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Statistical Process Control – A Method for Continuous Quality Improvement

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Continuous improving processes and product is must to excel in industry and sometimes necessary to sustain in completion. But it is perplexing to many companies, specifically for small and medium size. Many tools and methods are used by researchers for continuous quality improvement (CQI), success and failure depends on various factors, some of them are Lean, six sigma, etc. The intention of this paper is to review the implementation, benefits and challenges faced for SPC implementation with special emphasis on continuous quality improvement. The methodology uses a widespread review of literature through reputed publications — journals, conference proceedings, research thesis, etc. This paper provides an overview of SPC implementation to achieve continuous quality improvement. It should be of value to practitioners of SPC and to academics who are interested in how CQI can be achieved using SPC. It strained here that this paper is not intended to contempt SPC, rather, its purpose is restricted only to offer views toward SPC and CQI.

Keywords: Statistical process control (SPC), Quality, Continuous Quality Improvement (CQI), SMEs, Critical Success Factors (CSF).

1. Introduction

Over the years, the journey of quality tools and techniques is full of revelation. Many quality tools and techniques were adopted in the industry and advantages were also gained. The contributions of various quality tools and techniques in the industry growth, especially improvement in product and process quality, is highly cherished despite opinions that they have not brought about their intended result. Sometimes, its fact that small scale companies, suppliers to OEMs, only follows quality tools when enforced by their customers. In global competitiveness and quality consciousness end users make industry to produce products with highest quality with lowest cost which is not one company's job. It has to be maintained throughout supply chain and constantly achieved. Hence, it becomes utmost important to work on continuous quality improvement in all possible front. Many quality management and improvement tools have been evolved and proved, herein SPC is going to be explored for its impact on continuous quality improvement.

Statistical process control (SPC) is a methodology to the process control that has been widely used in many industrial or non-industrial fields. The main goal of SPC is an identification of variations with the aim to make the process stable, minimize the process variation and improve the process performance (Doshi, JA, et al., 2016 (a)). So, SPC is the application of statistical methods to the monitoring and control of a process to ensure that it operates at its full potential to produce conforming product. Under SPC, a process behaves predictably to produce as much conforming product as possible with the least possible waste. While SPC has been applied most frequently to controlling manufacturing lines, it applies equally well to any process with a measurable output. SPC techniques, in particular the control chart, have been widely used in the manufacturing industry. Usually, control charts are implemented for the purpose of process monitoring (Doshi JA, et al; 2014). SPC facilitates to monitor the performance of the manufacturing process in order to predict significant deviations that may later result in rejected product.

The control charts are of two types - control charts for variables and control charts for attribute. The control charts based on variable data that can be measured on a continuous scale, i.e. weight, volume, temperature etc. are known as control charts for variables. The control charts based on discrete data, which are counted as ‘‘present’’ or ‘‘not’’ are called control charts for attributes.

SPC indicates when an action should be taken in a process, but it also indicates when NO action should be taken. For example, a person who would like to maintain a constant body weight and takes weight measurements weekly. A person who does not understand SPC concepts might start dieting every time his or her weight increased, or eat more every time his or her weight decreased (Harsimran Singh, et al; (2016). This type of action could be harmful and possibly generate even more variation in body weight. SPC would account for normal weight variation and better indicate when the person is in fact gaining or losing weight.

2. CONTINUOUS QUALITY IMPROVEMENT AND SPC - IMPLEMENTATION CASE STUDIES

Indian industries have experienced many waves of transformation, both, before and after industrial reforms. The main thrust was on productivity based on Taylor's principles of scientific management. Quality was not the major area of concern. After industrial reforms, i.e., globalisation and liberalisation, quality surfaced as one of the major areas of concern along with productivity. By opening up of the geographical barriers and the compulsion of competing in the global market, overall operational excellence becomes the necessity for the Indian industries to remain globally competitive (Desai, 2012). The SMEs are often the suppliers of the larger companies, particularly in automobile sector that is very true; hence, the changes in the large companies affect the operations of SMEs. Some industries are consistently achieving the growth under competitive conditions while others are not. Nowadays, automotive OEMs are making compulsions of implementation of core tools, namely, APQP, FMEA, SPC, MSA and PPAP as an entry level, which gives them a sense of satisfaction on receiving parts. This has engendered demand of CQI to deal with this upheaval and to improve business performance for SMEs (Doshi and Desai, 2014).

