INTEGRATING SIX-SIGMA AND THEORY OF CONSTRAINTS FOR CONTINUOUS IMPROVEMENT: A CASE STUDY

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ABSTRACT

Facing an ever increasingly competitive market, manufacturing firms must make changes to improve their operations. This study proposes an integrated framework combining Six Sigma and Theory of Constraints (TOC) to illustrate how the two techniques can complement each other to improve performance. A case study of company implementation is presented.

Keywords: Six Sigma, Theory of Constraints, Continuous improvement

INTRODUCTION

Various continuous improvement (CI) strategies have been developed and applied to improve manufacturing system performance. This paper studies the combination of two distinct strategies, Six Sigma and Theory of Constraints (TOC), for improving manufacturing system performance. We first review these two strategies and the processes involved in each strategy. The possibility of integrating them for improving manufacturing system performance is examined. We then apply this integrated approach to a manufacturing company in the Midwestern United States that specializes in the production of axles. The effect of this integrated approach is examined and finally suggestions of applying this integrated approach are made.

Six Sigma is a business process improvement methodology first espoused by Motorola in the early 1990s. The Six Sigma strategy involves the use of statistical tools within a structured methodology for gaining knowledge needed to achieve better, faster, and less expensive products and services than the competition (Breyfogle III, 1999). A Six Sigma initiative in a company is designed to change its culture through breakthrough improvements by focusing on thinking out-of-the-box in order to achieve aggressive stretch goals. When deployed appropriately, Six Sigma can infuse intellectual capital into a company and produce unprecedented knowledge gains that could translate into shared bottom line results (Kiemele, Schmidt and Berdine, 1997).

The implementation of Six Sigma strategy involves a series of steps specifically designed to facilitate a gauntlet of process improvement. The strategy takes the key manufacturing, engineering, and transactional processes of entire process through the five transformational phases.

1. Define: Identify customer needs and a project suitable for Six-Sigma effort.

2. Measure: Determine how and what to measure the performance of the selected process.
3. Analyze: Understand and determine the variables that create quality variations.
4. Improve: Identify means to remove causes of defects and modify the process.
5. Control: Maintain the improvement.

The primary objective of the five-step process is to recognize critical customer requirements, identify and validate the improvement opportunity, and upgrade the business processes. A large number of companies have boosted their profitability, increased market share, and improved customer satisfaction through the implementation of Six-Sigma. Companies such as Allied Signal, General Electric, Sony, Texas Instruments, Bombadier, Crane Co., Lockheed Martin, and Caterpillar are beginning to directly see the impact of Six Sigma to their bottom line (Harry, 1998).

