

## A Review on Six Sigma (DMAIC) Methodology

Saad A. Shaikh<sup>1</sup>, Javed Kazi<sup>2</sup>

<sup>1</sup>Department of mechanical Engineering, Mumbai University, India

<sup>2</sup>Anjuman-I-Islam Kalsekar Technical Campus, New Panvel

**ABSTRACT:** The growth rate of fair-size institutions and Organization is directly related to the implementation of Six Sigma Methodology. This paper consists of detailed analysis regarding application of six sigma Methodologies in Organizations and Institutions. This paper provides an overview to the literature into various categories and considers various methods/techniques suggested in the literature. Based on the review, avenues for further research are also discussed.

**Keywords:** Six Sigma, DMAIC, DOE, Methodology.

### I. INTRODUCTION

Six Sigma methodologies have proved out to be very useful for all business organizations for achieving high profits by product up gradation and continuous improvement.

Few steps involved in implementing these Engineering techniques effectively in any organization:

- Team formation
- Study of Product, processes, systems, methods, product functions
- Values based upon the cost incurred.

To establish above mentioned, various tools, techniques and methods are used such as Project charter, SIPOC, Fishbone Diagram, FMEA, RTY, Gauge R&R etc these are the values to be found out first to get the product oriented figures. Then function-improving methods like Decision making matrix, Brain-storming methods, etc. are used. Six Sigma job Plan helps in effective implementation of these methods.

The most important factor to be taken care off by the Sigma Coordinator is CHANGE. People do not easily accept changes in their daily routine which is must for improvement of organization. This change forces them to put in extra effort to complete their tasks which they generally try to escape. Hence it becomes the responsibility of coordinator to motivate his team members to bring a change in major tasks.

All major issues related to product, processes, their functions, staff, management, teams, institutions and organizations are addressed using Six Sigma methods. This study is done with an objective to provide a review of Six Sigma methodology literature. Based on this review, means for further research can be accomplished in areas of interest in the manufacturing/technology field. The study includes 42 articles from 23 reputed referred Journals.

More specifically, the purpose of this study is to:

- Classify Six Sigma research articles according to their approach and Methodologies; and provide a brief overview of these methods/techniques
- Classify the journals that actively publish Six Sigma literature
- Consider the frequency of literature by year of publication
- Provides a brief overview of some of the salient methods that exist in literature to tackle the Six Sigma techniques
- Suggest a research agenda for future work, with special emphasis on the impact of frequent advancement in manufacturing methods/technology.

The paper consists of following:

- Section 2 provides a Literature review,
- Section 3 presents that classification of literature along several aspects,
- Section 4 provides methodology,
- Section 5 delineates avenues of further research and provides concluding remarks.

### II. LITERATURE REVIEW

Six Sigma is a very vast field consisting of extensive literature. Our main focus was on the literature for the period 2005 - 2014. Many research papers were referred from these proceedings especially, 2010-2014. A

list of journals was compiled based on a survey of literature on the editorial scope and contents of the journals. Journals stating in their editorial scope issues such International Journal of Production Economics, Journal of Operations Management, Procedia Engineering and Technovation were selected. The ultimate list of articles reviewed by this paper covers articles published in reputed refereed scholarly journals. Based on this review, Articles covered in this paper are the ones meeting the criteria of addressing issues related to Value based improvement in Products, Processes cost saving, management and Institution professionals training etc.

A comprehensive review of few relevant papers has been carried out in detail so as to get better ideal about the literature.

Kevin Linderman, Roger G. Schroeder, Srilata Zaheer & Adrian S. Choo, [1], In this study, authors help serve as a foundation for developing scientific knowledge about Six Sigma[1]. Studying the Six Sigma phenomena from a goal theoretic perspective also provides opportunities to develop more insights into goal theory. Goal theory has been developed in the context of day-to-day management of organizations and routine decision making[1].

Jeroen deMast , JoranLokkerbol, [2], In this study, we conceive of DMAIC as a problem solving method, and analyze it from that perspective[2]. DMAIC is applicable to empirical problems ranging from well-structured to semi-structured, but not to ill-structured problems [2].

