system and can even be detrimental. The CM approach consists of the following:

- **Key focusing steps:** This refers to Goldratt's five original "processes of ongoing improvement": 1) identifying the constraint, 2) exploiting the constraint, 3) subordinating everything else to the constraint, 4) elevating the constraint, and 5) repeating the steps. These steps apply whether the system is manufacturing, distribution, sales, or project management.
- **The thinking processes (TP):** These are the methods to enable the focused improvement of any system. The purpose of the TP is to help answer the three questions essential to achieving focused improvement: What to change? What to change to? How to cause the change?

- **Throughput accounting (TA):** This is the CM alternative to cost-based management accounting. TA is not costing, and it does not allocate costs to products and services. Rather than focusing on costs, it focuses on profit maximization by managing constraints.
- **Application-specific solutions:** This includes supply chain and operations activities and project management operations.

Combining CM with Lean/Six Sigma

Companies that have effectively implemented lean and Six Sigma have driven much of the waste and variation out of their processes. The easy gains have been achieved. So how do their managers decide which lean/Six Sigma improvement initiatives to launch next?

First, they have to keep in mind the ultimate goal of any improvement initiative: to increase shareholder value by improving net profit and ROI. Constraints management provides a framework for measuring the impact of a local initiative on those bottom-line measures. For example, when throughput is increased—without adversely affecting the CM definitions of inventory or operating expense—then net profits and ROI are simultaneously increased. When deciding whether to undertake a local lean/Six Sigma improvement, managers should take into account its impact on all three measures—throughput (making money through sales), inventory (all assets), and operating expense.

The CM position is that the emphasis should first be on increasing throughput, then on reducing inventory, and finally on reducing operating expense. By applying a CM framework to lean/Six Sigma efforts, companies can more easily avoid the problems incurred by placing too much priority on reducing operating expense.

Consider the many examples of businesses that have focused excessively on eliminating waste with the objective of cutting costs, while not applying at least as much effort to selling more. Excess capacity—usually in the form of people—is viewed as waste. This viewpoint can lead to several long-lasting problems. First, cutting capacity to match existing demand leaves little room for increases in demand. Once capacity has been reduced, it's not easy to increase it again. It takes time and money to find and hire skilled workers. A second problem is the effect of such moves on morale—and on future improvement efforts. Just how are workers expected to cooperate with any future lean/Six Sigma efforts if they know they are improving themselves out of a job? By that point, any hope of continuous improvement initiatives has been dashed.

To determine where the focus should be for improvement initiatives, it's important to remember that a system of dependent events is governed by a very small number of constraints. The 80/20 rule states that 20 percent of the initiatives will yield 80 percent of the results. Once you realize that constraints govern the system's performance, it becomes clear that only a few things can be done that will have a significant impact. In fact, the 80/20 rule becomes the 99/1 rule.

A process is needed to manage the system to confirm that the constraint is the center of attention. The following are the five focusing steps of constraint management:

1. ***Identify the system constraint.*** What and where is the limiting factor? A review of the company's symptoms can quickly lead to a diagnosis of the constraint. For example, in a plant that can't make enough products to meet demand, the constraint can be a capacity-constrained machine or work center.
2. ***Decide how to exploit the constraint.*** Once the location of the constraint has been identified, managers should try to maximize its performance. For example, if a machine is capacity-constrained, all sources of wasted and idle time should be eliminated.
3. ***Subordinate everything else to the constraint.*** It's vital to determine that the nonconstrained resources are working solely to support the constraint. For example, with a capacity-constrained machine, all other resources would produce at the same rate as this machine and run no faster.
4. ***Elevate the constraint.*** Managers have to take whatever action is necessary to eliminate the constraint. Additional capital investment is considered at this point. Breaking a capacity constraint could take the form of additional equipment or people.

5. ***Return to step one, but beware of inertia.*** At some point, the constraint is broken and moves somewhere else. It's essential to recognize the location of the new constraint and to redirect efforts rather than continuing to focus on the old broken constraint. For example, production capacity might be raised to the point that the market is now the constraint, and efforts should then be focused on improving sales and marketing.

Following these five steps helps facilitate the development of a process of continuous improvement. This has to happen because the company always has a new constraint. So lean/Six Sigma improvement initiatives should be evaluated and prioritized—and periodically re-evaluated and reprioritized—in the context of their impact on the company's successive constraints. For example, if a company is capacity-constrained, lean tools should be used to eliminate waste and improve the flow using demand-pull scheduling. On the other hand, if the constraint is external—if the company has more capacity than demand—then Six Sigma projects should be aimed at areas that will make the system's offerings more attractive to potential customers. Key areas in this regard include customer response time and the reliability of delivery promises.

A Complementary Approach

It's apparent now that these three business-improvement approaches are not exclusive of each other and are, in fact, complementary. Constraints management is a systems-based way of thinking to determine where the organization should focus its efforts. In short, Constraints management can be used to focus on the right problem and the right solution at the right time in the right place. Lean and Six Sigma tools and techniques can then applied where they will drive the most benefit—eliminating waste and reducing variation at the constraint.

Savvy supply chain managers don't waste time and resources on projects that are simply strengthening already stronger links of the chain. Instead, they are turning to constraints management to focus lean/Six Sigma efforts on the weak links. (The sidebar, on "Seagate's Achievements" offers a good example.) And they are making sure that when they've dealt with a constraint, they shift the focus of their efforts to the next constraint. For companies that are just starting their lean/Six Sigma efforts, constraints management will accelerate results by first focusing on the areas where the most improvement opportunity lies.

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Endnotes

[1]Peter S. Pande , Robert P. Neuman, and Roland R. Cavanagh, *The Six Sigma Way* (New York: McGraw-Hill, 2000).

[2]Ralph Rio, "Successful Execution of a Lean Program," ARC Advisory Group. (www.arcweb.com/Newsmag/auto/lean-mfg-ins37-111104.asp).

[3]Eliyahu M. Goldratt, *The Goal*, second edition (Great Barrington, MA: North River Press, 1994).

Seagate's Achievements

The world's leading provider of hard disk drives, Seagate Technology LLC, has adopted both constraints management and Six Sigma. The company has 42,000 employees worldwide; in fiscal 2004, it shipped more than 79 million drives, generating revenues of $6.22 billion and net income of $529 million.

In 1998, Seagate launched Six Sigma as a global initiative. The discipline has proved to be a resounding success, producing $1.2 billion in savings to date with 8,000 employees certified in Six Sigma and 4,700 completed Six Sigma projects in all. However, there were some drawbacks in the company's approach. Among them: The Six Sigma practitioners didn't have a way to prioritize projects, and projects were taking too long to complete—six months on average.

To address these problems, Seagate decided to integrate constraints management tools with Six Sigma. The move has had these results:

- Projects are now more focused.
- Problems are much less ambiguous.
- Project completion rate has increased by 80 percent.
- The number of projects completed within three months increased by 70 percent.

Seagate is now using constraints management tools to effectively identify and drive the most appropriate Six Sigma projects. The company has also implemented the CCPM Critical Chain Project Management application to bring the first 15,000 rpm disk drive to market. The drive maker reported on its ToC activities in a paper "Integrating the TOC Thinking Process and Six Sigma," which was presented at the Theory of Constraints International Certification Organization Conference in October 2004.