# INTEGRATED USE OF TOC, LEAN AND SIX SIGMA IN QUALITY ASSURANCE OF MANUFACTURING PROCESSES

*Lesya DEMCHUK, Roman BAITSAR*

*1 Postgraduate, Ukraine, demchuk_2@mail.ru*
*2 Doctor of Technical Sciences, Ukraine, baitsar@ukr.net*

**Abstract**:
Classic intention, which pursues the management of any company – is to improve the quality and competitiveness of its own production, aiming at the end to speed up the receiving of profit. Such an implementation is primarily made possible by optimizing production processes.

The manufacturing processes are influenced by various factors that may lead to deviations from the process requirements. Management of processes is needed to counteract such change in the process.

Processes that are not managed, can lead to the production of a large number of defective products earlier before the detection of nonconformity, causing significant damage and lead to disruption of production schedules. It is important to develop an effective system of management and control, capable of detecting variations in the process as early as possible so you can take corrective action before it is produced by a large number of defective products. To optimize production processes in quality assurance the following systems have been known as TOC, Lean, Six Sigma. Typically, these systems are used separately. However, their combination and comprehensive utilization can be more efficient and can give a much better result.

As a rule, first by using theory of constraints (TOC) the bottleneck is defined – weak area, which is an obstacle of improving of the quality and efficiency of the company and profit increasing. Then Lean tools manage this area. And the next phase includes Six Sigma, which allows you to receive a significant increase in the effectiveness and efficiency of production and profit.

Each of these techniques is unique and their complex usage is important in managing the quality of processes and products.

**Keywords:** Optimization of manufacturing processes, Quality assurance, Combined usage of quality management tools

## 1. INTRODUCTION

One of the important areas of modern society, which involves the bulk of all labor, material, energy, financial and intellectual resources, is manufacturing. Industrial production is the basis of the sustainability of society and functioning of all its social institutions. The state of industrial production, its effectiveness, technological and technical level, organization, performance management, resource and financial security depends on the nature and rate of social development.

Thereby the problem of efficient organization of industrial production is especially important and requires a comprehensive substantiation of all decisions, actions and activities that are aimed at the formation, development and effective functioning of production structures. Effectively implement the functions that can only manufacture which ensures maximum effectiveness.

Achieving high efficiency in modern conditions is a complex task. Its complexity is caused by the fact that efficiency depends on many factors of different nature, sources and causes. The main of these factors include: the technology of production, productivity, capacity resources, technical means of production (machinery and equipment), employee`s qualification, the level of organization and management of production processes, production conditions. Development of industrial production has led to the fact that modern industrial enterprises in organizational terms are presenting extensive and complex production and technological systems [1]. This leads to difficulties in forecasting, planning and management of such systems to maximize their effectiveness. These difficulties can be explained by following. High-tech, modern facilities and an appropriate level of workers training do not guarantee the achievement of high economic performance. It is necessary to ensure proper functioning of this whole complex as a single system.

This harmonization is carried out at organizational and technological preparation of production process, while the following questions are being solved what methodology should be applied for production process, what production means their number and characteristic features should be involved (machinery and equipment); how the production management system should be organized; which specialists are needed, their profession, qualification, quantity; how all of these elements must interact in the production process (the sequence of their inclusion in to the process, the relationship between them). That is the tasks of management of production processes.

The basis for solving problems is the usage of the relationship between financial and economic parameters of the operation of each production process element and results of operation of the whole enterprise. Only on the basis of this interaction, proper management and regulation it is possible to orgaznize the performance of the production process and identify its technological, organizational, financial and economic parameters aimed at achieving the necessary economic performance and ensuring the financial stability of the company.

It should be noted the management of production processes [2], representing the basis for the rational production organization belong to the many factors, the most severely affecting the economic results of the process.. Management is a complex of actions to be executed by the process control for effective production, i.e. production, which will result in obtaining the necessary technical and economic results. Achieving of these results is possible only due to ensuring appropriate management functions.