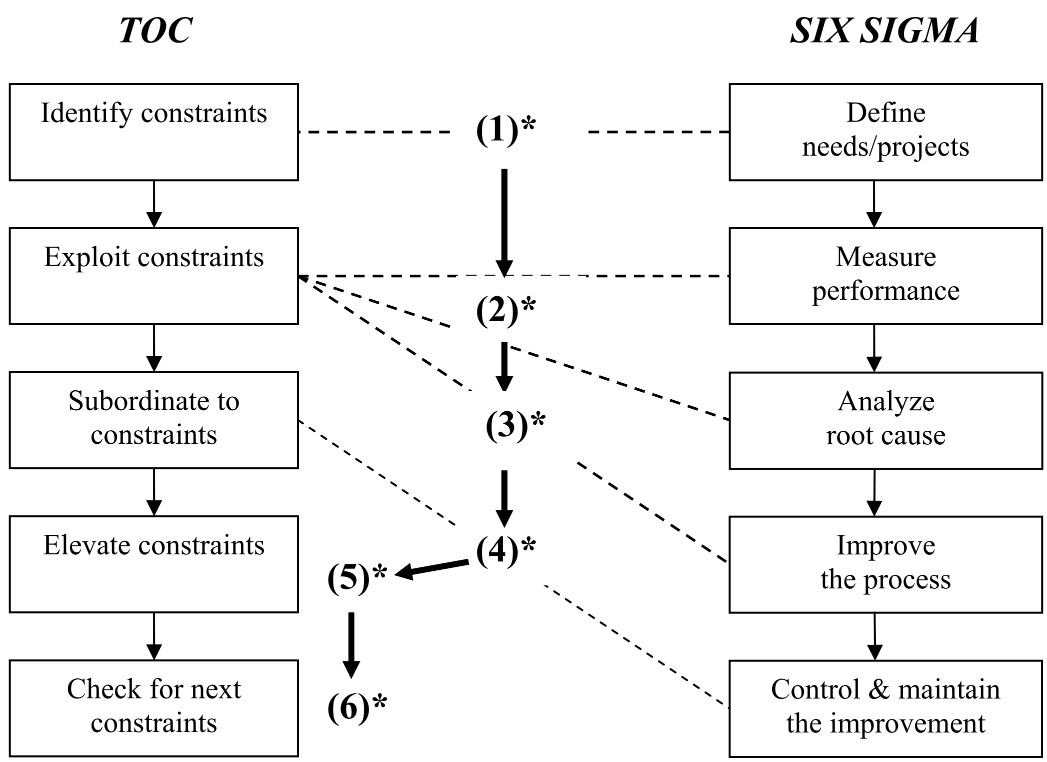
Theory of Constraints (TOC) was developed by Eliyahu M. Goldratt during the 1980s. The core idea of TOC is that every organization has at least one constraint that prevents management from achieving the goal of the organization to a larger degree. Constraints can be physical resources or policies. TOC develops a set of procedures and methodologies to identify and optimize such constraints. For the purpose of continuous improvement, TOC uses a systematic approach which consists of five focusing steps (Goldratt and Cox, 1992).

1. Identify the system's constraint(s).
2. Decide how to exploit the system's constraint(s).
3. Subordinate everything else to the above decision.
4. Elevate the system's constraint(s).
5. If a constraint has been broken, go back to Step 1. Do not allow inertia to cause a system's constraint.

Similar to the Six Sigma improvement process, the TOC five-step improvement process has been applied by many companies successfully (Cox and Spencer, 1998; Mabin and Balderstone, 1999). When one compares these two techniques, Six Sigma and TOC, one would naturally ask the following questions: how do these two techniques complement each other? Can they work together, or do they exclude each other? While different vocabularies may be used, both methods actually are very consistent with focusing on identifying key variables, designing critical measures, improving key processes, changing current systems to support improvement, and monitoring the results of improvement. Overall, these two strategies seem to complement each other. TOC could serve as the framework for continuous improvement, and Six Sigma could provide specific statistical tools and engineering techniques for implementing changes. Figure 1 proposes an integrated continuous improvement framework that combines TOC and Six-Sigma.

Step 1 of this integrated framework is identical to both strategies, and its purpose is to identify current constraint(s) that block the improvement of global performance, such as meeting customer needs or improving system throughput. Accordingly, a specific process is selected for improvement. Steps 2 and 3 follow the spirit of TOC by exploring the capacity of the current process.

Figure 1. An Integrated CI Framework: Combining Six Sigma and TOC



Step 2 measures the current performance of the process and identifies the root causes that need to be corrected. The two phases of Six Sigma, measure and analyze, are involved in this step. Once the root causes are confirmed, Step 3 applies conventional Six Sigma strategy by using the key manufacturing, engineering, and statistical techniques to remove root causes of the problem for making necessary process improvement. The purpose is to best utilize the current capacity of the process.

Step 4 ensures the changes made are properly supported by the rest of the system. For example, managers may need to change policies and obtain buy-in from employees to implement the changes. Training is often required for a revised process. Steps 5 and 6 are taken from the TOC process. If the improvement of the current process is insufficient to satisfy customer needs or goals, managers have to consider additional investment to raise the capacity of the process. Finally managers must stay alert to the dynamic nature of the manufacturing system and monitor new constraints. The remainder of this paper applies this proposed integrated framework to actual company implementation.

