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Lean Cost of Production Through Quality Improvement- A Doe Approach Within Dmaic Framework

[1]M. Vengatachalam and [2]P.K. Palani

[1]Nehru Institute of Technology, Coimbatore, 641105, India
[2]Government College of Technology, Coimbatore, 641013, India

Abstract: In the present context of globalised open market which is totally seamless, the trade practices have taken a total transformation from the traditional and conservative practices, existed so, to a very tougher environment wherein the competitions are exacting, at the advent of Japanese practice of offering the best quality products at the least feasible price post to the world war II. And, moreover, amidst the stifling competitions, it is of paramount importance for the manufacturers to get slashed down their cost, to realize profit, since the selling price is either dictated by the customers themselves or by the prevailing competitors in the market. At this juncture, it is imperative for the manufacturing companies to get reduced their wastages due to rejection of their products, in a viable way to cut down their cost-the rejection leading to repair, rework or even scrapping the products, adding to additional cost of production. The cost cutting measures with enhanced quality alone would be the last opportunity for the manufacturers to cope up with the most demanding market situations. Quality when achieved with optimal utilization of the resources going into manufacture of goods, the cost of production is proved to be minimized since the cost incurred due to rejection of goods is directly influencing the quantum of resource being input into the process. It is a compulsion of time to take initiatives for establishing working methods following the footsteps of Japanese who had founded 'Toyota Production System (TPS)' later adopted getting refined as 'Lean Manufacturing'. The apt combination of tools to have an integrated approach suiting to the situation would prove to be the most appropriate. Lean manufacturing aims at transforming the work culture, elimination of all kinds of wastes, especially MUDA. Six sigma works towards achieving 'zero defects' of products by way of ensuring control on process variation which is the primary cause behind the rejection of products. The proposed methodology getting fitted within DMAIC framework enumerates upon the steps, if got adhered to and implemented, which would facilitate any manufacturer to realize more of bottom line improvement and also of the cost of quality (CoQ) drifting down, attributed to quality enhancement.

Key words: Lean Manufacturing · Design of Experiments · DMAIC Framework · Quality Improvement · Lean Cost of Production

INTRODUCTION

The economic well being of any nation depends upon how productive it is-GDP being its yardstick. It raises the standard of living of the populace [Mohan Prasad *et al.* [1], 2013]. Productivity is simply understood as the ratio of output to input [A. Gunasekaran *et al.* 1994]. Input normally means the resources like Men, Machine, Materials and Methods, known as 4M's [2]. Output could either be goods or services. We need to adapt to the best strategies to achieve tangible results in key aspects viz. cost, quality and delivery time [S. Vinodh *et al.* 2014]. Prevention and elimination of defect bears a positive impact on quality [3], speed of delivery, dependability and performance, in the cost front, of the organization implementing these measures [Ioannis Belekoukias *et al.* 2014].

A possible enhancement in quality is not only contributing to cost reduction but also paves way for productivity improvement [A. Gunasekaran *et al.* 1994] which is made possible by optimal utilization of resources going into production and by elimination of any rework

Corresponding Author: M. Vengatachalam, Nehru Institute of Technology, Coimbatore, 641105, India.

and unnecessary inspection during and post production. Quality lays the foundation for cost reduction and a focus on quality is the present need of time [4].

In this research paper an attempt is made to get conceived a framework to work within, to enhance upon the quality of products which in turn would lead towards reduction of cost as well as CoQ (Cost of Quality) involved in ensuring final desirable quality of customer requirement.

Objectives: The main objective of this research paper is to get conceptualized and propose a methodology in line with a design of experiment by Taguchi method within six sigma DMAIC frameworks to improve upon the quality level of the products manufactured [5]. It is aimed at utilizing the resources going into production in an optimal way and getting slashed down the quantum of defective products by ensuring control on process variation for that to be within the permissible statistical upper and lower limits (UCL and LCL).

Literature Review: Till the evolvement of the concept of TQM, quality and productivity were perceived as though they are related conversely. At the outset, improvement in productivity could not be achieved without improving quality. This is because of the fact that if a product is perceived as defective while in production or post to it, this is asking for rework and re-inspection [6], disturbing the normal flow of material and scheduled operations, resulting in increase of lead time and reduced productivity [A. Gunasekaran *et al.* 1994].