The automotive sector is a prime example of quality management principles, illustrating both positive and negative implications of quality paradigms. They had revealed that the implementation of a consistent and sustainable quality approach is the foundation for process improvements, especially in the automotive industry (Raisinghani et al., 2011). If, on the other hand, management was only interested in implementing a rigid quality framework, then this was perceived as a pure tool, lacking both commitment and practices for employee empowerment and additional process adjustments. Companies pursuing this approach either fared worse than before or lost their business improvements shortly after the processes were implemented. They had concluded that, rather than implementing a rigid quality framework, it is more important to have a consistent and continuous quality approach, which applies at all levels and involves all employees, incorporating the organisational functions with a holistic approach. To ensure product quality is essential to remove errors respect to their resources. The research has highlighted a need for a specific and practical implementation framework for CQI through lean Six Sigma (LSS) in SMEs (Timans et al., 2014).

In quality improvement, many tools can be used but using them in amalgamation is more useful. The researcher (Doshi et al., 2012) had used Ishikawa diagram in the company with the help of available resources, many causes are contributing to the Fin problem. From the analysis of the fin opening problem, it seems major issues with the clamping device used in fin assembly area. However, they had suggested the use of further technical methods like SPC, MSA and Pareto analysis to priorities the each cause which helps to solve the problem properly. Quality control is much required in small automotive firms as to imitate the big companies as well as to match the quality to differentiate their product or services from their competitors. Furthermore, it will help automotive SMEs to improve significant returns, performance improvements, better teamwork and decision in services (Osman et al., 2009).

Rahardja (2005) compared the effectiveness of the X-chart alone to that of the individuals and moving range chart combination (X/MR charts), in terms of average run length (ARL) after designing for a common 'all OK' (in control) ARL. Comparison has been made under five different non-standard conditions, including both IID and non-IID circumstances. He conclude that adding the moving range chart to an X-chart, while generally not helpful for detecting IID departures from standard conditions, can be beneficial in detecting some non-IID conditions. Lillrank and Kujala (2006) examined on the applicability of SPC in non-repetitive processes and open systems, non-routine processes and project-based business activities. They also proposed guidelines for adjusting the logic of common and specific causes for project-based businesses are proposed.

According to Benton (1991) and Talbot (2003), the advantages of implementing SPC could be categories into the following categories, viz., maintain a desired degree of conformance to design, increase product quality, eliminate any unnecessary quality checks, reduce the percentage of defective parts purchased from vendors, reduce returns from customers, reduce scrap and rework rates, provide evidence of quality, enable trends to be spotted, ability to reduce costs and lead times. In other words, SPC implementation can also help to accomplish and attain a consistency of products that meet customer's specifications and thus fulfil their expectations. In general, SPC can be used to monitor the natural variation of a process and minimise the deviation from a target value and thus play a major role in process improvement. The range (R) charts are widely used in industries to monitor the process dispersion. Monitoring process dispersion is as important as monitoring the process mean. In actual practice, some process outputs are correlated, the performance of R chart may have adverse effect on it. Tao et al. (2012) have recommended managing in information system quality control and more generally to all control chart users in cases where outliers occur in the charted data. Sometimes to measure the performance of an information system, unusually long response times of database operation need to be identified. They had compared with Lloyd's SPC chart, and proposed an outlier resistant robust locally weighted scatterplot smooth (loess)-based control chart that identifies effectively all the out of control points of operation. Singh and Prajapati (2014) had counter the autocorrelation by designing the new R chart named modified R chart, based on sum of chi-squares. The performance of this modified R chart is computed for sample sizes of 3 and 5. It is observed that when the level of correlation (Φ) increases, the performance of the modified R chart deteriorates. The researcher (Shah and Booth, 2012) had presented that for the development of computer-based SPC, it would be useful to have an algorithm that performs the work of a Shewhart control chart without actually having to construct such a chart. They had tested the use of fractal dimension, an algorithm to track 'out of control' states and find it to be moderately successful and suggested the use of computer-based SPC system.

Some authors propose methodologies for SPC Implementation. Krumwiede & Sheu (1996) present six steps for implementation: getting support from senior management, choosing a leader of the SPC, determination of the production process for the pilot study, process documentation preparation, training in SPC and the construction of control charts. Kumar & Motwani (1996) suggest 16 steps to lead to the implementation, ranging from staff training for deployment to actions for process control. Does et al. (1997) present a model with four phases, involving awareness, pilot projects, full implementation and total quality. Mason & Antony (2000) and Antony & Taner (2003) propose a conceptual model for the implementation of the SPC, developed from the critical analysis of publications on the subject, which focuses on four key areas: management issues, engineering skills, statistical knowledge and skills for group work.