However, the problem is, that till now there is no comprehensive systematization of these functions with described contnet and their interactions. This has negative consequences due to the fact that the creation and development of control systems for complex manufacturing systems with modern irregular structure of the functions of management leads to significant complications, or inability to address many organizational, administrative and economic tasks with corresponding negative effects.

Therefore, the best solution of the problems describe is combination and practical application of three methodologies: Lean manufacturing, Six Sigma and Theory of constraints.

## 2. MATERIALS AND METHODS

The content of this article is based on the researches of the known popularizers of Lean manufacturing (James Womack,Jeffrey Liker) [3,4], the Theory of constraints (Eliyahu M. Goldratt, William Detmer) [5-7] and Six Sigma (Bill Smith, Jack Welch) [8], aimed at practical application at the building of business processes the philosophy of continuous process improvement and avoiding various kinds of constraints. The long-term sustainable development in the coming years will be available only for the companies, which are continuously searching the optimal organizational decisions regarding the effective establishment of quality control of production processes. First, let us consider each methodology.

*Theory of Constraints*

Logical, consistent approach, that focuses on improving of the whole system. It operates first of all at the chain of values defining the weakest link or limitation. According to the theory of constraints (TOC) an enterprise is considered as a system (as an aggregate of interrelated elements) that is created for a particular purpose. The purpose of business is to ensure profit and investment profitability for shareholders; for state institutions - to provide an appropriate level of service. Therefore, before improving individual components of the system, it is necessary to define a global target and indicators, to judge the impact of each subsystem and each local solution to a global goal.

Constraints ("bottleneck") is that which impedes the system to achieve higher efficiency towards the goal (for industrial enterprises is that which impedes to increase profits).

Goldratt`s Theory of Constraints comes from the fact that at any given point of time the system has only one restriction. "Bottlenecks" can be any portion of the company - workshop, warehouse, machine or even a particular person. If there were no constraints, the profit would be limitless. However, the constraints are keys to the system management. At proper management restriction can "bump" the whole system to a new level. Concentration of efforts on constrint can make a significant breakthrough in the performance of the company. The task of management is identifing maximum use and "expansion" of the "bottleneck" because one hour of outage means the entire hour of downtime. In other words, the challenge is to ensure that the constraint as a source of the problem turned into a source of income.

*Lean production*

In recent years, many countries actively explore Japanese`s enterprise management system, becuase the rapid and successful economic development of the country allowed it to take the leading place in the world.

Lean Manufacturing (Lean production) – is a system for organizing and managing product development, production, relationship with suppliers and customers when products are manufactured in strict accordance with the needs of consumers and with lower losses compared to the mass production.

The purpose of lean manufacturing concept is to get rid of all epxenses and maximize resource efficiency through continuous improvement of all processes of an organization, aimed at improvement of customers satisfaction. “Lean Manufacturing" system can be implemented due to a significant reduction or even removal processes that do not bring value. These processes include transport, storage, expectations, control and defects, excessive movement, move, and others. Elimination of these processes is a challenging job. Decreasing the proportion of those processes in production, can significantly reduce production costs and thus the cost of production without losing quality. It is not possible to completely eliminate the costs of quality assurance, but they can be reduced to an acceptable level.

*Six Sigma*

Six Sigma is an approach to improving the business, which aims at finding and eliminating the cause of errors or defects in the processes by focusing on the output parameters that are critical to the consumer.

The concept of "Six Sigma" is a philosophy of excellence in business, where the emphasis is on customers satisfaction and continuous improvement processes and willingness to make decisions based on actual statistics.

Greek letter "sigma" in statistics means mean square (standard) deviation of individual values of the characteristic comparing to some mean value. Average deviation is the square root of the variance.

The essence of the concept of "Six Sigma" is to reduce process variability and stabilize the characteristics of the product. Index of tolerance for some important product characteristic must have a natural variation in the production within stable limits, and should be kept within these limits 12 times, which is «± 6σ».