Even world renowned quality guru Dr. Deming firmly believes that reduction in productivity is mainly caused by defects, rework and scrap [7]. Moreover many researchers [A. Gunasekaran *et al.* 1994] too are of the basic belief that quality improvement goes hand-in-hand with productivity improvement. A delay caused in day-to-day process is a great impediment to the completion of a job within delivery time committed with the customer and is the cause behind the ineffectiveness, inefficiencies and under performance [P. Arunagiri *et al.* 2013].

Taguchi method is used as an orthogonal array robust design to host an offline quality control effectively to improve the quality of the end product at a relatively cost [Shyam Kumar Karma *et al.* 2012]. The same Taguchi method has been used way back in 2002, in optimizing the process parameters in Die Casting to enhance upon the casting density [G.P. Syrcoss *et al.* 2003].

Lean manufacturing technique combined with six sigma known as 'Lean Sig Sigma', has been found to be implemented so popularly in health industry [Gun Zheng *et al.* 2012] [8]. It is a combination of waste elimination by lean tools and process improvement aimed at 'zero-defects' through Six Sigma.

A unified theory for implementation of different lean elements viz. Value Stream Mapping (VSM), Cellular Manufacturing (CM), U-Line System, Line Balancing, Inventory Control, SMED, Pull System, Kanban, Production Leveling etc [9]. is emphasized to competently respond to the fluctuating and highly demanding business environment [R. Sundar *et al.* 2014].

In purview of outsourcing which has turned inevitable in large sized companies [J. Antony *et al.* 2005] especially MNCs, to get JIT implemented and to have control on inventory-to be cost effective amidst stiffer competitions, researchers [J. Antony *et al.* 2005, S. Michael Raj *et al.* 2012, M. Kumar *et al.* 2006] have taken up the investigation of implementing lean six sigma in SMEs (Small and Medium Enterprises) [10]. SME sector of India is perceived upon by economists as the backbone of economy since it contributes to around 45% of Indian total industrial output and when measured in terms of exports, it is parting with 40% of India's exports, catering to the needs of roughly 60 million workforce as per data made available for 2012 by Ministry of Small and Medium Enterprises (MSME).

DMAIC approach of six sigma methodology remodeled as DOLADAMAICS suiting to be implemented in small and medium enterprises is conceived and designed [S. Michael Gnanaraj *et al.* 2012]. It consists of two additional levels in addition to the traditional five levels i.e. Define, Measure, Analyze, Improve and Control (DMAIC). The first additional level is known as 'Deficiencies Overcoming Lean Anchorage' which devotes towards sensitizing the human resources and manoeuvring other deficiencies which might impede the implementation. Another level is to stabilize the improved outcomes of Six Sigma [11]. The implementation is carried out in an engine cylinder frame machining company.

Implementation of Lean six sigma frame work in an aluminium alloy die casting unit (Indian SME), catering to the needs of automobile industry is taken up as a case study [M. Kumar *et al.* 2006]. In this study, bottom line (profit) of the organization is marginally improved, attributed to the combined lean sigma methodology. Lean tools such as VSM, 5s, TPM (Total Productive Maintenance) within six sigma DMAIC methodology have fetched the results in the form of appreciable saving on cost to the company.

