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Using Six Sigma DMAIC to improve the quality of the production process: a case study

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Abstract

Over the last two decades there has been a growing awareness of the need to improve quality in the industrial sector. This paper presents how to implement the DMAIC cycle as an element of continuous improvement in practice. In order to achieve it, the problem of quality and quality improvement is widely discussed. Based on the recognized problem in the organization, an analysis with the application of DMAIC is done. The propositions of improvements, which can be implemented in the organization in order to increase the effectiveness of production process, are also presented.

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Keywords: DMAIC; quality; improvement; Six Sigma

1. Introduction

Nowadays, there is a huge pressure on organizations to improve the customer satisfaction and quality in the organization, and at the same time to decrease ineffectiveness and reduce the number of errors. The organizations have to solicit to gain and keep customers, because now, they are the key elements that drive economy. There are many different conceptions, methods and tools that may be used to maintain the good quality level and help in continuous development in the company (Zu, et al., 2008; Bendoly, 2016; Gołaś, et al., 2016). For example, it can

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be Six Sigma which is an innovative method of quality management introduced in Motorola by Bob Galvin and Bill Smith in the middle of the eighties (Schroeder et al., 2008; Evans & Lindsay, 2014).

"Sigma" is a notion taken from statistics. It means any standard deviation of the random variable around the mean value. Therefore, Six Sigma means six times the distance of standard deviation. To achieve Six Sigma a process cannot produce more than 3.4 defects per million opportunities. A defect is defined as anything outside the customer specifications (Moosa, & Sajid, 2010; Lei, 2015). It is inseparably connected with the principles of TQM. Due to its dynamic character it has become one of the most effective tools in continuous development and pursuit of excellence. Six Sigma has developed and systematized many statistical and business tools while reducing costs, defects and cycle time of production, and at the time increasing market share, maintaining customers, product development. Its program can be used at every stage of the production and administrative process (Zu, et al., 2008; Glasgow et al., 2010).

Six Sigma is perceived as a philosophy or concept of a broad sense. Using it as a philosophy helps with changing the world and transformation of an enterprise. Treating it as a strategy ensures development and increases the position of the company. It is based on six main principles which should be implemented in companies that want to develop and increase their position on the market. The very first point is concentration on the customer. Every action, which is taken, should be in agreement with customers' specifications and requirements. Six Sigma is also based on real data and facts which are used to perform a detailed analysis. It is based on continuous improvement of all aspects of functioning development in the organization as well as proactive management and cooperation without boundaries at every level in enterprise. It should be underlined that it is not only an approach for solving the problems with manufacturing but also business processes (Taborski, 2010).

2. DMAIC cycle

Among many different tools of quality management which may be considered as methods of quality improvement, there are two main ones used in Six Sigma concept: DMAIC and DMADV (Kumar & Sosnoski, 2009; Jones, et al., 2010). DMAIC is an acronym from the words Define-Measure-Analyze-Improve-Control. This method is based on process improvement according to Deming cycle. It is a process improvement of many different areas in the enterprise. DMAIC cycle consists of five stages which are connected with each other (Sokovic, et al., 2010; Sin, et al., 2015):

- Defining the goal and its requirements:
  - ✓ defining needed resources and responsibilities,
  - ✓ defining organization structure which is favorable to achieve the goals,
  - ✓ identification of the elements and setting the estimated date of the end of project,
  - ✓ obtaining support from management.

The main purpose of this stage is to verify if the actions, which should be taken in order to solve the problems, are connected with the priorities in the organization and that there is support from management and availability of required resources. It starts with identifying the problem which needs a solution and ends with understanding this issues as well as a clear evidence of management supervision. There are a lot of ways how to identify a project for improvement. Firstly, it is better to focus on external factors, which create the cost for organization and take the actions to eliminate them and after that solve the internal-costs problems. A useful tool which helps to narrow the problem can be Pareto diagram (Shankar, 2009).