Gulcin Buyukozkan , Demet, [3], In this study, authors aims to develop a novel approach based on a combined ANP and DEMATEL technique to help companies determine critical Six Sigma projects [3].

Satya S. Chakravorty, [4], One reason many Six Sigma programs fail is because an implementation model on how to effectively guide the implementation of these programs is lacking [4]. In this study, author provides a model to effectively guide the implementation of Six Sigma programs to reduce variation or waste from the operations. This is particularly relevant because today's competitive environment demands that companies reduce variation (waste) to meet or exceed efficiency and responsiveness requirements of customers [4].

M. Sokovic , D. Pavletic , S. Fakin,[5], In this study, authors deals with application of Six Sigma methodology in process design [5]. The application of some isolate tools from Six Sigma methodology provides benefits in process improvement [5]. These results could be improved with more widespread use of Six Sigma tools & methodology[5].

Young Hoon Kwak, Frank T,[6], Understanding obstacles, and shortcomings of the six sigma method allows organizations to better support their strategic directions, and increasing needs for coaching, mentoring, and training[6]. Evaluating fidelity of the attacked images is important for attack development and consequently watermark development [6].

Chantal Baril , Soumaya Yacout , Bernard Clément,[7], In this study, authors presents a global methodology for designing product for Six Sigma[7].

Tongdan Jin , Balaji Janamanchi,[8], In this study, authors proposes a Six Sigma based framework to deploy high product reliability commitment in distributed subcontractor manufacturing processes[8]. The majority of the field failures were defect driven since the failures due to design, structure and materials were often eliminated or reduced through design for reliability (DFR) practices or relentless reliability tests [8].

George S. Easton, Eve D. Rosenzweig,[9], In this study, authors studies the role of individual experience, organizational experience, team leader experience, and experience working together on a team (team familiarity) in the context of improvement teams[9].

S.J. Harjac, A. Atrens , C.J. Moss,[10], In this study, authors provides a summary of a desktop review, using the Six Sigma methodology, of root causes for corrosion incidents in Hot Potassium Carbonate acid gas removal plant. A methodology like Six Sigma can be used to assist in overcoming the corrosion problem in HPC plants[10].

J.P. Charles, F. Hannane , H. El-Mossaoui,[11], In this study, authors presents a novel application of the Design of Experiments (DOE) method as a practical method to detect any dysfunction of an operating photovoltaic (PV) panel[11]. The main advantages of the method of Design of Experiments are to bring together in one relationship all the information that can be contained in each factor separately or jointly and to minimize the number of a priori characterization experiments [11].

Kent Cronholm,[12], The case study shows that the VMEA method may be useful even if the information is limited. In this study, author presents a method where the Variation Mode and Effect Analysis is used to convert subjective knowledge about variation and importance of parameters for a certain characteristic among practicing engineers into numerically comparable values[12].

Shuiquan Li , Ye Zhang,[13], This study is applicable to analyzing other subsurface data-poor environments, where key performance metrics can be evaluated against different conceptual models, and over time[13]. The SA results are compared among the families to identify parameters that have 1st order impact on predicting CO<sub>2</sub>storage ratio (SR)at two different time scales, i.e., end of injection and end of monitoring[13].

Kedar Sambhoos, Christopher Bowman, James Llinas,[14], This work has shown how the processes of Design of Experiments. The emphasis of this paper is to design a performance evaluation methodology for Level 1 distributed data fusion processes [14].

Ralph Evins , Philip Pointer , Ravi Vaidyanathan , Stuart Burgess,[15], This work has shown how the processes of Design of Experiments with system decomposition, optimisation at varying levels of detail, and “innovisation” techniques for graphically extracting information from outputs can be combined into a powerful framework[15]. Design-of-Experiments analysis is performed to determine the significance of each input to the outputs of Standard Assessment Procedure (SAP)[15].

Gaia Franceschini, Sandro Macchietto,[16], In this study, authors has intended to present a selected overview of model-based experiment design techniques for increasing parameter precision[16]. Due to the wide use and key importance of mathematical models in process engineering, experiment design is becoming an essential tool for the rapid building and validation of these mechanistic models[16].

