Lean versus Six-Sigma -- Friends or Foes?

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Background

"Lean Manufacturing" was introduced by Toyota about 50 years ago, and "Six-Sigma" was introduced by Motorola just over 21 years ago. At first glance, it would appear that lean manufacturing is a method to reduce waste, or "fat," in the manufacturing process, which results in both a reduction in product manufacturing time-to-market and work-in-process (WIP) inventories; whereas, six-sigma addresses reduction in process variability such that the product tolerance limits are six standard deviations from target. Since lean manufacturing is a production-throughput philosophy and six-sigma, a quality methodology, shouldn't they complement one another and be "friends" versus "foes?" As engineering educators, we need to clearly understand the answer to this question in order to effectively teach either philosophy.

To answer this question requires an historical perspective. Let's begin with "lean." A key metric to determine a company's degree of success in implementing lean manufacturing is inventory turnover associated with the lean technique of just-in-time (JIT) delivery of raw materials and components from suppliers to the manufacturer. (Turnover is best understood as the average length of time inventory is in the system, or 365 days divided by turns per year). For example Toyota's inventory turns per year ranged from 60 to 80 in the 1970's, which meant that inventory turned every 4.5 to 6 days. Many domestic companies, including Blount International, Harley Davidson, and General Electric adopted and were successful with JIT about the same time. However, from that time to the present, inventory turns have dropped steadily for many of them. Toyota's turns per year dropped to the 20's in the 1980's to 12.2 in 2001. General Electric had its leanest year in 1973 and has lost ground since that time.[1] So, some of these companies began comparing improvement techniques such as "Total Quality Management" (TQM), "Enterprise Resource Planning" (ERP), and "Theory of Constraints" (TOC) as supplements, or alternatives, to lean techniques. Many companies brought confusion and conflict to their organizations as they would try out the latest "program of the month" with short-term success at best, and no long-term success in general. Their engineers began comparing such improvement initiatives and were hungry for reassurance that the initiatives are, deep inside, members of the same team working towards a common goal.[2] Unfortunately, the confusion worsened.

Where then does "six-sigma" enter into all of this? In General Electric's search for a new initiative, CEO, Jack Welch, visited Motorola resulting in his adopting six-sigma in 1995. In a quote to a Fortune magazine editor, Jack Welch stated, "The results (of six-sigma) are fantastic.

We're going to get $1.2 billion of gain this year. For years our operating margin was never over ten. It's been improving and it's going to be 16.7 this year. Our working-capital turns were four for 35 years. It will be nine this year."[3] Other companies had similar successes and, as a result, two camps have emerged -- one promoting the virtues of lean and the other promoting six-sigma.

Both camps have promoted their programs and have generalized them beyond the original areas where they have been successful. Lean manufacturing is about specific types of manufacturing processes (more on that subject in the next paragraph) not insurance or airline management. The creators of six-sigma view it as a revolution in management and not just a quality program; and, in their desire to break out of the quality niche, their attempts to do so create confusion as to the nature of the program and actually weakens its appeal.[2] As a result, the lean camp believes it infringes on their management approach and is a "foe" of their program. In a lean conference presentation in Dallas on May 30th, 2002, the Executive Director of the Shingo Prize for Excellence in Manufacturing, made a case to show that lean companies weather the current recession better than those steeped in six-sigma. He pointed out that the lean company stock prices dropped less during their previous 12-month highs than six-sigma company prices. For example, the lean companies -- Delphi, Johnson Controls, and Deere -- dropped 7%, 4%, and 11% respectively. On the other hand, the six-sigma companies -- General Electric and Selectron -- dropped 40% and 70% respectively.[4] Shigeo Shingo, namesake of the Shingo prize, stated, "When I first heard about statistics in 1951, I firmly believed it to be the best technique around, and it took me 26 years to be completely free of its spell."[2] Are you confused? Think of how our students react to these mixed signals from the "experts."

