A Review on Organization practise of Conventional Design of Experiment (DOE) with DMAIC

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ABSTRACT

This article narrate the review on literature pertaining to applicational usage of conventional experimental design approach such as Classical, Shanin, Taguchi DOE with six sigma DMAIC. This provide the scope of incorporating conventional DOE in organization sector.

Design / Methodology / Approach: In the initial stage of the literature review, the case study related to effective usage of classical, Shanin and Taguchi DOE was reviewed. The reviewing of case study narrowly tailor on only case studies that are applied, validated and implemented by numerous researchers and practitioners for identifying the optimal process parameter for improving the customer recurrence problem (Critical To Quality (CTQ)) with six sigma DMAIC in the gemba were reviewed in the present article.

Findings: The case on applicational usage of Classical, Shanin and Taguchi DOE with six sigma is latent and have a huge scope of usage on improving the "process parameter setting" to improve the problem recurrence with Six Sigma DMAIC in manufacturing, service and public sector.

Research Limitation: The present article narrow down on the usage of experimental design approaches along with six sigma DMAIC. The survey will usage the researchers and practitioners to identify the niche among classical, Shanin and Taguchi DOE for improving the recurrence problem solution that improve the Productivity (P), Quality (Q), Cost (C), Delivery (D), Safety (S) and Morale (M) in gemba.

Originality/value: The implementation study reported in this paper is an original contribution of the authors.

KEY WORDS: DOE, Six sigma, DMAIC, Productivity, Quality, Delivery.

1. INTRODUCTION

In modern era, company were highly stressful due to continuous pressure from internal and to control cost, achieving improved quality and customer satisfaction from external customer cum competitor (Kaushik and Khaduja 2009). To overcome from the stress present day organization day in and out like to be flexible for overcoming the pressure, the various way of organization control is the change in paradigm through changing in quality approach. In recent era, a shibboleth is connote as "Continuous quality improvement" to create the robust and consistent organization sector (Kaushik, 2009). The organization way forward to quality enhancement is a continuously journey by using an effective strategy. The Total Quality Management (TQM) one of the commonly used approach in organization was practised to control the heat waves from external market, TQM a people and analytical approach uses tools, techniques and system very similar to Total Employee Involvement (TEI), Training and Development (T&D), cause and effect diagram, kaizen, quality functional deployment (QFD) and ISO 9000 series based quality management system (QMS) (Lo, 2009) with operator level skill matrix for enhancing the operator skill. In present day organization faces a high onerousness on practising and implementing TQM that lead to failure on improving the process quality improvement day in and day out (Jirasukprasert, 2014). These prolong failure made organization to look after TQM practise in organization as a profit making approach. This result in a birth of evolving approach namely six sigma, emerged from Motorola (Jirasukprasert, 2014; Montgomery, 2010; Ghosh, 2014). The origin of six sigma was founded from the heyday of Carl frederich gauss (1771-1885) who describe the concept of noble curve later on the same was slightly modified by Walter shewart who illustrate the core of product variation (Pande, 2013). Six sigma is a structural approach narrow down on eliminating variation, defects through product, process and service quality (Saravanan, 2011). In general, six sigma reveal the trio concept such as statistical measurement, management strategy and quality culture (Park, 2002). The numerical goal of six sigma is to produce defect < 3.4 parts per million (PPM) or defects per million opportunity (DPMO). The defect reduction in gemba start from recognizing and enhancing the product defects (Cheng and Kuan, 2012). The recurrence customer problem is solved using process improvement approaches such as plan-do-check-act (PDCA), Define- Measure-Analyse-Improve-Control (DMAIC), Initiating – Diagnosing – Establishing – Acting - Learning (IDEAL) cycle, ISO/IEC 15504 etc (Yi, 2012). Each and other approach vary with their respective functions and its application usage, DMAIC proves to be a prudent approach by adding value to eliminate Muda by creating a change management (Yi, 2012). The theory and practical application of DMAIC had got derived from statistical quality control, total quality management, taguchi offline quality control (Mast and Lokkerbol, 2012).

The define phase in DMAIC reveals the concept of problem definition, statement and mission statement (Mast and Lokkerbol 2012; Prashar 2016). In measure phase, the woe from the customer end was assess through critical to quality (CTQ), process variable and mapping to create a useful measurement system (Cheng and Kuan

2012; Prashar, 2016). In analysis phase, the root causes on the identified CTQ had been looked upon (Cheng and Kuan, 2012; Prashar 2016; Gijo and Scaria, 2014). In improvement phase, process adjustment were carried out by creating the relationship among output variable (Y) and input variable (X). To understand the relationship between the X and Y the dual known design approach had been most endemically used, such as classical DOE developed in US and UK in 1920 by Sir Ronald fisher in the field of agriculture (Prashar, 2016; Sharma and Chetiya, 2009). The second one being the Taguchi DOE developed by Dr.Genichi Taguchi in 1950 by introducing the concept of "orthogonal array (OA)" that decreases variation from experiment through " optimum setting" of control parameters (Prashar, 2016, Sharma and Chetiya, 2009). In present days, a new design system by the name shanin system (SS) was designed by Dorian Shanin (Prashar, 2016).