Doshi and desai (2016), had conducted research in two automotive SMEs to introduce and implement the SPC tool as one of the most effective techniques to measure and monitor the process accuracy and variations. Benefits observed after SPC implementation are identifying critical process parameters, identifying variations in process, analysing and eliminating them from the roots, quality improvement parameters and ways. SPC results indicates there is a high rejection rate due to process variation. Reasons for the same are different for each of the companies. The basic requirements of the manufacturing processes were studied in both the companies then the process capability index of the specific process is found out. To identify solutions to reduce rejections, root cause analysis and brainstorming sessions were conducted by the team of respective company. Recommendations were implemented and found that process capability is improved. Although the companies have many constraints to implement all suggestions for improvement within a short period of time, the companies recognised that further improvement is still possible, if the suggested improvement opportunities can be implemented in future, which again decrease the loss to the industry in terms of both money and time.

3. SUCCESS FACTORS IN THE IMPLEMENTATION OF THE SPC

The factors that affect the implementation of the SPC are complex and numerous (Rohani et al., 2010) and can be called Critical Success Factors (CSF). If there is a better control over these factors, the chance of success in the implementation of SPC is higher (Gordon et al.,1994; Elg et al., 2008; Rohani et al., 2010).

The implementation of the SPC involves technical factors and organizational factors, both are considered critical for successful implementation (Does et al., 1997; Elg et al., 2008). Xie & Goh (1999) emphasize an holistic approach to the implementation of SPC, based on three basis: the first, related to the SPC Management, which involves issues such as the role of senior management, focus on Continuous Improvement, training and teamwork; the second, related to the human factor, which presents resistance to change issues, difficulties with the use of computer technologies and the need for incentives; the third, focuses on the implementation of the SPC, including the use of appropriate tools for monitoring the process.

Based on extensive literature review for CSF, below is compilation of most cited CSFs.

Table 1. CSF for SPC implementation

Sr No	CSF	Cited by
1	Commitment and senior management responsibility	Gordon et al., 1994; Does et al., 1997;Rungtusanatham et al., 1999; Xie & Goh, 1999; Antony et al., 2000; Rungasamy et al., 2002;Antony & Taner, 2003; Grigg & Walls, 2007b; Chen et al., 2008; Elg et al., 2008;Phyanthamilkumaran & Fernando, 2008; Putri & Yusof, 2008, 2009; Rohani et al., 2009a, b;2010; Mahanti & Evans, 2012; Lim & Antony, 2013; 2014; Rantamäki et al., 2013; Lim et al.,2014; 2016; Sharma & Kharub, 2014
2	Education and training in SPC	Gordon et al., 1994; Rungtusanatham et al., 1999; Xie & Goh, 1999; Antony et al.,2000; Mason & Antony, 2000; Rungasamy et al., 2002; Antony & Taner, 2003; Grigg & Walls,2007b; Chen et al., 2008; Elg et al., 2008; Phyanthamilkumaran & Fernando, 2008; Putri &Yusof, 2008; 2009; Rohani et al., 2009a, b; 2010; Mahanti & Evans, 2012; Lim & Antony, 2013;2014; Rantamäki et al., 2013; Lim et al., 2014; 2016; Sharma & Kharub, 2014
3	Team work	Does et al., 1997; Rungtusanatham et al., 1999; Xie & Goh,1999; Mason & Antony, 2000; Antony et al., 2000; Rungasamy et al., 2002; Chen et al., 2008;Elg et al., 2008; Phyanthamilkumaran & Fernando, 2008; Putri & Yusof, 2008; 2009; Rohani etal., 2009a, b; 2010; Mahanti & Evans, 2012; Lim & Antony, 2013; Rantamäki et al., 2013
4	Identification and measurement of critical product characteristics	Does et al., 1997; Rungtusanatham et al., 1999; Mason & Antony,2000; Antony et al., 2000; Rungasamy et al., 2002; Antony & Taner, 2003; Grigg & Walls, 2007b;Chen et al., 2008; Elg et al., 2008; Rohani et al., 2009a, b; 2010; Mahanti & Evans, 2012; Lim &Antony, 2013; Rantamäki et al., 2013; Sharma & Kharub, 2014
5	Definition and correct application of control charts	Does et al., 1997; Rungtusanathamet al., 1999; Mason & Antony, 2000; Antony et al., 2000; Rungasamy et al., 2002; Antony &Taner, 2003; Grigg & Walls, 2007b; Chen et al., 2008; Elg et al., 2008; Phyanthamilkumaran &Fernando, 2008; Putri & Yusof, 2008; Rohani et al., 2009a; 2010; Mahanti & Evans, 2012; Lim &Antony, 2013
6	Cultural change and communication	Xie & Goh, 1999; Antony et al., 2000;Rungasamy et al., 2002; Chen