- Measuring the current process:
  - ✓ identification of valid and reliable metrics,
  - ✓ checking if there is enough data to measure,
  - ✓ documentation of current performance and effectiveness,
  - ✓ performing comparative tests.

The measure stage concerns gathering information about processes which are going to be improved. It focuses on

information which is needed in order to better understand all the processes in organization, customers' expectations, suppliers' specifications and identification of the possible places where a problem may occur. It may be done by creating a process map of the actual situation and performing failure mode and effect analysis (FMEA) which will indicate the places of possible risk. The main issue of the measure phase is to collect and analyze the data which will be needed in the control phase to show the differences and assess the progress which will be presented to the management. It is also essential to assess the measurement system and to ensure that all data are veritable and collected in a proper way (Shankar, 2009).

- Analyzing the results of measurements, determining the causes of process imperfections and possible solutions for them:
  - ✓ identification of key reasons for problems,
  - ✓ identification of the differences between current and target performance,
  - ✓ estimation of resources required to achieve target,
  - ✓ identification of possible obstacles.

In the analyze stage different tools and methods are used to find root causes, assess the risk and analyze data. To confirm the analysis some samples should be performed and potential problems have to be proven to be real problems. In this phase it is needed to define process capability, clarify the goals based on real data gained in the measure phase and start root cause analysis which has impact on process variability. By calculating process capability which is defined as "sigma" of the process, ability of the process to meet customers' requirement is measured. Process capability will be a key point for planned improvements.

- Improving the process, implementing the changes, which eliminates the imperfections:
  - ✓ preparing the structure of work division,
  - ✓ developing and testing possible solutions, selecting the best one,
  - ✓ designing the implementation plan.

The goal of this stage is to take necessary information to create and develop an action plan in order to improve the functioning of the organization, financial aspects and customer relationship issues. The possible solutions for the action plan should be presented and performed. Some kind of pilot solutions, confirming the validity and accuracy of analytical work which allows to make any corrections before applying the solutions on a large scale, are carried out.

- Controlling of the improved process, monitoring the results in a continuous way:
  - ✓ documentation of the plan of standardization and process monitoring improvements,
  - ✓ confirmation of the improved procedures,
  - ✓ transferring the ownership of the relevant teams after the completion of the project.

The control stage is about confirmation if changes implemented at the improve stage are sufficient and continuous by verifying the quality of the improved process. It also controls the future state of the process in order to minimize deviation from the objectives and ensure that the correction is implemented before it would have bad influence on the result in the process. Control systems such as statistical process control should be implemented. The process has to be continuously monitored. In the control phase control charts are used to identify if the process is controllable or not.

Six Sigma allows to implement scientific methods in the organization to deliver the best value to the customers. There are also some additional steps that should be taken in DMAIC cycle:

- observation of important issues of the business and external environment,
- development of a hypothesis based on this observation,
- making predictions upon hypothesis,
- testing the predictions and further observation, conducting experiments and using statistical methods,

- repeating two last steps and comparing the hypothesis to the results for observation and experiments (Pyzdek, 2014).

3. Case Study

3.1. Defining the problem

The research study started with a meeting in the company to discuss its problems. A deep analysis of the whole production process was carried out. As a result of it some bottlenecks connected with visible downtime in the production process were observed. They referred to performing the process of connecting blocks and covers on the machine Kolbus BF 511. There were also others machines, which were used for this kind of activities, but only this one had low effectiveness. The first issue to deal with, was to eliminate all the external factors which resulted in the lower effectiveness of the process and then focusing on the internal ones.

At the meeting with the managing director and production director it was established that in a case of any needed support the management would be ready to help. Every person involved in this project had to declare that he understood his own position and responsibilities in performing and focusing on continuous improvement of quality in the whole organization. The roles for performing this project mainly involved: Managing Director, Production Director, Production Manager, the representative of financial aspects and Quality Controller. The needed resources were defined as internal documentation of the company as well as own an observation of the processes on a production line. The deadline of the project was set up for the end of April 2016.

