# Quality Improvement by Application of DMAIC Technique: A Review

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**Abstract**
Today manufacturing, automobile and services industries are highly impacted by the fast-changing economic conditions. In this scenario industries are facing global competition due to globalization. The major problems are being faced by these industries are declining profit margin, customer demand for high quality product with different variety. A very recent and power philosophy in this area is DMAIC (Define, Measure, Analysis, Improve and Control). DMAIC is becoming very popular and its advantage is being taken for improving productivity and quality performance and also to make the process robust to quality assurance. DMAIC is an approach that improves quality by analysing statistical data integrated with methodology. DMAIC refers to the minimization of variation through proper work flow maintenance and it leads to performance improvement. The critical objective of industries nowadays is to complete a project within a stipulated time, minimization of waste, organizational potential and efficient use of resources by using DMAIC technique. The main aim of this paper is to conduct rigorous review and to identify the potential aspects of their application in industries management. Most of the industries face poor client satisfaction due to non-completion of the work as per the required standard and specifications. This paper reviews related to DMAIC technique applied in different industries for perspective problem solving and describes the methodology, implementation of DMAIC phases. The main objective of this review is to offer a broad and extensive picture of the role of quality improvement technique in manufacturing, automobile and service industries.

**Keywords**
DMAIC, Design of Experiment (DOE), Key Process Input Variable (KPIV), Analytical Hierarchical Process (AHP).

## I. Introduction
DMAIC is the most effective methodology available for improving the performance of any organization by minimizing the defects in its products or services. Every error committed has cost associated to it in form of losing customers, redoing a task, replacing a part, waste time/material or loosing efficiency.
Key to achieving DMAIC Level is "Process knowledge, correct selection and application of Design of Experiment Tool and innovative solutions in improving the process"

**Key to the success of DMAIC**
- Top Management Commitment
- Process knowledge
- Knowledge in selection and application of DOE tools
- Strong Review Mechanism

### A. Selection of DMAIC Projects
DMAIC in manufacturing industries gives a upper hand for the organization to reduce cost due to scrap & non value adding activities. Projects can be of two types:
- Problem solving
- Process Optimization.

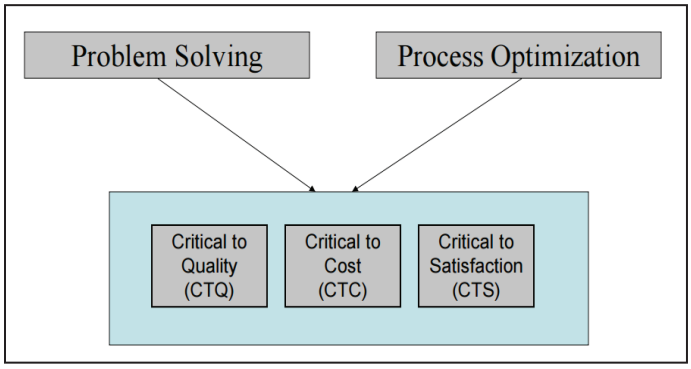

Fig. 1: Selection of DMAIC Projects

#### 1. Critical to Quality
It is an attribute of a part, assembly, subassembly, process or product which has direct impact on actual and perceived quality. It is quality of a product or services that is derived from voice of customer. A good CTQ statement is one that is measurable which includes definition of defects and it includes performance standard.

#### 2. Critical to Cost
There are four types of cost which affects on the quality.

#### 3. Internal Failure Cost
It includes scrap and rework. This cost must be decline so as to little or no defective work obtained.

#### (i). External Failure Cost
It includes warranty cost and product liability. This cost also decline so as to no dissatisfied customer.

#### (ii). Appraisal Cost
It includes inspection cost. This cost again decline so as to very little inspection required.

#### (iii). Prevention Cost
It includes process improvement product simplification training cost. This cost must be increases so as to an ounce of prevention is worth a pound of cure.

#### 3. Critical to Satisfaction
Customer satisfaction with a company's products or services is often seen as the key to company's success and long-term competitiveness. To achieve customer satisfaction, something more is needed. In order to attain customer satisfaction, corporations must not only achieve the highest quality by eliminating defects but also provide our products and services with excellent attractive qualities.

### B. The Implementation System of Six-Sigma Program
The huge contribution of the implementation of the Six-Sigma program is due to the realization of better practices and operation systems. In the initiative stage, Motorola and GE designed a

complete implementation system. The main features of the system are discussed below under the following headings

**Implementation phases:** DMAIC project methodologies have five phases.

**1. Define :** A business team first analyze voice of customers (VOC) identifies the improvements issues and estimate financial benefits.