THE CASE

ABC Corporation is a leader in the development of modular systems technology and a worldwide resource for engineering, research, and development. The company is one of the world's largest independent suppliers of vehicular components to automobile manufacturers. It employs nearly 80,000 people worldwide and has sales reaching over $10 billion. One of the divisions of ABC Corporation, Axle facility, manufactures a variety of axle products and related components for internal operations for original equipment vehicle manufacturers including DaimlerChrysler, Ford, Isuzu, and Land Rover. The Axle division incorporates the latest advanced technological manufacturing systems and engineering methods to perfect product design in a very cost-effective manner. Each new component and axle system is put through rigorous testing, such as fatigue, metallurgical, dynamometer, and chassis dynamometer/quiet chamber testing. Axle uses the latest and the most effective manufacturing technology to produce quality products.

The Axle facility had extensive experience in applying Six Sigma to its process improvement. After learning about TOC, managers decided to combine TOC and Six Sigma to guide their improvement effort. With careful study and planning a project team was formed, and the proposed integrated framework was adopted to make the improvement. The various stages of the process implementation are discussed below.

Phase 1: Identify the constraint and determine the process to be improved

According to TOC and Six Sigma, the first phase of making improvement involves identifying the constraint(s) that block the goals of making money and satisfying customer needs. A specific operation is then selected for improvement. In this study, sales have eroded 23% due to a declining production target, and there was need to increase asset capacity without incurring additional capital expenditure. The management team made a thorough evaluation of the plant processes from the aspect of customer satisfaction and throughput. While there were many operations that could be improved for potential benefits, the team focused on the global impact of the next local improvement suggested by TOC. Specifically, traditional unit cost reduction or local operations productivity increase was not used to determine the improvement effort. Instead, the impact of the improvement on overall quality of axle and system throughput was used to select the improvement project. Based on the feedback from the customers and capacity analysis, the gear cutter operation in the manufacture of the axles was chosen as the target for improvement. The project team confirmed that increasing the gear cutting capacity would increase the plant throughput and bottom-line performance.

The project team discussed options of purchasing more cutting capacity. The company was using a solvent-cutting device where the cutting head was lubricated to increase the shelf life of the cutting blades. Newer technology in this process had advanced to dry cutting, a significant increase in the life of the blade, thereby increasing the capacity. However, with the capital constraints facing the plant, it was not feasible to upgrade to the dry cutting process. Therefore, following the TOC concept, the team decided to "exploit" the current technology before making investment to "elevate" the constraint or purchase additional cutting capacity. In other words, the plant was to utilize the current solvent-based cutting machines and find ways to increase quality and throughput without additional capital expenditures. The machine cycle that includes the cutting operation is both a customer and operational value-added activity. Improving the yield of a high-value added activity such as blade cutting would increase the overall capacity of the plant. A Pareto analysis of the cutting operation was conducted, and it was found that about

75% of the downtime was due to the blade cutting operation. Increasing the gear cutting effective capacity would have a positive impact on bottom line financial performance.

Phase 2: Measure current performance and identify the root cause

At this phase the performance measure of the selected process is determined and analysis made to identify the root cause for poor performance. This is a very critical stage of the process because any breakthrough in process improvement stems from measurement to establish some baselines. Labor utilization was used as the measure to drive the improvement effort on the cutting operation. Current labor utilization was first determined over a two-month period. This was done to establish a baseline for the study. Labor utilization was about 65 percent, which indicates the proportion of parts produced through the cutter process actually met customer quality specifications. The performance outcome established for this process was 85 percent labor utilization.

To identify the root cause of poor labor utilization, the project team analyzed the downtime experienced at the cutter process. The project team discovered that the cutter grinder showed up quite often when tracking downtime on the cutting machines. This was due to the fact that many cutting heads sent to the machines did not reach their maximum shelf life. When this happened, the cutter grinder found it hard to keep up with production schedule, and the cutting machines sat idle while waiting for blades to be ground. Therefore, low labor utilization was due to the idleness of the cutters created by the dullness of the blades, which must be ground to extend their shelf life. A dull blade would result in number of defect-prone items that included rough finish along the cutter lines and machine crash. Cutter downtime was further analyzed using both the Pareto chart and the fishbone diagram to hone in on the critical-to-quality factors. The major findings were that the oil coolants used during the cutting process were being deflected from the blades that cut the coastline of the ring.

