# Rejuvenate Six Sigma and Lean: an Inquisitive Approach

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**Abstract**

*Six Sigma and Lean are the recent developments in continuous improvement methodology that have been popularized by several high-profile companies. The success and complementary nature of these methodologies has led to their combination into a single methodology, commonly called "Lean Six Sigma". A Company we studied uses Six Sigma to constrain improvements in product quality and achieved significant bottom-line results over several years. Recently, the company incorporated Lean principles to confront waste and cycle time, and witnessed additional improvements. But the company has now encountered cycle time and waste problems for which Lean approaches are not working. By combining Six Sigma and Lean, Six Sigma exclusively to perk up quality and Lean exclusively to improve process flow by reducing waste and cycle time, the improvement must come on all fronts: quality, cost, delivery, customer satisfaction and more. In this paper a comprehensive approach of Six Sigma and Lean with a case study is demonstrated.*

**Keywords:** *Six Sigma, Lean, Cycle Time, Customer Satisfaction*

## Comprehensive Enhancement—the Eventual Objective

Six Sigma and Lean manufacturing are the most advanced methodologies in the current scenario. Although the overworked warning seems familiar, it bears repeating: The leveling effects of globalization and IT have enabled organizations and individuals around the world to compete successfully. The objective is not to integrate Lean and Six Sigma but rather to improve performance as comprehensively and sustainable as possible. Six Sigma and Lean can be successful by-

- Taking a comprehensive view of the business and of business improvement.
- Adopting a comprehensive improvement method.
- Establishing an integrated project management system.

## Comprehensive Vision

Reducing waste, cycle time and variation, alone will not result in success. A comprehensive approach to improvement— a broader view of how to improve business performance and a deeper understanding of the various approaches to improvement is needed.

A comprehensive approach to improvement:

- Works in all areas of the business.
- Works in all cultures, providing a common language and toolset.
- Addresses all key measures of performance.
- Addresses all aspects of process management, such as process design, improvement and control.
- Addresses all types of improvement, including manufacturing, non-manufacturing, transactional, service and administrative.
- Includes a management process for improvement such as plans, goals, budgets and reviews.

## Craft a Comprehensive Improvement Methodology

As figure 1 suggests, many companies have focused on Lean or Six Sigma, but rarely both, individually have an improvement approach. Today, some organizations are working to integrate the two under a common name called as 'Lean Six Sigma'. To achieve maximum performance improvement, however, Lean, Six Sigma and other approaches should be as part of a comprehensive improvement method. An effective improvement method must be able to improve quality, cost and delivery anywhere in the organization and anywhere in the world. Lean principles and tools can be used to deal with issues of waste, cycle time, process flow and non-value added work. Six Sigma tools can be used to shift the process average, reduce the variation around the process average, find the operating sweet spot, help create robust products and processes, and reduce waste and cycle time.

Figure 1. **Evolution of Lean Six Sigma**

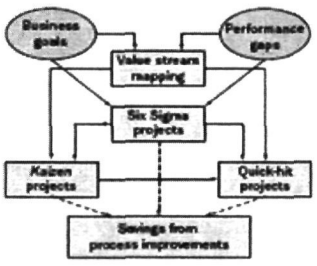

The other improvement tools such as Redesign, the General Electric (GE) Workout Approach' to basic team problem solving with minimal tool use, and Baldrige assessments can also be useful. However, in a comprehensive improvement method, the overarching strategy is not to run parallel improvement programs but to create a system in which Lean and Six Sigma mutually reinforce each other. For instance when Six Sigma is applied to reduce variation in process flow or Lean is used to improve the quality of products that might age rapidly by improving flow through the system and reducing cycle time to the end customer.

The execution of projects in this comprehensive improvement method can be guided by the familiar Define, Measure, Analyze, Improve and Control (DMAIC) approach. Although DMAIC originated in Six Sigma, it can be sharply distinguished from the Six Sigma tools with which it is associated and generalized to a higher level as an overall framework for process improvement. Then the tools that are appropriate to a particular problem—whether they are Six Sigma or Lean tools—can be applied at the appropriate point in the highly structured and sequenced approach of DMAIC. There are improvement tools, "Six Sigma tools" or "Lean tools" simply as a convenience to indicate those tools typically associated with each of these initiatives.

## Integrated Project Management System

To create a comprehensive improvement method, create an integrated system for managing projects rather than separate systems for Lean or Six Sigma projects. The TQM Guru, Joseph Juran admonished, "improvement happens project-by-project and in no other way." The project management system should therefore employ a project-by-project selection and management approach. With effective project management system, there should be processes to guide and sustain improvement, project tracking and review, communications, recognition and reward, and training.