As one of the main issues of the whole Six Sigma project is to focus on a customer, his needs and requirements for the process had to be defined. The investigated company had only B2B (business-to-business) customers which meant that it did not cooperate with individual clients. The main customers for this enterprise were the biggest publishing houses from Poland and abroad, and their main requirement was to have orders on time. In order to provide them high quality products and services it was essential that the production process run smoothly with the greatest effectiveness and without any unnecessary downtimes.

3.2. Measuring data

After the problem was defined the next step was to collect historical data to get the information about processes which were to be improved, check if there was enough data, documentation of the current situation and also perform the comparative tests. However, the main assumption was to collect and measure data which would be needed at the control stage in order to show the differences and asses the progress. The obtained data are shown on Figure 1.

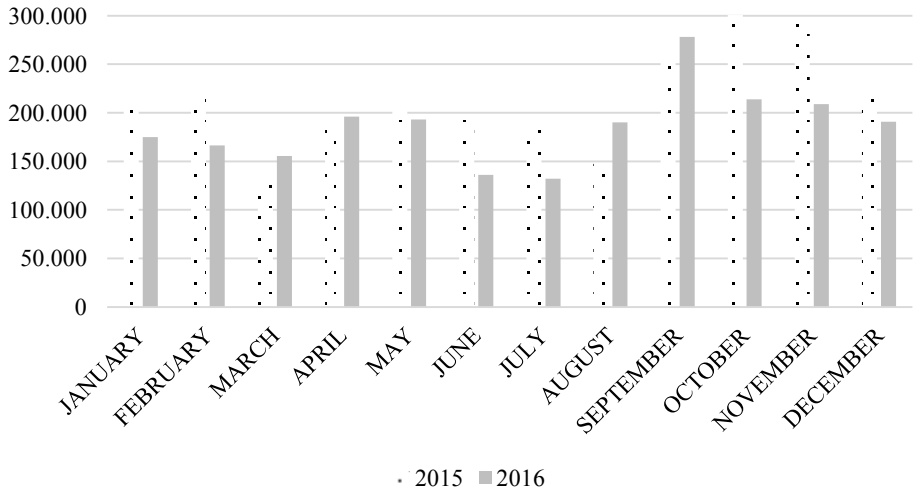

Fig. 1. Efficiency on the machine BF 511

As it can be seen the effectiveness in year 2016 was lower than in 2015. The biggest difference appeared in October and November, which were the most productive months connected with a calendar season. In October the difference was 86 464 pieces and in November 86 246 pieces in comparison to the previous year. It resulted from the fact that there was an increase in orders from the customers, but decrease in their edition (number of printed volumes in one order) what led to the increased number of changeovers on this machine .

3.3. Analyzing the main issue

In order to analyze the effectiveness of the machine Kolbus BF 511 brainstorming was performed. At first it was organized in a form of an individual brainstorming and then there was a discussion about different ideas and propositions. Every person involved had to present their own ideas in the form of a list on a Flipchart. On the basis of these data it was possible to determine four main groups:

- work organization
- machine
- method
- man.

In a case of work organization the implemented control system was not sufficient enough to control the work organization of every employee. Moreover, bad organization resulted from too long time spent on changeovers on the machine due to too many customer's orders. Till then the orders performed on this machine were selected by the earliest date of delivery of materials what influenced negatively the production cycle to a large degree.

The technical state, age, construction of the machine and unexpected breakdowns also decreased the effectiveness of the analyzed production processes. As the years were passing by, the machine was getting older. Its maintenance was time-consuming and required engagement of employees from the company. However, the cost of a new machine was really high and not adequate to benefits.

Another group of causes referred to methods of work. They were divided into: lack of instructions and procedures, old technology and specification of production. The lack of procedures and clear instructions was an impediment especially for new machine's operators. They had to be informed how to choose formats of orders to make the process much more effective. Although, this company developed quickly and tried to follow new trends there was still old technology which slowed the production process and influenced its effectiveness.