To better understand why these two camps have emerged requires a better understanding of the basic processes where each approach has excelled. Lean manufacturing originated in the automotive industry. Assembly plants produce very high quality without the use of statistical quality control (SQC), since quality problems are not generally related to process capability (statistical variability) but to human error. Emphasis for quality improvements in these processes are then placed on mistake-proofing (poka-yoke) created by Shigeo Shingo. In the electronics fabrication processes, SQC emerged as the way to attack quality issues. In the early years at Bell Labs, Dr. Shewhart, the mentor of Dr. W. Edwards Deming, authored the well-known *Western Electric Statistical Quality Control Handbook*. Eighty years later, the semiconductor industry uses SQC for yield enhancement. The reason for the prevalence of SQC in this industry is not the intrinsic instability in the manufacturing process, but the rate of innovation that forces such companies to proceed with high-volume production before their processes reach the maturity that is the norm in automotive processes. In semiconductor fabrication, if the process is mature, the product is probably obsolete.[2] So, it should be clear at this point, the best management philosophy and resulting methods for improvements in productivity and quality are dependent upon the nature of the product and the nature of the process itself. If a company is not an automotive assembly or an electronics fabrication operation, the best method may be a synthesis of both lean and six-sigma. This synthesis mandates a corporate philosophy on how to deploy the techniques from the top down, considering the culture change impact to personnel, and to sustain and continuously improve over the several years it takes to become a truly "lean" operation. Before synthesis is possible, it becomes necessary to look at "the basics" of each approach to understand how to customize and integrate them into a particular process. Additionally, since many companies believe they are already lean, there should be some theoretical methods that can be used to internally benchmark a manufacturing operation to see how lean it really is now, or has become. Some original Japanese "transplant" automotive suppliers for Nissan have been in operation for over 20 years and have changed ownership and management in the recent past. In most of these companies, the lean techniques have not been sustained.

Back to basics

The late great Green Bay Packers Coach, Vince Lombardi, understood the concept of "back to basics." After a rare loss, he would meet with his players, look each one of them in the eye, and say, "We must get back to basics." Everyone expected a lecture on blocking and tackling, which he would get into; but first, he would pick up the ball, hold it up in front of everyone and seriously proclaim, "Gentlemen, this is a football!" To understand how to apply lean and six-sigma, and how their combination will fare, the "basics" must clearly be understood. Many are oftentimes overlooked even by the best of companies in their headlong pursuit of instant profits.

As discussed in the background section, the basics of six-sigma initially appear to be very simple based upon process variability reduction. Later, the scope of six-sigma expanded into the management realm and confusion resulted due to overlaps with lean. What is six-sigma? John Allen states that the six-sigma objective is customer satisfaction through improvement in quality. It is both a quality and an improvement process resulting in dramatic quality improvements and cost reduction. Six-sigma is the goal: products and processes will experience only 3.4 defects per million opportunities, the sigma value is a metric indicating process performance, and, sigma measures the capability of the process to perform defect-free work.[5] Corrective action comes in the form of defect, cycle-time, and cost reductions.[6] Further, by defining quality in terms of value rather than in terms of defects, six-sigma quality involves a search for ways to reduce *muda* (waste in any form -- defective work, time, motion, and materials). Thomas Pyzdek proposes the following definition for six-sigma: a general approach to reducing *muda* in any environment; a collection of simple and sophisticated methods for analyzing complex cause-and-effect relationships; and, a means of discovering opportunities for improvement. Six-sigma applies to the problems addressed by lean but also seeks to solve other problems common to a high-variety production process.[7] How does six-sigma translate to the bottom-line results that Jack Welch saw at General Electric? Table 1 gives the answer in terms corporate executives understand.