**Tools and technique:** Customer complaint analysis Cost of poor quality (COPQ).

**2. Measure :** After problem defines team identify inputs and Outputs, establish measurement system for inputs and outputs and understand the existing capability of process.

**Tools and technique:** Process map (SIPOC), Cause and effect matrix, Gauge R&R, Control charts, Process capability analysis.

**3. Analyze :** The data investigate and verify using DOE relationship and identify sources of variation in process potential critical inputs and discover the root causes.

**Tools and technique:** Cause-and-effect diagram Pareto diagram Brainstorming Analysis of variance (ANOVA).

**4. Improve :** The team then confirms key variables and Create the strategic actions to eliminate the root causes Conduct improvement actions Use Experiments Optimize critical inputs.

**Tools and technique:** Process capability analysis, Better Vs Current.

**5. Control:** The future states process to ensure that any deviations from target are corrected before they result in defects by standardizing the process, maintain critical inputs in the optimal area, verify long-term capability and evaluate the results of improvement projects.

**Tools and technique:** Process capability analysis, Fool-proofing (Poka Yoke), Run charts, Variation analysis.

## II. Literature Review

A literature review of the recently published research work on DMAIC is carried out to understand the research issues involved and is presented here,

**More and Tilekar (2017)** Presented application of DMAIC for gear box system for dent minimization purpose. They studied different causes that lead to gear box rejections such as assembly jam, noise, damages, leakages etc. Analysing all these defects at the final inspection, apart from this they specially focusing on Dents. Applying DMAIC methodology which is a part of Six Sigma to find out the root cause. Authors checked each process those are taking place in gear manufacturing and investigated that there is absence of chuckle Plates between the synchromesh Gears. This Synchromesh Gears get in contact with each other due to which Dent marks are generated on them which creates a problem to the Shifting mechanism of gear box. The dent minimization carried out successfully and has a satisfactory effect on improving future quality issues [1].

**Chhikara et al. (2017)** explained various methods and technique used for identification of DMAIC projects. While identifying projects one must know the input parameter such as as Kano Analysis, Value Stream Mapping, Theory of Constraints, Hoshin Planning, Cost of Poor Quality, Quality Function Deployment, Strategic Development plan and Voice of Customer etc. they have also explained Methods and Techniques used for Selection of DMAIC Projects such as Programming Methods, Scoring and Ranking, Real Option Analysis and Data Envelop Analysis along with they focused on value creation, improving the process-capability making the process more reliable [2].

**Vante & Naik (2016)** presented the dimensional variations in casting wall thickness in 3-cylinder metric block casting shows major defect contributing in rejection. From Pareto analysis it was clear that dimensional variation at water jacket wall i.e. wall-less has the maximum share responsible for the increased rejection percentage and it needs to be minimized. Different type of chaplets were tried and tested as remedies. The previously used 3-disc round chaplet was replaced by rectangular v-make chaplet. This change contributed in reduction in rejection as well as cost of poor quality. Rejection due to water jacket wall-less was reduced from 7% to 2.13%. Increased accuracy in dimensions and specifications according to standard indicates improvement in quality [3].

**Santana and Carvalho (2016)** identified the relationship between critical success factors for DMAIC programs and its projects performance, considering DMAIC projects. They had explored the relationship through PLS (Partial Least Squares) method, using a sample of 149 respondents in Brazil and Argentina. The variables were collected initially by a survey conducted with Black Belts, Green Belts, program managers and after that documental analysis. As a result, that shows the significant impact of DMAIC method, Project Management and the Project Manager competencies on project performance. For future research in order understanding the difference between long term and short-term results, an analysis of the measurable results of DMAIC projects [4].

**Srinivasan et al (2016)** presented case study on reduction of two imperative responses in spray painting process producing shock absorbers, namely peel off and blisters using the DMAIC (DMAIC) approach that highly impacts quality at customer end. Main root causes that impact the responses were identified as cleaning temperature, phosphate temperature and phosphate pH by using fish bone diagram, Results of experimentation had been analyzed by using ANOVA and multivariate regression which identifies the condition of optimality on blisters and peel off in the pre-treatment process. From response diagram for peel off and blisters it was clear that both blisters and peel off can be optimized effectively by setting, phosphate PH, phosphate temperature and cleaning temperature at 3.5, 600C and 700C respectively [5].