		et al., 2008; Elg et al., 2008; Phyanthamilkumaran & Fernando,2008; Putri & Yusof, 2008; 2009; Rohani et al., 2009a, b; 2010; Mahanti & Evans, 2012; Lim &Antony, 2013; 2014; Lim et al., 2014; Sharma & Kharub, 2014
7	Measurement system analysis in relation to its capability and applicability	Does et al., 1997; Rungtusanatham et al., 1999; Antony etal., 2000; Rungasamy et al., 2002; Antony &Taner, 2003; Grigg & Walls, 2007a, b; Chen et al.,2008; Rohani et al., 2009b; 2010; Mahanti & Evans, 2012; Lim & Antony, 2013; Rantamäki etal., 2013; Lim et al., 2016
8	Process definition and prioritization, focusing on waste, rework or variability problems	Does et al., 1997; Xie & Goh, 1999; Antony et al., 2000; Rungasamy etal., 2002; Chen et al., 2008; Elg et al., 2008; Rohani et al., 2009a, b; 2010; Mahanti & Evans,2012; Lim & Antony, 2013

CSFs for the implementation of the SPC can be related to three types of actions for implementation: managerial actions, organizational actions; and technical actions and training. Below is the detailed Actions and CSFs derived for SPC implementation (Toledo JC, et.al; 2017).

Table 2. Actions and CSF for SPC implementation

Sr	Actions	Critical Success Factor
1	Management	• Commitment and senior management responsibility • Management of cultural change and communication • SPC use for Continuous Improvement • Involvement and empowerment of employees • Development of statistical thinking
2	Organisational	• Launching meeting of the project • Pilot Project use • Team work (SPC Team) • Use of facilitator • Use of computers and software for SPC
3	Technical and Training	• Process definition and prioritization • Education and Training in SPC • Critical quality characteristics identification • Measurement system analysis in relation to their capability and applicability • Definition and correct application of control charts (type of chart, sampling, etc.) • Capacity to interpret the control charts and the allocation of appropriate actions • Documentation and knowledge updating on the process • Auditing, analysis and review of control charts for continuous improvement • Feedback, continuous learning and knowledge sharing • Focus on customer satisfaction

4. CHALLENGES:

SPC as a concept can be considered as a simple technique but the implementation is a more multifaceted subject (Antony et al., 2000). The main reasons for failures in implementing are related to: organizational and social factors (Does et al., 1997); lack of senior management commitment (Antony et al., 2000); lack of training and understanding of SPC (Does et al., 1997; Antony et al., 2000); decreased attention after the introduction (Does et al., 1997) and the lack of understanding of the potential benefits of the SPC (Mason & Antony, 2000).

Study on SPC – one of the ACT for quality improvement in Malaysian automotive manufacturing SMEs (Rahman, et al., 2009) results that the implementation of quality SPC has encountered some barriers related to system and management, attitude, organisational culture, machine and equipment, facilities, cost and training issues. From this study, it was found that, implementation of SPC system is more difficult in SMEs, because smaller companies unable to afford high technology system (hardware, software, networking and security) and involved high cost. Some companies prefer to operate simple control charts and manual system using paper and pencil. Furthermore, any company which is seeking to implement a comprehensive SPC system will require having good levels of internal expertise and a good source of external advice. Large companies that using SPC has fewer problems in recruiting or educating workers. Other problem or barrier in the implementation of SPC system is due to the lack of commitment and support from top management. They also lacked awareness of SPC as a powerful problem solving technique. On top of that, lack of training and education in SPC also contribute as one of the major issue for the SPC implementation.

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The problems faced in implementation are also related to CSF: it needs to invest time, money and training in the implementation of the SPC (Does et al., 1997); it needs constant attention and Senior Management support (Antony & Taner, 2003; Does et al., 1997); it is important the effective use and correct interpretation of control charts; it must overcome the difficulties in the use of statistics to build the chart, understanding and identification of corrective actions; it is important to plan for the implementation of the SPC and the management after implementation (Antony & Taner, 2003). The identification of CSF for the implementation of the SPC is crucial, but only the consideration of factors is not enough, they must be connected in a coherent plan (Lim & Antony, 2014).

5. CONCLUSION:

SPC implementation is somewhat difficult as it requires technical, statistical and methodical understanding about process and product. But in practice there are many factors, including mentioned above, that may not considered when implementing and applying SPC. It often led to incorrect implementation and effects to achieve desired results. Many researchers had functioned on SPC implementation to originate benefits and issues. SPC was used to monitor processes, reduce rejections and improve processes as well as products. Also, SPC implementation with the special emphasis on the SPC as the problem-solving process was also explored by Dasgupta (2003). Unfortunately this proposal does not respect all phases of the problem-solving process. But very few have proposed the comprehensive framework for the SPC implementation with the special emphasis on achieving continues quality improvement. SPC must be well-thought-out as methodology to monitor processes, identify problems and its solution, implementation of solution and validation to achieve continuous quality improvement.

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