The main idea of this approach is aptly formulated by company General Electric: «Our customers are sensitive to variation and not to mean". Indeed, consumers are more interested not in average statistics, but in the quality of a particular product purchased.

The features of the concept of Six Sigma are: wide use of statistical methods, focus on customer satisfaction, the use of engineering methods to achieve tangible results, focus on the end result.

## 3. EXPERIMENTS

These three methods are used for the improvements from different sides. But this does not mean that these methods are not compatible, we can say that they complement each other.

Every time it is necessery define the specific tools that will work best in a particular situation. It is always better than using only one tool.

In many cases the problem/-s is are common and visible and the choice of one of these methods is not a big issue. But sometimes some problems are more complex and require proper assessment and reassessment of key-processes. In such situations, TOC, Lean and Six-Sigma can act as a complete set of integrated tools. How to make decision which methodology and when to use for improvement? In fact most of the companies have limitations. Therefore improvements initiatives should be evaluated and distributed by priority in the context of their impact on the subsequent limitations of the company. The TOC provides here a framework for measuring of the initiative`s influence, and a line allows to determine where concentration is required.

TOC will provide you a different approach to find and define the real pain areas of the company and enable a better alignment of Lean or Six-Sigma projects. This leads to a clear focus during the define phase of Six-Sigma and ensures that the project starts in the right direction and with the right goal to address the core issues of the company.

The selection of any such methodology depends on the nature of problem and on organization`s culture. If the problem requires an analytical and systematic approach then TOC and Six-Sigma combination can work better while if you want visual changes in short span in systematic manner then Lean or TOC can be combined. So, when you want to increase throughput and, at the same time, meet customer expectations along with adding value for the customer - you need a correct mix of these improvement methods. However, before you start with such a project it is imperative that your company's environment is ready to take it up. That is applicable right from the infrastructure to human resources, to culture. Also, you should be aware of the speed at which the chosen method would be accepted at your organization.

In any case a right combination of these methods can deliver much better results than expected independently if you are already using one of these methods or you are about to begin. Integration of TOC, Lean and Six-Sigma begins with correct strategy. The strategic roadmap provides the direction for the areas of the organization that can benefit total system by applying improvements first. TOC identified constraints can get more throughput with the help of Six-Sigma implementation while Lean can help to eliminate any waste associated with it. They might also be used to drive out disruptive variations or reduce wastes in non-constraint processes that interfere with the constraint. Suppose, if the constraint is in the market; that is, if you have more capacity than demand, then internal Lean and Six-Sigma projects should be aimed at doing things that will make the systems' offerings more attractive to potential customers - typically associated with customer response time and reliability of offered promises, etc.

Finally, it is important to understand that all three methods discussed here i.e. TOC, Lean and Six-Sigma are compatible to each other and are complementary. By using right tool, right job can be done by working on the correct issue. This integrated approach facilitates focused and lasting improvements which improve efficiency of the company as a whole and also provides few more benefits such as:

- Improvements that benefit the entire organization, not just a single department
- Increased profits with a better return of investment
- Process stability which improves strategic target achievements
- Project and deployment failures happen not because of the methodology, but usually because they are implemented in the wrong way.

So, in due course of implementation few precautions like differences among these methodologies with regard to balanced systems should always be kept in consideration. You should be aware that where Lean and Six-Sigma tend to improve certain area by reducing wastage or variation, TOC focus only upon system level constraint for the higher level process.

Any change is worthwhile only if it brings desired improvement and to bring such a change sometimes you need to take a step further than whatever methods you are currently using. To accomplish this, you may need to integrate Lean, Six-Sigma with the Theory of Constraints to help in focusing project efforts on the areas that are hampering business or need further strengthening. Without that level of focus, real and sustainable benefits are hard to come by. This integrated approach can actually simplify things by providing a focused and systematic mechanism for improvement initiatives.