**Vante & Naik (2015)** focused on solving the problem of dimensional variations in 3-cylinder metric block casting. They had applied pareto analysis for defect categorization and to find out root cause by using cause and effect diagram. The application of quality control tools such as KAIZEN, 7QC, TPM, why-why analysis, Pareto analysis, brainstorming etc. for reducing rejection rate of castings and thus improving quality of casting by better control. Initial research shows that casting was facing higher percentage of rejection due to dimensional variations at casting wall. Successful implementation of these tools resulted into reduced rejection rate of casting and achievement of quality improvement [6].

**Sao & Sridhar (2015)** presented DMAIC approach into a powerful business improvement methodology in many Global industries and its importance is growing. Authors describes some critical barrier while implementing DMAIC methodology in manufacturing industry such as internal resistance, lack of training and knowledge and lack of executive commitment etc. Explained implementation issues for the growing number of organizations and focus should be on improving overall management performance. Also presented

statistical tools which give the basic idea of DMAIC, states that if process performance is improved then cycle time, inventory, capacity, reduction waste will also improve [7].

**Gangai & Naik (2015)** presents case study on DMAIC to reduce the rejection of EA16 engine cylinder head due to valve guide surface roughness out of specification in small scale industry. In define phase problem selection using pareto analysis and process mapping are carried out. Tool used for problem solving are paired comparison & multivary analysis. In multivary analysis they studied time to time variation, stream to stream variation and part to part variation and find out root cause of the problem. In measure & analyse phase they studied Process capability before and after implementation of new tool using Minitab software. The cost saving achieved through successful implementation of this project is 6.26 lac/annum [8].

**Vijay (2014)** presented to reduce the cycle time of the patients discharge process using DMAIC Model at KG multidisciplinary hospital Coimbatore, India. one critical issue consists of delay in handover of discharge summary to the Patients was identified. To reduce and optimize the patients discharge process with specific focus on a Medical and Surgical Department. It includes Time consumed for manually checking the case reports of the Patients, Time consumed for getting the Investigation Report to be merged with discharge note, Centralized Discharge Summary Preparation Process, Time consumed for Proof reading, Time consumed for getting Billing & Insurance Clearance etc. so, Time factor that are controlling the Opportunities of the Patients Discharge process. Identified the root cause which is that Failure to utilize Information Technology system to generate and verify the required patient Information. after DMAIC implementation; there is a 61% reduction in the cycle time of the Patients discharge process. Also, a control plan check sheet has been developed to sustain the Improvements obtained. The average discharge time reduced from 234 minutes to 143 minutes [9].

**Youssouf et al. (2014)** focused on the efficiency of maintenance of the industrial systems and Studied some major economic issues for their business concern. Identified some critical parameters for the quality, that is, those whose influence on the result is the largest. In define phase they understand the problem and its financial impact. In measure phase develops methods of data collection and find out the root cause of the problem. They try to optimize the number of personal maintenance and focussed on preventive maintenance by using different methods of analysis of processes such as: the FMEA, design of experiments, Pareto analysis, cause and effect diagram and 5S tools etc. [10].

**Joshua Chan et al. (2014)** proposed a Lean DMAIC framework in Small scale printing company. Small scale industry facing the problem of pressure from its competitors; especially large companies as they could provide products of greater value with lower cost as compared to Small medium enterprise. The management wants to implement Lean DMAIC because the label printing has low productivity and produces high wastage that's leads to time of the production and the cost of the product. Test printing time is directly proportional to how well each setup is being made so if each setup is carried out correctly, then test printing time will eventually be low. In order to reduce the time to find the die cut mould and ink, a proper storage has to be designed. Standard Operating Procedure (SOP) are used as a control tool in the Lean DMAIC framework because 5S provides a guideline to sustain the arrangement of the die cut mould. Now this Small medium enterprise label printing company produces various types of labels such as computer labels, offset & silkscreen stickers and bar code labels. The productivity of the label printing section shows an increase by 584 impressions per hour [11].