In control phase of DMAIC , the changes made up using DOE and DM were amended in the working standard operating procedure (SOP), Quality Control Process Control (QCPC)/ Control Plan, and Process Failure Mode Effective Analysis (PFMEA) (Gijo and Scaria, 2014). The adherence to the modified results in the improvement phase were closely examined through internal audits of ISO 9001 system (Gijo and Scaria, 2014).

This article on the writing is to put forward the scope on applicational usage of classical, taguchi, SS with six sigma DMAIC in the field of manufacturing and servicing organization to improve process quality with good customer perception. The hierarchical structure of the present article covers the methodology in level-2, Literature Review in Level-3, Inference from Literature Review in Level-4 and Conclusion in Level-5.

2. METHODOLOGY

The applicational usage of DOE with the DMAIC phase of six sigma is shown in fig.1.

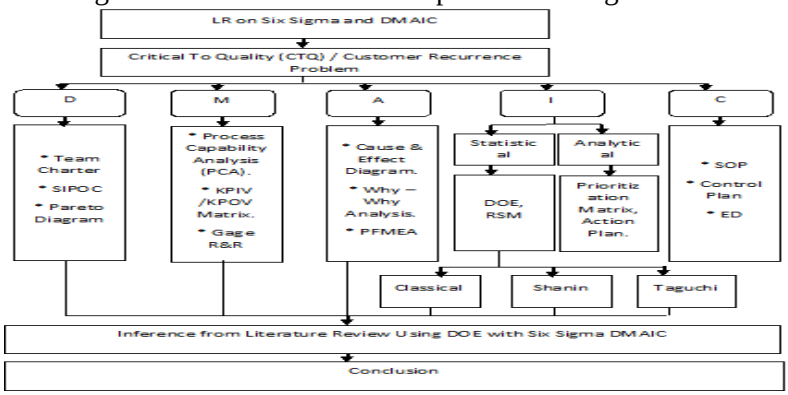

Figure.1. Hierarchical Flow of Conventional Usage of DOE with DMAIC

As Shown in Fig.1, initially the literature review is perform with respective to six sigma DMAIC and DOE to understand the what, how and why part of using the DOE with DMAIC in various case study. The usage of DOE with DMAIC starts with the identifying the customer recurrence problem from the end customer that reveal the stale mate faced by end customer during the utility of the end product. The first step for the present problem is to define the customer experienced problem that are analysed through most endemic used tools such as Supplier – Input – Process – Output – Customer (SIPOC) diagram, pareto diagram, Team charter etcetera. This provide the path for measuring the critical processing stage using PCA, Gage Repeatability and Reproducibility (R&R) study to perform data collection then performing the data analysis using cause and effect diagram, KPIV / KPOV Matrix, Process Failure Mode Effective Analysis (PFMEA) to conclude the scope for improvement parameters. The improvement on conventional way of working is carried out in two fold way initially using statistical approach through DOE, Response Surface Methodology (RSM) and another one being the analytical one using the Prioritization Matrix and Action Plan to deploy, implement the identified improvement and incorporate the same into Standard Operating Procedure (SOP), Control Plan, PFMEA and Engineering Drawing (ED) to solve the customer face problem recurrence in the manufacturing, service and public sector.

Literature Review: In the initial stage of the literature review, the case on practical application of classical DOE, Shanin DOE and Taguchi DOE with DMAIC is reviewed. The review emphasize on case studies tested and implemented by various researchers and practitioners to control the process variation with six sigma DMAIC. In overall, this article will provide the gap analysis to provide huge scope of usage on practising experimental design approaches such as classical, Shanin and taguchi DOE along with six sigma DMAIC in the gemba for improving the Quality (Q), Cost (C) and Delivery (D) in present day organization.

Applicational usage of classical DOE in DMAIC: The versatile customer perception in present day competitive marketing sustainability had urged organization to continuously improve on product quality by reducing the variation in process quality. The DMAIC a Meta routine problem solving approach tap the problem that produce high impact from the customer end and assessing the end results through improved sigma level with low DPMO by achieving the numerical goal of producing less than 3.4 defects ppm in the process (Cheng and Kuan, 2012).

(Cheng and Kuan, 2012) applies the classical DOE in DMAIC stratum for improving the reliability for the

CCFL (light tube). Through DOE the optimal process parameter for inner pressure, lamp diameter, current, electrode material team was chosen to reduce the CFFL failure. Experimental design on controlling the factor identify the optimal control setting with subsequent improvement in the MTTF to the satisfied level in the CFFL light tubes.