Table 1 -- Sigma and Cost of Poor Quality[5]

Sigma Level	Defects/Million Opportunities	Cost of Quality
2	308,000	Not competitive
3	66,800	25 to 40% of sales
4	6,210 *Industry Average*	15 to 25% of sales
5	233	5 to 15% of sales
6	3.4 *World Class*	< 1% of sales

Lean manufacturing can be defined as an enterprise philosophy which shortens the time line between the customer order and the shipment by elimination of *muda*.[5] As mentioned earlier it was introduced into this country by Toyota and is known as the Toyota Production System (TPS). Its definition has been expanded by Michael George to cover any process. He states that lean is a methodology used to accelerate the velocity and reduce the cost of any process (be it service or manufacturing) by removing waste. Lean is founded on a mathematical result known as Little's Law: Lead time of any process equals the quantity of "things in process" divided by the average completion rate per unit of time. The lead-time is the amount of time taken between the entry of work into a process (which may consist of many activities) to the time the work exits the process. In procurement, the "things in process" are the number of requisitions; in product development, the number of projects in process; and, in manufacturing, the amount of work in process (WIP). Lean contains a well-defined set of tools that are used to control and then reduce the number of "things in process," thus eliminating the non-value added costs driven by those "things in process." Whereas, six-sigma is most closely associated with defects and quality, lean is linked to speed, efficiency, and waste (identified using the Value Stream Mapping methodology). Six-sigma does not contain any tools to control lead time (e.g., Pull Systems), or tools specific to the reduction of lead time (e.g., setup reduction).[8] When properly implemented, a lean production system can dramatically improve productivity (by as much as 95% when compared with traditional batch-and-queue production systems).[7]

Why then are so many companies "backsliding" or reaching plateaus? In Japan the decade of the 1990's was an economic "downer." The fortunes of its manufacturers were the same. One reason for worsening inventory patterns (discussed earlier) may relate to Japan's cherished, though fading, reluctance to reduce labor. In the face of declining sales, an excess labor force just keeps overproducing.[1] Overproduction is the largest contributor to *muda* in manufacturing operations today.[9] Here are six other reasons why most companies are not getting lean:[1]

1. Complacency -- fallout of the prosperity of the 1990's.

2. Stock-hyping deal making -- executives looking past the basics of good process management.
3. Growth and retention of unprofitable customers and product variations -- the company's fault for not bringing sales and marketing into multi-functional teams with finance and operations.
4. Legacies -- mega-machines that produce fat inventories (overproduction), outsized factories that require marathon product flow distances (poor layout), systems that bog down rather than link up manufacturing and supply chains, and job designs that instill mindless boredom rather than inspiring waste-chopping ideas (lack of empowerment).
5. Retention of command-and-control management that stifles broad development (and employee empowerment).
6. Job-hopping managers and engineers who launch initiatives but do not follow through, and favor "what's hot?" and lose touch with "what's still good but not."

Complacency and job-hopping are already on a course of self-correction. And the "basics" of solid management are back in style, especially in the aftermath of the Enron debacle.

Lean and Six-Sigma can become "friends"

How can one develop and implement a custom strategy for a particular operation that gets the best, most applicable aspects of both lean and six-sigma without confusion and duplication? Jim Womack, President and Founder of Lean Enterprise Institute, concludes that everyone making a "lean leap" will need to deal with capability issues (TQM/Six Sigma) and with availability issues (total productive maintenance, or TPM) while removing steps and introducing "flow" and "pull" in every value stream (TPS). He further concludes that there is no "right sequence" to follow in tackling these problems. Rather, it depends on the nature of the product, the nature of the process technology, and the nature of the business. He says, "Where there is a 'right' versus a 'wrong' is with leadership and management."[10]

Thomas Pyzdek, Six-Sigma consultant and author of The Complete Guide to Six Sigma, says that the approaches should be viewed as complements of one another and can be combined to develop a high degree of synergy as shown in Table 2:

Table 2 -- The Synergy of Six Sigma and Lean Production[7]