Low effectiveness of the production process also resulted from the lack of experience, qualification and knowledge of the employees, their predisposition, culture and motivation for work. In the company there were not organized any trainings except obligatory health and safety training. The workers were not aware that their daily actions contribute on a large scale to the functioning of the whole organization. As there was no bonus system the lack of motivation for work was clearly visible. The predisposition of employees was also very important as some people were more willing to work in specific conditions than others. It can be connected with their psychophysical conditions which should be checked before hiring a new employee.

4.4 Improvement proposition

The first improvement proposition was to perform Single Minute Exchange of Die (SMED) on the machine Kolbus BF 511 to reduce the time needed for changeovers and set-ups during production time. In order to achieve it, it was proposed to:

- gather parts and tools at spot,
- eliminate internal operations,
- simplify set-up to reduce adjustments,
- replace only necessary parts and make all others as universal as possible,
- measure time.

It was suggested to develop and complete the external set-up checklist to define the needed tools, materials and gauges and their storage location. Moreover, it was proposed to develop and fill in a set-up observation form on the basis of video of the process. As its results there should be done a classification of activities into internal or external groups. Internal activities concern actions that can be only performed while the machine is shut down, whereas, external activities can be performed while the machine is running. Thus, this division should lead to the conversion of all possible internal actions to external set-up. For this aim, the employees, who perform the changeover or set-up, should be invited and they should participate in brainstorming. In the next step, if it is possible, standardization of tools and "one-touch" fasteners could be introduced. Furthermore, the possibility of performing operations simultaneously could be taken into consideration. The introduced propositions should be measured in time to evaluate their effectiveness.

Another proposition how to increase the quality of production process on the machine Kolbus BF 511 was to perform trainings for the employees to make them aware how their actions contribute to productivity on this machine and the whole production process. There is also a need to introduce clear instructions and procedures at workplace. Each employee should know how to perform their tasks correctly. It is necessary to ensure that the workers know how to collect orders for the process of connecting blocks with the covers. This issue does not only concern machines' operators and workers at the production line, but mainly employees working with production planning and control.

The last proposed improvement concerns the implementation of Total Productive Maintenance (TPM) which is a maintenance of machines and equipment performed by operators and workers inside the organization. It is based on the elimination of breakdowns, changeovers, downtimes, decrease of speed of work, errors and corrections. It requires involvement of machines' operators for daily routine activities, not only employees from maintenance department as it is in traditional methods.

4.5 Continuous control

After implementing the changes they should be controlled to check if they influence the production process positively and bring any profits to the company. It can be performed by creating a control plan where it should be exactly define what data, how, how often and who should control. If any non-conformance is detected, instructions regarding needed actions to undertaken, should be also included. Over time, such a plan should be updated depending on the evaluations after its implementation.

4. Conclusions

Nowadays, Six Sigma is getting more and more popular among organizations from various industries. It focuses mostly on improving production processes what leads to the increase of profitability of the company. Achieving Six Sigma level requires from organizations understanding the reasons of processes variability, performing their analysis of cause and effect and the assessment of their costs. The application of DMAIC, which is one of the methods of quality improvement used in Six Sigma concept, can increase the effectiveness while adequate reacting for the appearing problems. As it was shown on the example of the machine Kolbus BF 511, it can be achieved by implementing SMED, trainings for employees, work standardization and Total Productive Maintenance and after that, it is necessary to introduce continuous control on the efficiency of the processes performed on that machine. The proposed solutions may bring many different profits not only for the company, but also for other entities involved in their functioning. Benefits of this implementation can be as follows:

- company - avoiding penalties for non-compliance with the agreement, lower costs of production, increased productivity, and consequently reduced amount of work in progress,
- customers - increased customer satisfaction due to increased timeliness,
- employees - increased comfort and better organization, lack of overtime,
- other - the possibility of taking more orders during the „calendar season".

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