(Dambhare, 2013) uses the classical DOE to reduce the rework in the engine block line counter depth of Ingersoll special purpose machine. The way long analysis reveal the factor for improvement as oil temperature, lever pressure, slide pressure and ambient temperature. The confirmation run on optimal condition reduces the rework to merely 2.20% per month from 16% per month and man hour loss of nearly 42 hours.

(Jirasukprasert, 2014) had used the DMAIC for reducing the defect in the rubber gloves manufacturing organization. The factor for improvement were temperature and conveyor speed. The team incorporate the two way analysis of variance (ANOVA) for improving the optimal setting. The validation of optimal factors through confirmation rum decline the defect to nearly 8.38% from 19.51% with subsequent enhancement in the sigma level from 2.4 to 2.9.

(Kaushik, 2012) explain the usage of six sigma DMAIC in the bicycle manufacturing organization. Through 2*2 DOE the factor for improvement were skilled and unskilled operator, rod replacement (after 15h and after 25h) and rod holding the confirmation trial validation through p-test, two sample t-test, response table and diagram result in rod replacement as minor factor and rod holding mechanism as major factor.

Applicational usage of Taguchi DOE in DMAIC: Chen (2009), uses taguchi DOE to control the hole roundness in the old plasma cutting process. The improvement factor identify were tip size, feed rate, voltage and amperage by varying at three levels, noise factors such as air pressure and piercing time at two levels. The successful confirmation run illustrate the improvement in the sigma level with reduction in the time and cost of the plasma cutting process.

Gijo and Scaria (2014), espouses the successful usage of taguchi experimental design approach with six sigma DMAIC to improve the first pass yield in automotive parts manufacturing. The team conclude the factor for improvement as grinding stock, dressing frequency, dressing feed rate, dressing depth and grinding feed rate to be vary at three levels. The final run with optimal setting had been conducted by choosing 1000 parts for a period of 2 months. The analysis reveals the enhancement in the sigma level to 4.08 from 3.31 in foot thickness and 4.07 from 3.13 inn plunger taper in the automobile industry.

Gijo (2011), espouses the use of six sigma DMAIC for reducing the defect percentage in the fine grinding process of an automotive company in India. The analysis and discussion with Subject Matter Expert (SME) and brain storming session reveals the vital few causes as load applied, initial load setting, coolant flow rate, Upper wheel RPM, Lower Wheel RPM, Cage RPM with all varying at three levels. The analysis through ANOVA, S/N ratio, main effect plot, interaction plot for identifying the optimal setting for the aforesaid influential factors.

Gijo and Scaria (2010), garner the use of six sigma DMAIC for reducing the rejection and rework percentage in the honing process The prolong analysis and discussion with SME and brain storming session reveals the vital causes as feed rate, impulse, stock, stroke and temperature with all varying at three levels. The proper selection of factors and level allows the charter team to select the L27 OA, conduction of confirmation run by taking the limited sample in the gemba of the automobile industry culminate the enhancement in the first pass yield from 88% to 100% and subsequent increase in the sigma level to 6.0 in the automobile manufacturing organization.

Lo (2009), explain the usage of six sigma DMAIC to improve the surface precision of optical lenses in the injection-moulding process. The cause and effect diagram identify influential factors as melt temperature, screw speed, injection speed, injection pressure, packing pressure, mould temperature and cooling rate all varying at three level expect melt temperature that vary at two level. The mixed L18 OA with 36 experiment runs were analyze using S/N ratio, ANOVA and regression analysis (Srinivasan, 2016) portray the usage of L9 OA for conducting experiments for improving the diameter in the furnace nozzle hole. The analyse and identify the vital control factors that impacts the nozzle hole diameter as speed and feed rate by varying at three levels. The confirmation run reveal the enhancement in sigma level to 3.67 from 3.31 with subsequent reduction in the DPMO to 15,000 units from 35,000 units in a furnace manufacturing concern.

Saravanan (2011), defines the crystalline silicon solar cell technology as an imperative over available photo voltanic (PV) technology using the L27 OA with six sigma DMAIC. The control factors for improvement were silane layer 1, layer 2, ammonia layer 1, layer 2, time layer 1, layer 2 and RF power. The experimentation analysis improves the sigma level from 2.67 to 4.01 and improvement in the efficiency of solar cell electrical characteristics.

Tong (2004), had embodies the usage of classical DOE for improving the screening process capability in the printed circuit board manufacturing organization. The team uses the mixed DOE, prolong analysis with SME reveals the vital few factors as age of stencil, solder paste volume, blade type, and side of the pencil at two level. The full factorial experimentation reveals the optimal setting of the control factors, confirmation run and standardization control to improve the sigma level from 1.16 to 5.92 with reduction in ppm to 3.4 from 122,173 in the PCB organization.