Lean	Six-Sigma Contribution
Establish a methodology for improvement.	Policy deployment methodology.
Focus on customer value stream.	Customer requirements measurement, cross functional management.
Use a project-based implementation.	Black-Belt project management skills.
Understand current conditions.	Knowledge discovery.
Collect product and production data.	Data collection and analysis tools.
Document current layout and flow.	Process mapping and flowcharting.
Time the process.	Data collection tools & techniques, SPC.
Calculate process capability & takt times.	Data collection tools & techniques, SPC.
Create standard work combination sheets.	Process control planning.
Evaluate the options.	Cause-and-effect FMEA.
Plan new layouts.	Team skills, project management.
Test to confirm improvement.	Statistical methods for valid comparison.
Reduce cycle times, product defects, changeover time, equipment failures, etc.	Seven management tools, seven quality control rules, design of experiments.

Companies that consider only lean without six-sigma concepts are missing out and can have the following problems:[11]

1. Poor choice of the best projects to work on, which could result in either sub-optimizing the system or making the system worse.
2. Typically six-sigma tools such as Design of Experiments (DOE) are not formally considered.

For companies that consider only six-sigma without lean concepts, there are benefits to lean:[8]

1. Lean will add another dimension of improvement in process speed and reduction of non-value added costs, which provide more responsiveness to changing customer needs, and improve the company's competitive position.
2. By accelerating process speed, lean provides faster feedback and more cycles of learning which enhances the power of six-sigma tools. For example, a Design of Experiments might require about 100 separate runs to optimize parameters and minimize variation. Reducing the lead time by 80% will allow the fractional factorial design to be completed five times faster.

Theory of lean

Very little has been done for determining what is theoretically possible, or practical, other than optimization through simulation programs. In the excellent textbook, ***Factory Physics***, by Hopp and Spearman, of Northwestern University and Georgia Tech respectively, Little's Law is used and modified mathematically to account for "maximum randomness" in the production system.[9] The assumptions are that the production line is balanced, all stations consist of single machines, and process times are random and occur according to an exponential probability distribution. This simplified model provides a good tool for "internal benchmarking" to see how lean the current process is operating versus the theoretical case. One formula indicates whether or not the process line is considered lean by providing the theoretical cycle time for a given WIP level with a given bottleneck rate and processing time sum for the stations; and, the other formula provides the theoretical throughput for a given WIP level. Anything equal to or higher than these numbers indicates the process is operating in the lean region. Now we are getting to something that can be taught effectively, based on the science of manufacturing. Armed with the statistical & management tools of six-sigma, the practical lean tool of "Value Stream Mapping," and the applied theoretical tools of ***Factory Physics***, students have demonstrated they can effectively perform productivity-improvement projects in most manufacturing operations in companies in the middle Tennessee region. As engineering educators we must be sure to teach, not only the techniques presented, but also the underlying theory. Confusion is eliminated and students will understand effective application for each circumstance encountered.

Summary and Conclusion

After reviewing the history of both lean and six-sigma, it becomes apparent why the two approaches can be viewed as competitive due to their overlapping areas -- primarily in the management function and waste-reduction techniques -- in solving productivity and quality concerns. Also, it is apparent that certain processes are more suited for one approach over the other with automotive assembly favoring lean; and semiconductor fabrication, six-sigma. Most processes fall between these two, so it makes sense that a combination of both approaches would be practical. Indeed, based on the experience of leaders in both fields, there is a growing consensus that both approaches complement one another. If applied properly, based upon the nature of the product and/or process technology, a synergy results that is not possible with just one or the other. The key is visionary management that is willing to lead change in the corporate culture, empower their subordinates, provide an environment of continuous improvement; and, most importantly, realize that lean and six-sigma are not the latest "program of the month" subject to discarding if results are not immediately forthcoming. These approaches are not just a set of tools, but a corporate philosophy that takes years to implement and sustain. Multi-fold productivity and quality improvements are realistic and are necessary if manufacturing operations are to survive in a competitive global economy. Therefore, it is imperative that manufacturing management become better educated in order to understand that lean and six-sigma are not "foes," but are "friends" that need to be applied properly if their organizations are to achieve world-class standing.

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