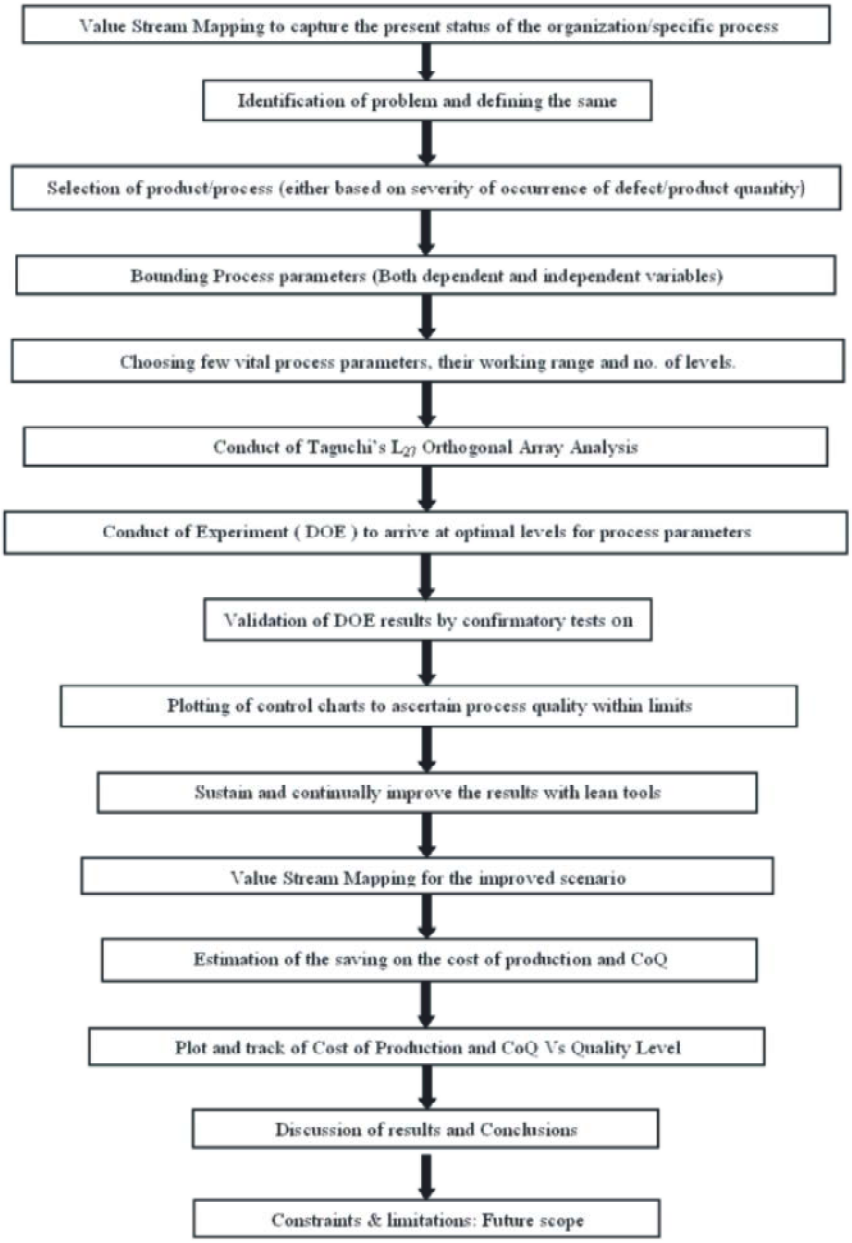
The implementation of lean sigma (lean within DMAIC frame work) in an Indian rotary switches manufacturing organization [S. Vinodh *et al.* 2014] has brought about dramatic improvements In key metrics like process capability, FTY (First Time Yield) and OEE (Overall Equipment Effectiveness) apart from the marginal bottom line enhancement. A model to correlate cost through time named Cost-Time-Profile is explained in this paper.

Description of Proposed Methodology: Value stream mapping (VSM) captures the whole picture of the organizational or process flow and facilities us to get assimilated the 'before' and 'after' scenarios [Fawaz A. Abdulmalek *et al.* 2007] so as to encapsulate the potential benefits viz. reduced lead-time as well as lowered inventory (WIP). In the measure phase, measurement system analysis is to be carried out to ensure that variation in the measurement system is well within limits. This is done by way of a Gauge Repeatability and Re-productivity (R and R) study [M. Kumar *et al.* 2006]. In the analyze phase [12], brain storming sessions by researchers sitting along with the engineering team of the organization in purview are a must to explore the various causes for the effect. The cause and effect diagram (fish bone diagram) paves way for deciding about the most important process parameters that contribute to the failure (effect) [S. Vinodh *et al.* 2014]. Pareto analysis is performed arranging the causes in a hierarchical manner (descending order) based on the percentage of contribution to the total of defects or rejection quantity. It is also known as 80:20 rule, since the universal phenomena is of the nature that mostly near about 20% of the causes are attributable for 80% of the problem or effect.

In the improvement phase of DMAIC framework, a design of experiment (DOE) is set forth with an aim of identifying the significant process parameters [M. Kumar *et al.* 2006] influencing the objective function and to get the process optimized. Taguchi method is followed in carrying out DOE. Taguchi method makes use of an orthogonal [13] array (balanced experimental combinations) in studying the response for the effect of process parameters in total with less number of experiments, when compared with the run of experiments in fractional factorial design [G. Taguchi *et al.* 1989 and M. Nalbant *et al.* 2007]. In this method, the value of loss function is understood in its equivalent term as signal-to-noise ratio (S/N ratio) [M. Nalbant *et al.* 2007]. S/N ratio is a fraction between the wanted signal i.e. response and unwanted noise i.e. environmental influences which are uncontrollable [C. Gologulu *et al.* 2008]. This method is very robust in design, aimed at adjusting the design parameters (process variables or input) which are controllable to their optimal levels so as to have the system response (output) insensitive to the environment over which we have no control on [Shyam Kumar Karma *et al.* 2012]. As far as the objective function is considered, S/N ratio is of 3 types of characteristics viz. larger the better, smaller the better, on-target or minimum variation (nominal the best), depending upon the situation [Shyam Kumar Karma *et al.* 2012].