**E. Kabir et al. (2013)** improved productivity of fan manufacturing organization by applying DMAIC technique. They have used different tools like 5s, Supermarket, cause and effect diagram, line Balancing and Bottleneck process etc. The running way of case of organization is too much complex with the criteria of time and distance. There are almost 18 defects which are occurring everyday due to lacking existing layout. The main reasons are improper handling, heavy working pressure of each worker, random movement of some workers, performing critical activity in small space, so all time they perform repetitive task which leads to waste of time. As a result, sometimes they produce defective fan. authors explained effective layout model where to hit upon the bottleneck process through benchmark capacity. By applying 5s and supermarket, it is possible to reduce repetitive task by saving time which have shown on data analysis. It reduces the floor space and best utilization of floor space. Supermarket reduces the hazards of the production shop [12].

**Chowdhury et al. (2014)** analyzed the production defects in case of manufacturing of thermoformed refrigerator liners with the help of different statistical tools like FMEA, Test of Hypotheses and try to find out the exact source of variation and identify the issues which are critical to quality (CTQ). The liners are produced by the thermoforming process in a Refrigerator manufacturing plant. The liners are rejected against a defined checklist that forms the acceptance or rejection criteria for a thermoformed liner. Non-conformance generally occurs due to incomplete or over forming of the sheet, due to incorrect setting of heater temperature, forming temperature etc. The KPIVs are responsible for the effects on the rejected liner thus produced. By using cause and effect diagram root causes are identified - incorrect setting of heater temperature and prolonged heating liner due to this Wrinkle formation or variation in thickness. Improve process carried out by using quality control tools like FMEA, Lean and System Dynamics etc. [13].

**S. Soni et al (2013)** explained reduction of welding defects using DMAIC Approach. They revealed that internal customer is affected by low SAW boom Machine welding process yield. By applying cause and effect diagram analysis improper removal of tab plates, improper weld groove and zurking of tractor machine. They prepared critical to quality tree, why-why Analysis to solve the problem as a result considerably reduction of possibility of failure, cost of poor quality and reduces labor expenses. They studied a real time monitoring system as a result reduced shear strength of the weld without destructive testing [14].

**Taneja and Manchanda (2013)** used DMAIC Approach to Improve Productivity in Manufacturing Industry. In his paper They begins with an overview of DMAIC, followed by thorough literature review on DMAIC phases, application of DMAIC in small medium scale industries and also in large manufacturing industries. They also done literature survey on various DMAIC quality tools used in the industries. These include Process capability analysis, Fishbone Diagram, Two-sample T-test, X bar and R bar charts [15].

**L. Rhman (2012)** explained how the DMAIC approach will helps to solve the safety and environmental hazards in organizations. Authors identified the critical factors related to low safety in organization such as lack of concentration at workplace, bad handling of tools & materials, disregard to safety regulations, vast variation to co-worker background etc. As per DMAIC approach once the caused identified one has to suggest the solution to reduce the risk brought by these factors. Authors suggested few

improvements such as safety courses should be included in the induction training program and safety regulations [16].

**K. Ganguli (2012)** provide the solution to the large aluminum company in developing hot rolling mill capabilities and reduction in down time due to strip slippage. Authors apply DMAIC principles and identified the current situation that the rolling mill worked out. While authors studying he observed that temperature loss was the major reason for slippage. To solve these issues author initiated work in two directions one is to reduce the heat loss by installing monitoring coil rolling time, idle time and coil to coil time and second one raising the average rolling temperature from 510 to 575C means keeping the slabs hot enough so that any heat loss from the rolling ingot may not have any effect on its roll ability. As a result, the company remains in competitive without any investment of new hot rolling mills [17].

**Kumar et al. (2012)** used DMAIC approach to reduce process variability of a food processing industry in Bangladesh. Large amount of data which are out of control so here P type control chart used. Regression analysis is used to identifying any relation between the defects to each other. At the last stage of analysis, employed AHP & MCDM techniques to reinforce the decision regarding vital few. After employing AHP techniques it was found that presence of black particles and leakage are the main problem for shifting the process mean from the desired value. So, For This reason 5S philosophy can be implemented for reducing black particles. In this study various tools used such as pareto analysis, fishbone diagram, multi criteria decision making (MCDM) and control charts etc. [18].

**Dalu (2012)** evaluated DMAIC implementation in medium scale Indian automotive enterprises. In this paper he has discussed critical success factors for successful DMAIC implementation in medium scale automotive industries in India. The survey was conducted using the questionnaire method. his concluding remarks is very little research carried out in automotive sector and the study finds that only a 25.64% of medium scale automobile sector has implemented DMAIC. He also stated that Medium Scale Automotive Enterprises are having good foundation of ISO 9000. He concludes that there is little implementation of advanced quality management system like DMAIC in MSAI's which can hamper gain from World market. They also firmly said that the expensive consultation charges can be saved through in-house training [19].