Phase 3: Exploit the constraint by improving the process

In this project, the key cutting process variables were identified by way of statistically designed experiments. For each process variable that proved to be leverage in nature, performance specifications (tolerance) were established. While tracking the downtime of the cutting machines, the project team discovered that many cutting heads sent to the machines did not reach maximum life, which made it impossible for Cutter Grind to keep up with production schedules. Consequently, cutting machines set idle while waiting on blades to be ground. The critical element here was to increase the blade efficiency, reducing the downtime and subsequently increasing the labor utilization. The goal was to design a system that would have equal flow and pressure for the blades that cut the drive and the coast sides. After careful analysis of the current process, the project team found that little coolant reached the blades, since most of the coolant was deflected from the blades that cut the coast side of the ring.

The solution was to acquire a locally manufactured muffler pipe that discharged an equal flow of coolants to all faces of the cutting operation. Because pressure and flow were important to the life of the cutter body, several actions were taken to insure that filters were changed on a timely basis. The first action taken was to install coolant lines that would feed coolants to the coast side of the cut. This increased the yield of the blades and increased their shelf lives.

Phase 4: Subordinate the systems to sustain the improvement

Once the new processes are in place, the goal shifts to supporting the change and monitoring the processes to make sure the improvements are sustained (Plotkin, 1999). The phase is designed to document and monitor the new process conditions via a statistical process control methodology. In this study, the operators were equipped with the appropriate statistical tools to help monitor the new process. Process capability was reassessed on an ongoing basis to ensure that the improvements were being maintained. Additional training was necessary to support the changes. A greater portion of employee training was held on the job, because the company retained the same experienced technicians who were running the machines before the process improvement. Finally, a crucial aspect of the control phase was the buy-in of the operators in the new system. The company had a gain-sharing plan in which its employees share benefits from any improvements made. In this project, many employees received additional pay from the savings resulting from the implementation of the Six-Sigma/TOC improvement. The additional employee-sharing benefits reduced most of the resistance to the changes.

This project had clearly improved the cutting operation by raising its utilization from 65% to approximately 85%. Meanwhile, the yield increased from 106% the first week of implementation to an approximate average of 130% the next four weeks after implementation. Since the first four phases were able to improve the cutting process significantly enough to address current customer needs, there was no need to “elevate” (i.e., acquire) cutting capacity.

CONCLUSIONS

Many studies have investigated the conjunction of various CI techniques, such as TOC and JIT (Cook, 1994; Rahman, 1998), TOC and TQM (Ronen and Pass, 1994; Lepore and Cohen, 1999), and TOC and Reengineering (Libby, 1994). This study adds to the CI literature by demonstrating the value of a method of combining TOC and Six Sigma. Specifically, we proposed an integrated TOC/Six Sigma framework and applied this framework to an axle manufacturing company to improve its gear-cutting operation. Under this framework, TOC outlined the direction of improvement considering system constraints and throughput. Six Sigma provided various statistical tools and engineering techniques (such as value analysis and control charts) for defining the specific process to be improved, analyzing the root causes, and designing actions for making improvement. After the implementation of the change, the TOC/Six Sigma framework ensured the new change was supported and substantiated by proper employee training and continuous monitoring. Communication for obtaining buy-in was made to reduce resistance to changes from employees. Ultimately, the gear-cutting project improved labor utilization, increased throughput and quality of the cutting operation, and reduced the inventory level of blades. It was estimated that the project resulted in a total saving of $200,000, exceeding the average savings for a typical Six-Sigma project. The integrated TOC/Six Sigma approach was clearly a success.

REFERENCES [Available Upon Request]