Figure 2. **Novel Approach to Project Selection**



- For Lean and Six Sigma to be as effective as possible—that is, to achieve and sustain desired improvements—nothing is more critical than project selection. Before the project starts, the project selection process identifies the right improvement approach and thus identifies the right personnel and tools to be used. This principle not only takes project selection to a new level but also puts the selection of both the project and the improvement approach ahead of personnel selection. Many organizations mistakenly begin with personnel selection.

  Figure 2 illustrates the novel and powerful approach of selecting the right projects that includes elements both of Six Sigma and Lean, all with the ultimate goal of achieving maximum sustainable process improvements. Although there are many types of improvement projects, process improvements typically result from three major types of projects, requiring varying amounts of time for completion:

- Kaizen projects are typically completed in 30 days or less.

- Six Sigma projects are typically completed in four to six months but are often completed more quickly.

As Figure 2 advocates, these different types of projects are generated directly or indirectly from business goals or performance gaps. A top-down approach employs business goals to generate projects, while the bottom-up approach addresses performance gaps that arise from within the operations of the organization. Business goals and performance gaps can directly generate Six Sigma projects, which is the customary approach for project selection in purely Six Sigma improvement systems.

But in the comprehensive approach described here, goals and gaps can also provide inputs for Value Stream Mapping (VSM); a technique often employed in Lean can also be used to generate Six Sigma projects. For example, Six Sigma is usually used to address complex problems for which the solution is unknown. If a VSM effort uncovers a complex problem with no known solution, then a Six Sigma project might result.

A Six Sigma project might uncover quick hits or generate Kaizen projects in the course of its execution. If VSM uncovers non-value added activity for which Lean tools might be appropriate, then a Kaizen event might be convened to brainstorm solutions. The kaizen event then might initiate a Kaizen project. Employing Lean tools, it might uncover a quick fix or find there is no known solution, which would then generate a Six Sigma project. The Lean Six Sigma projects category is conspicuously absent from the framework. That's because in a holistic improvement method, in which the overarching goal is improvement—no matter how it is achieved—all projects are, in effect, Lean Six Sigma projects. They draw on a common toolbox that contains tools that have in the past been kept apart. Depending on the nature of the problem, of course, tools traditionally regarded as Lean or tools associated with Six Sigma might dominate. The types of commonly encountered improvement needs are:

- Streamline process flow to reduce complexity, decrease downtime, shorten cycle time and reduce waste
- Improve product quality
- Achieve consistency in product delivery
- Reduce process and product costs
- Reduce process variation to reduce waste (such as the waste of defective products)
- Improve process control to maintain stable and predictable processes
- Find the sweet spot in the process operating window
- Achieve process and product robustness

In all these cases and others, the nature of the improvement to be pursued and the root causes standing in the way help define the appropriate approach and tools to be used. In

cases when shifting the process average or reducing process variation is appropriate for the problem at hand, Six Sigma will dominate. In cases where improving process flow or reducing process complexity is appropriate, Lean tools might dominate.

## Process Performance

In the real world, an opportunity for process improvement and the problems associated with it are rarely one-dimensional. Such opportunities often consist of multiple process steps as well as process flows between the steps. However, Lean and Six Sigma approaches can be used to deal effectively with reduction of waste, cycle time and non-value added work (Figure 3). This is another mark of the desirability of truly integrating Lean and as Six Sigma to make available the best possible tools, regardless of the origin of their method. Figure 4 illustrates, information and material flow between the process steps (between the boxes). They are often the root cause of poor process performance. But value adding transformation takes place at the process step, which might also harbor these root causes of poor performance.

Figure 3. **Convergence of Six Sigma and Lean**

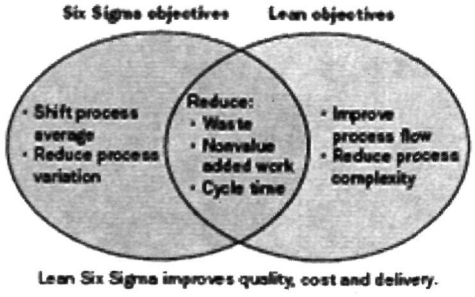
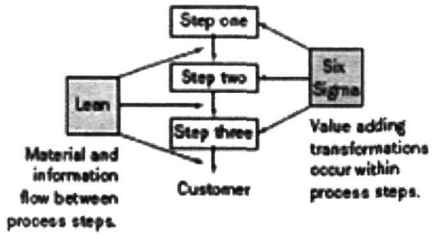



Figure 4. **Process Flow and Value Adding Tranformation**




Lean principles are typically highly effective when used to deal with the flow of information and materials, while Six Sigma approaches are typically most effective when used to address poorly performing value adding transformations. However, it is to remember that the goal is to get at the rootcause of poor process performance, not simply to focus where symptoms appear. For example, a poorly performing transformation can cause process flow problems, and poor flow can result in problems in the transformations (perhaps due to excessive aging of materials). It is therefore more effective to draw on Lean and Six Sigma simultaneously to achieve the maximum improvement possible and to address the entire root causes of poor process performance.