Applicational usage of Shanin DOE in DMAIC: Prashar (2016), portrays the use of SS approach for providing solution to chronic quality problems in an Indian automotive gear manufacturing organization. The two level

suspected source of variation (SSV) was identified as repeatability of diaphragm chuck, span variations after heat treatment and Ovality in dots over pin (DOP) after heat treatment in level one. Similarly the Ovality after shaving, PCD run out after shaving and heat treatment process were chosen as second level. The improvement on major was considered as fixture loading during the heat treatment process that was validated through better Vs Current (B vs C) analysis for taking the limited sample on checking the PCD run out in the gear manufacturing organization.

Inference from Literature Review: The present article experience the applicational usage of various experimental design approaches such as Classical, Shanin and Taguchi DOE approaches with six sigma DMAIC in the present day organization. In initial phase the reviewing of cases as discussed in afore mentioned sections on their success fully testing cum implementation of applicational usage of Classical, Shanin, Taguchi DOE and DM in improvement stratum of six sigma DMAIC. DOE an experimental tool had been endemically used in various areas such as manufacturing, composites, foundry, chemical, small and medium enterprise and many more. There exist a huge scope on using DOE as a quality improvement tool with DMAIC, Fig.2, reveals that merely 13 cases had been successfully used along with six sigma DMAIC in present day organization year on year (YOY). In the year 2012 nearly 2 cases had been worked out using classical DOE and 6 Cases using Taguchi DOE in similar manner the other years have been worked out. The figure reveals the wide scope of implementing and testing the usage of Classical, Shanin and Taguchi DOE with six sigma DMAIC for providing solution to various quality control problem from the quality bank of the organization.

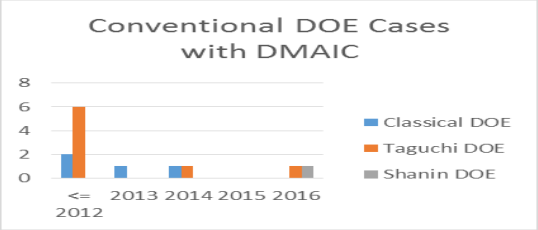

Figure.2. Case Study application using Classical, Taguchi, Shanin DOE with DMAIC

The present article also provide the comparative study on the various metrics of experimental design approaches for reducing the process variation and by improving the product quality as shown in Table.1.

Table.1. Comparative Difference on performance of Classical, Shanin and Taguchi DOE

S.No	Paper	Metrics	Classical l DOE	Shanin DOE	Taguchi DOE
1	Ghosh and Maiti (2014), Sharma and Chetiya (2009)	Tool	Fractional and Factorial Design	Multi Var, Concent Chart, Comp Chart, Pair Comp, Var Search, B Vs C	Orthogonal Array
2		Data Collection	Off line	Offline	Offline
3		Cost / Time	Moderate	Low	Moderate
4		Complexity	Moderate	Low	High
5		Ease of Usage	High	High	High
6		DWM / DRM Impact	High	High	High

The Table.1, reveals the applicational usage of classical, Shanin and Taguchi DOE with respective to various metrics such as data collection mode, cost / time, complexity, ease of usage, DWM / DRM in the present day organization.

3. CONCLUSIONS AND FUTURE SCOPE

In modern era, Organizations universally imbibe the pressure to control cost, achieving high quality and customer perception from external customer and competitor (Kaushik and Khanduja, 2009). Organization flexibility on facing the pressure makes to identify the best strategy namely a change in the paradigm shift from changing the program or quality approach (Gijo and Scaria, 2014). Six sigma an evolutionary approach narrowly tailor on reducing variation, defects by enhancing quality of product, process and services (Saravanan, 2011). The numerical goal of six sigma from the output perspective is to achieve or to reduce the defect < 3.4 parts per million (PPM) or defects per million opportunity (DPMO). The defects most endemically faced by the present day organization were solved in the hierarchical way by using a rigorous process improvement approach such as DMAIC for designing nuance in a pragmatic way of solving the well – structured and ill- structured problems (Mast, Lokkerbol 2012). This article provides the survey on the applicational usage on various experimental design approach such as classical, Shanin and taguchi DOE in the present day organization.

The cases covered in the previous section reveal the following conclusion: The case on applicational usage of classical, Shanin and taguchi DOE have been latent and have a wide scope of usage on identifying the “optimal setting” for control factors along with six sigma DMAIC in the present day organization.

Future Scope: In future days, applicational usage of an offline data collection approach namely classical, Shanin and Taguchi DOE will have a wide scope for improvement in manufacturing, service and processing organization.

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