On arriving at the optimal levels for the process parameters, it is mandatory to conduct confirmatory tests at those levels to get validated the results of DOE. Further to this, stability of the process has to be ascertained by way of plotting X bar chart and R chart (statistical charts). The process for its adherence to the control limits both on their higher and lower levels is ensured. Having taken care of the process variability to abide by the statistical limitation, there ought to be an overall exercise of implementing appropriate lean tools like TPM, 5s, Kaizen (Continuous Improvement) [14], Kanab, SMED, FMEA (Failure Mode and Effect Analysis) etc. on a regular basis, to bring about improvement in OEE (Overall Equipment Effectiveness), Safety of Operations, FTY (First Time Yield), Process Capability and reduction in RPN (Risk Priority Number), DPU (Defects per Unit) etc. Next in action is to depict the value stream mapping for the improved state of operation (Future state mapping).This would illustrate and intimate to us as to where lies any scope of attempting at further improvement, if and where possible. It takes us subsequently to the stage of enumerating upon the cost effectiveness of the whole exercise [15]. Cost of production as well as cost of quality (CoQ) has to be worked on a continuous basis, for the respective quality levels which is expected to always ascend through pass of time. The graph considering the costs of production and cost of quality versus quality level along the time line would depict a converse relationship of both with the quality level. That is to say that as the quality improves [16]; both the cost of production and CoQ diminishes.

Flow Diagram of Proposed Methodology



The following flow diagram depicts the sequence involved in the research methodology proposed to improve upon the quality and hence to enhance productivity by way of making the cost cutting measures feasible.

CONCLUSIONS

The cost of production would be brought down consistently, say, to the extent of 30% to 35% by way of elimination or diminishment of defects-which would otherwise result, normally, either in repair or rework, escalating the cost of production. The improvement in quality vis-a-vis reduction of defects gets reflected as less of repair / rework / rejection of products and hence leads to cost of production drifting down.

Cost of quality, too, involved in assurance of quality is hoped to be potentially and gradually brought down as the level of quality improves. Albeit of the fact that the cost involved in prevention and appraisal might surge up, in the efforts of hiking up the quality level, the very fact that the cost through failure (internal + external) would

disproportionally decline appreciably and moreover to behave in leverage with the additional shoot up in prevention and appraisal cost, leading to overall cost reduction in ensuring quality i.e. CoQ being reduced.

In furtherance to quality improvement which sets in a long lasting effect, continuous improvement in process which always would impact the cost conversely (i.e. cost slashing down) is achieved by implementing other lean tools like TPM, Kaizen, 5S, FMEA, Poka-Yoke or SMED etc.

Constraints and Limitations: The proposed methodology is not taking into account the human aspects viz. physical fatigue, MSD (Muscular Skeletal Disorder) or heat stress etc. perhaps caused by non-conducive work postures. Although it is not under purview of this proposed methodology to consider the above ergonomic factors directly to influence upon the process, it is for sure that these too would have their implications upon the performance of workers, that to influence the labor productivity.

Scope for Future Work: In this paper, a methodology embracing Taguchi method to arrive at the optimal working levels for the process parameters is suggested in the improvement phase of DMAIC framework. Optimization could be attempted using even ANN (Artificial Neural Network) or Genetic Algorithm (GA). On and above the cost measures getting achieved through quality improvement, invariable attempts to get reduced the carbon foot print, energy utility or to embrace a perspective of sustainable manufacturing are to be strongly endeavored up so as to get labeled the working environment as 'Lean Green Manufacturing' which guarantees the availability of natural resources, going into manufacture of goods or services getting extended, for the generations afar.

Additional experimental exploration into the arena of ergonomics would be reinforcing further research, facilitating the human side being considered for their utmost comfort on the job, for the very reason that they constitute a prime portion of resources going into production.

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