## Essence of Value Added Transformation

In the current state of improvement methods, issues of material and information flow and the ability of Lean principles to address them are relatively well understood. The power of those principles to simplify and streamline processes, as well as the relative simplicity of the principles themselves, is impressive. The process in which the product is created by process inputs coming together under the right process conditions and being physically or chemically changed to produce the product. For example, when two pieces of metal are welded together, critical factors include current level, weld material, and thickness and type of metal. In those processes, the transformation that occurs inside the box, where the welding takes place, is where problems are likely to occur. The case is even clearer in the extremely complex value adding transformations typically found in the chemical, pharmaceutical, biotechnology and high-tech industries. Often, in those situations, developing functional models of the form $Y = f(X)$ is frequently needed to

understand. This is not to argue that one approach is superior to another but that both are needed to aid our understanding optimally address performance gaps. Both approaches affect the outcomes that have traditionally been seen as dependent on one or the other's approach.

## Value Stream Mapping - a Case Study

Value Stream Mapping is the Lean technique used to analyse the flow of materials and information currently required to bring a product or service to a consumer. At Toyota, where the technique originated, it is known as "Material and Information Flow Mapping". It is converged to detect the potential improvements that can be achieved, to enhance the Quality & Manufacturing aspects of the components that are available in 'Undercarriage Track Chain Assembly', which is being mounted on to various earth moving vehicles. All the vital processes that are concerned to the salient components of the 'Track Chain Assembly' are emphasized to perceive the areas of enhancements and abridge the manufacturing process, in turn leading to furnish better Productivity, Quality and Profitability for the firm. Value Stream mapping method (VSM) is a visualization tool oriented to the Toyota version of Lean Manufacturing (Toyota Production System). It helps to understand and streamline work processes using the tools and techniques of Lean Manufacturing. The goal of VSM is to identify, demonstrate and decrease waste in the process. Waste being any activity that does not add value to the final product, often used to demonstrate and decrease the amount of 'waste' in a manufacturing system. VSM can serve to help management, engineers, production associates, schedulers, suppliers, and customers recognize waste and identify its causes. As a result, Value Stream Mapping is primarily a communication tool, but is also used as a strategic planning tool, and a change management tool.

The imperative objectives of Case Study accentuate:

- Meticulous study of Undercarriage Chain Link Assembly
- Methodologies and modus operandi of Manufacturing Processes.
- Effective utility of Plant & Machinery and Human work.
- Augment Quality and diminish errors.

The major advantages in prospect are yielding excellent productivity, condensing lead-time and better material handling. Although Value Stream Mapping is often associated with manufacturing, it is also used in logistics, supply chain, service related industries, software development, and product development. The activities become easily separated into the value stream which is the focus of one type of attention and the 'waste' steps another type. The value stream is the process and the non-value streams is the operations. The thinking here is that the non-value adding steps are often preparatory or tidying up to the value-adding step and are closely associated with the person or machine/workstation that executes that value adding step. The Value Stream Mapping method visually maps the flow of materials and information from the time products come in the back door as raw material, through all manufacturing process steps, and off the loading dock as finished products. Intensely mapping out the activities in the manufactu-ring process with cycle times, down times, in-process inventory, material moves, information flow paths, helps to visualize the current state of the process activities and guides towards the future desired state. The process usually includes the physically mapping of the "Current State" while also focusing on the "Future State" map,

which can serve as the foundation for other Lean improvement strategies.

The case study accomplished under the epithet "Value Stream Mapping of Undercarriage Track Chain Assembly" is a major break through for augmenting the productivity and quality attributes. The modifications were incorporated in by noticing the belligerent aspects by adopting brainstorming. The modifications were estimated theoretically and practically to meet the stringent quality standards resulting in better manufacturing resource planning for implementing the KAIZEN approach. Kaizen is a process of continuous improvement. Normally processes become less efficient, and produce lower quality, as the machinery and equipment ages. The idea of Kaizen is to not only maintain the equipment to keep it as good as new, but to continue to make minor modifications that tailor it better to the process, for example making it interface better with upstream and downstream handling, part supplies and so on. The case study helped to enhance productivity and manufacturing resource planning for the mechanism of Undercarriage Track Chain Assembly. A Sample case study is illustrated below,

## Die Setting

Total time for die setting 2.5 Hrs

Production loss for 2.5 hrs Rs 33000

Output of 1600 T press will be ideal during the die setting

Clamping and declamping done manually

Due to improper torque, part dimensions varies from setting to setting

Proposed

Addition of a die holder assembly

Purpose of new design

To enhance production capacity in the existing facility

Benefit to the company

Off line die setting

The entire die holder can be moved out

The total cycle time for the above process accepted maximum 30 min.