## 4. RESULTS

For understanding the importance of methodologies combination, the global California`s electronics manufacturer with 21 manufacturing sites, 45,000 employees and 211 team leaders, who stood in the front of the growing demand from its major customers in the medical, aerospace and defense, precision machining, telecommunications and computer industries will be considered as an example . There was concern, that each manufacturing site is not using the best approach, and leaders were striving to find solutions and establish appropriate processes [9].

As a result of dissatisfaction the company has hired the consultants, which have made a unique conclusion: to combine the best components of TOC, Lean and 6 Sigma. The leaders of the company hoped that this new methodology will help them to optimize processes to achieve maximum cost reduction and quality improvement. As a result:

- 11 manufacturing sites used 6 Sigma;
- 4 manufacturing sites used Lean;
- 6 manufacturing sites applied TOC, Lean and 6 Sigma.

211 team leaders of manufacturing sites studied and then used one of these three methodologies. During more than two years of research production companies completed 101 projects. These projects were analyzed to obtain accurate data about improvement, cost reduction and approaches.

The company measured and tracked a series of key process measures which were decisive in projects selecting. These indicators include delivery time, warranty costs, customer revenue, reduce inventory and reduce cycle time. Combining of methodologies is deployed as a standard approach for the process of continuous improvement. The sequence of operations begins from the application of TOC`s management philosophy. This allows users to investigate the problem and find existing or potential constrints.

After defining the problem at the system level, the mobile teams developed a definition of specific task, which refers to the bottleneck of the organization.

The next step was to define the flow value creation (a process of development, production and delivery of goods or services on the market).

Concurrent use of tool Lean 5S (sorting, setting in order, shine, standardizing, sustaining) was also considered at this stage. These steps must give order and process discipline, help to maintain any progress and to promote continuous improvement as work style.

Then users have to implement a system for drawing out of material, taking care that the materials are not put into production until a signal is received from the user. As a result, the company will be able to develop products or services only on request. The focus here should be directed to produce the right amount of product at the right time and delivered it to the right place. To do this, it is necessary to create a new flow. At this stage of the process input variables must work consistently and repeatedly with minimal variability to achieve better results in waste minimizing, cancellation and processing. This led to the following steps - five and six - of the Lean methodology process: to strive for excellence and introduce flexibility.

In pursuit of excellence the improvement methodology of 6 Sigma («Define, Measure, Analyze, Improve, Control") has been applied. It allows workers to identify and isolate the source of the deviation of the process and systematically remove or minimize these deviations.

Statistical process control is another important task, since it allows users to apply statistical methods for control and correction of operations.

Finally, there should be a process audit worked out to examine performance over time. If any deviations are observed during the audit, they should cause the creation of corrective and preventive action plan.

Methodology for process optimization has brought much more benefit for the company. In particular, its share was 89 per cent of the total resulting cost reductions. 6 Sigma by far the winner came second with contribution of 7 per cent, the share of Lean had 4 per cent of different independent applications.

As a result of investigations of selected integrated application of lean manufacturing, six sigma and theory of constraints there remains no doubts about the reasonability of their combination.

## CONCLUSIONS

The practice of quality management of production processes a multifaceted with existing problems and unsolved problems. To ensure efficient operation of production units it is necessary to solve these challenges quickly and find practical solutions on how to work in specific conditions of production processes.

It is important to know, what should be done and how exactly to improve the quality of management processes, since their order of execution is largely dependent on the nature of products, forms of production organization and so on. They should be progressive and reflect the current level, use advanced methods of technical control and processing, to ensure increased productivity and product quality, reduce costs, reduce harmful effects on humans and the environment.

One of the fundamental principles of quality assurance is continuous improvement. The process of continuous improvement is essential as a means of improving the effectiveness and efficiency of the organization, improve customers and other stakeholders satisfaction.

Indisputably, as shown by numerous examples of famous companies, integrated implementation of three methodologies in the development of modern manufacturing is extremely important. Any change makes sense only if it brings the desired result. Integrating Lean, Six-Sigma and Theory of constraints is one of the most promising combinations of methodologies that provide an opportunity for focused and long-term improvements in both production processes and in the organization as a whole.

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