**J. Mast et al (2012)** compare critically the DMAIC method with insights from scientific theories in the field of problem solving. They had selected five themes from the problem-solving literature generic problem-solving task, problem structure, domain specificity of methods diagnostic problem solving and remedial problem solving. Author claim that perspective gives useful insights and results in useful conclusions about the method, but author emphasize that this perspective is by no means exclusive and other perspective may result I equally interesting conclusions. Authors believe that DMAIC methodology and the DMAIC problem solving approach should be aware of their characteristics of the DMAIC approach and its limitations specifically from a problem-solving perspective [20].

**H. Yeh et al (2011)** presented DMAIC technique in Sectors such as health care, power generation are also not left far behind in DMAIC practices. In recent year's factors such as competition, patient safety, healthcare costs etc. have become more prevailing in health care industry and competition within the industry has been intensified. They established a model which developed a suitable structure of DMAIC to improve service delivered to AMI (Acute myocardial Infarction) patients [21].

**Suhail et al. (2010)** studied on the problem to optimize the cutting parameters using surface roughness. Optimal cutting parameters for each performance measure were obtained employing DOE techniques. This study discussed an application of the DOE method for optimizing the cutting parameters in CNC operations using surface roughness (Ra). The focus of present experimental study is to optimize the cutting parameters using two performance measures, work piece surface temperature and surface roughness. Optimal cutting parameters for each performance measure were obtained employing Taguchi techniques. The orthogonal array, signal to noise ratio and analysis of variance were employed to study the performance characteristics in turning operation [22].

**Vassilakis and Besseris (2009)** to identify the causes behind the defects detected during maintenance process in a large aerospace company. Fish bone diagram was used to identify the cause behind defects. The analysis shows that the aero engine maintenance unit need a change in its TQM policy and a new statistical quality control scheme should be deployed [23].

**Montgomery and Woodall (2008)** the evolution of DMAIC and describe its major components, including how it is usually implemented in business organizations, and the role of statistics and statisticians in the process. We also discuss the implications of DMAIC for education and training of statisticians and the potential impact on the statistics profession. support the process design and improvement principles of DMAIC, which have been used to great success in improving quality and productivity in applications around the world. The use of statistical methods is a key component of this metric-driven approach [24].

**Noorani et al. (2005)** investigated the effects of the most significant parameters such as spindle speed, depth of cut, feed rate and tool size on the surface roughness. Each parameter that would have an influence on the surface roughness of the machined parts was taken into consideration. The Design of Experiments (DOE) was chosen for the research. A statistically designed experiment was used to determine the processing factors that affected the surface roughness. A two-level, four-factor full factorial experiment was used to select the best combination of factors level that would minimize the surface roughness. The significant factors, their interactions, optimum setting and the physical interpretation of the effects of the process parameters on surface roughness were studied [25].

**Anbari and Kwak (2004)** analyzes and synthesizes the lessons learned from successful management of DMAIC projects and their potential applications in managing traditional projects. It considers further improvements to the methodologies used for managing DMAIC projects and addresses wider applications of promising practices to organizational change management. The paper also discusses challenges and obstacles in the application of the DMAIC method. The promising practices learned from the successful management of DMAIC projects could have important applications in managing traditional projects and wider applications in managing organization [26].

## III. Research Issue

- There is great potential for research on DMAIC and its linkages with other initiative such as DMAIC in supply chain management and lean manufacturing.
- Less work reported considering the effect of input and material related suspected sources of variation.
- Work carried out using the statistical tools and to find out

the defects using Control Charts and Scatter diagrams not explored yet with full potential.

- There is a need to have more case studies clearly presenting the application of DMAIC within each domain in a proposed framework.

## IV. Conclusion

The objective of this review paper was to understand the status of application of DMAIC. Instead of discussing much about the basics, we should more focus on how to integrate other quality tools into DMAIC to achieve quantum gains. In service sector like Banking, Education, Healthcare are major areas where DMAIC no more visible. It was found that not sufficient work carried out using DMAIC tools for quality Improvement in small scale industry for process parameter variations. The Implementation of DMAIC will save money which result in low Cost of Poor Quality (COPQ) and higher profit of the organisation. This study gives new management approach on improving business process for consistent quality customer service.

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