Cost saving for two hrs Rs 33000 (250 No.s / Hrs x 66)

## Comprehending Process Variation

Process variation is the main course of quality problems, whether in business (transactional) or production processes. The main task of statistical process improvement methods such as Statistical Process Control, Six Sigma and Measurement Systems Analysis and the Taguchi approach to Experimental Design is to control and reduce process variation. Process variation and process precision are closely related. A process with little variation is said to be 'precise'. When studying process variation it is important to make a clear distinction between process accuracy and process precision.

Process variation provides another window into the desirability of combining Lean and Six Sigma. Process variation that results in defective product, scrap and rework also impedes process flow. The root causes of the variation might be differences between operators and process teams, differences in raw material lots, poor process understanding and control, and numerous others. But the consequences are the same: reduced process flow due to increased inventory, increased material movement, overproduction, and wasted motion. Process flow improvement studies should therefore not be confined to Lean principles but should also include analysis of process variation.

**Table 1**
**Customers Food Process Variation**

| Supplier | Delivery time (days) | Mean | Range |
|---|---|---|---|
| 1 | 17,2,5,12,4 | 8 | 15 |
| 2 | 7,9,9,8,7 | 9 | 2 |

Customers, too, often feel the impact of process variation. Typical delivery times for two suppliers are shown in Table 1. Although supplier one sometimes delivers products in as few as two days, customers prefer the more predictable delivery times of supplier two. In some cases, in fact, delivery too early is worse than too late if the customer is not ready to receive it. Delivery is typically thought to be an issue of process flow, and the application of Lean principles to reduce non value added and wasteful steps might help improve supplier one's performance. But process variation must also be taken into account to achieve maximum improvement.

## From Understanding Variation to Understanding Processes

Understanding process variation leads to process understanding and you cannot improve or control a process you don't understand. In fact, sustainable improvement depends on process understanding. Developing models of the form Y = f (X) are a highly effective way to achieve such process understanding. Understand a process:

- Critical variables (Xs) that drive the process are known
- Critical uncontrolled variables (noise) that affect the process outputs (Ys) are known
- The process has been designed to be insensitive to these uncontrolled variations (robustness)
- Measurement systems are in place, and the amount of measurement variation is known
- Process capability is known
- Effective process control procedures and control plans are in place
- The performance of the process over time can be reliably predicted

Lean Six Sigma provides the concepts, methods and tools for developing process understanding. Six Sigma brings rigorous approaches for developing cause and effect understanding, and Lean brings proven principles based on a wealth of knowledge and experience across the globe.

## Self-effacing Proposal

Despite the nearly universal imperative for organizations to focus keenly on growth and productivity to remain competitive in the 21st century, many organizations lack a comprehensive method for improvement that could deliver the maximum possible benefits. Lean arose in environments such as automobile manufacturing, where assembly was paramount and addressing problems of process material flows over greatly improved performance operationally and financially. Also, decreasing various kinds of waste often meant a drive to simplify and streamline processes. Six Sigma arose in environments such as high tech and chemicals, where value-adding transformation dominated. Reducing variation often meant an effort to optimize, stabilize and control the interaction of complex variables. Instead of seeing these two approaches as opposed, it is far more productive to see them as complementary. Achieving comprehensive improvement requires both the ability of Lean to achieve simplicity and the ability of Six Sigma to manage complexity. Harnessing their mutually reinforcing power most effectively requires a comprehensive improvement system that:

- Focuses on improvement of the entire business
- Uses a careful project selection process that identifies the right projects and right improvement strategies for each project
- Uses a generalized DMAIC framework to guide projects
- Encompasses robust improvement methods that can handle the wide variety of problems an organization experiences as well as the wide variety of problems encountered in individual projects

- Employs analysis of process variation as part of any improvement project
- Strives for process understanding using Y = f (X) thinking to sustain improvement

## Conclusion

The recommendation of this research is that a continuous improvement initiative's success should be measured using existing metrics, voice of the customer, and employee satisfaction. Existing metrics will indicate the bottom line business benefits realized. The voice of the customer will accentuate the external reaction to the continuous improvement initiative's implementation. Eventually, employee satisfaction will further drive culture change throughout the organization. All that is required is a modest shift of perspective. Instead of narrowly pursuing Six Sigma, Lean or simplistic versions of Lean Six Sigma and achieving only temporary improvement, we can successfully meet the challenges of 21st century competition by encompassing multiple improvement methods in a comprehensive system. In such a system, the ultimate criterion of success is neither reduced waste nor reduced process variation, but achieving maximum sustainable improvement.

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