### III. CLASSIFICATION OF LITERATURE

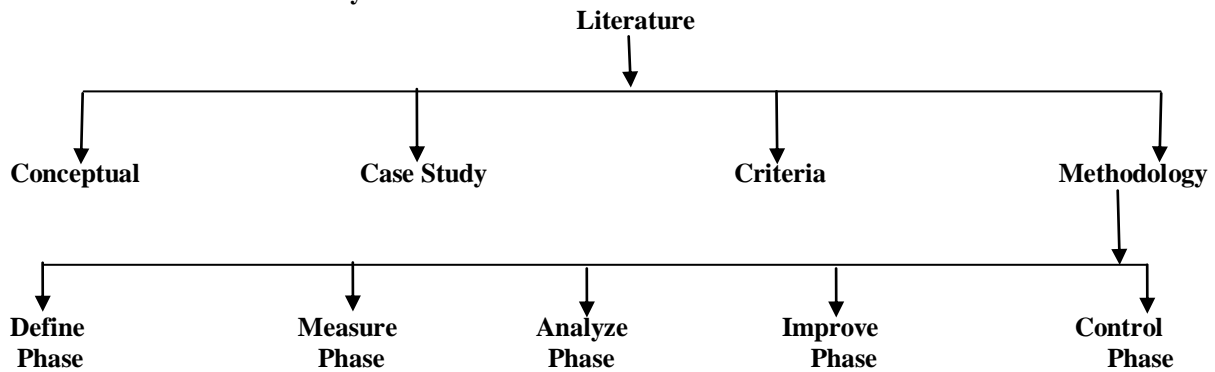
#### 3.1 Frequency of Articles in Journals

The journals were categorized as high or low contributors to the supplier selection research based on the criterion of number of articles published. Table 1 presents the outcome of the survey. As can be seen from Table 1, journals were segmented on the basis of number of articles published. Based on the literature review, Journal of Operations Management published 16.6 percent of the articles on Six Sigma. International Journal of Production Economics and Procedia Engineering have published 14.3 percent of the articles on Six Sigma. Journals classified as low contributors published around 2.4 percent each of the articles.

Journal Outlets of Selected Articles	No. of Papers	Percentage
Journal of Operations Management	7	16.6
International Journal of Production Economics	6	14.3
Procedia Engineering	6	14.3
Expert Systems with Applications	3	7.1
Chemical Engineering Science	2	4.2
Engineering Failure Analysis	1	2.4
Computers & Industrial Engineering	1	2.4
Technovation	1	2.4
Aerospace Science and Technology	1	2.4
Electrical Power and Energy Systems	1	2.4
International Journal of Greenhouse Gas Control	1	2.4
Information Fusion	1	2.4
Building and Environment	1	2.4
Journal of Air Transport Management	1	2.4
Automation in Construction	1	2.4
Measurement	1	2.4
Journal of Manufacturing Systems	1	2.4
Applied Energy	1	2.4
Journal of Material Science and Technology	1	2.4
International Journal of Machine Tools & Manufacture	1	2.4
Journal of Bio mechanics	1	2.4
Microelectronics Reliability	1	2.4
Journal of Cleaner Production	1	2.4
<b>Total</b>	<b>42</b>	<b>100.00</b>

**Table 1: Frequency of Six sigma Methodology in Journals**

3.2 Classification of Articles by Content



The literature is classified into four broad categories based upon the content of the literature. These categories are conceptual, case studies, criteria and methodology. Further the methodology is classified in five phases they are Define phase, Measure phase, Analyze phase, improve phase and Control phase

	Count	Percent
<b>Conceptual</b>	20	47.6
<b>Case study</b>	15	35.7
<b>Methodology</b>	4	9.5
<b>Criteria</b>	3	7.2
<b>Total</b>	<b>42</b>	<b>100.00</b>

**Table 2: Classification of the Articles**

Table 2 presents the outcome of the classification of literature. As can be seen from Table 2, literature were classified on the basis of content. Based on the content of literature, Conceptual papers has a contribution of 47.6 percentage of total literature, Case studies has a contribution of about 35.7 percentage of all the literature, whereas methodology and criteria has a contribution of about 9.5 percentage and 7.2 percentage respectively of the total literature.

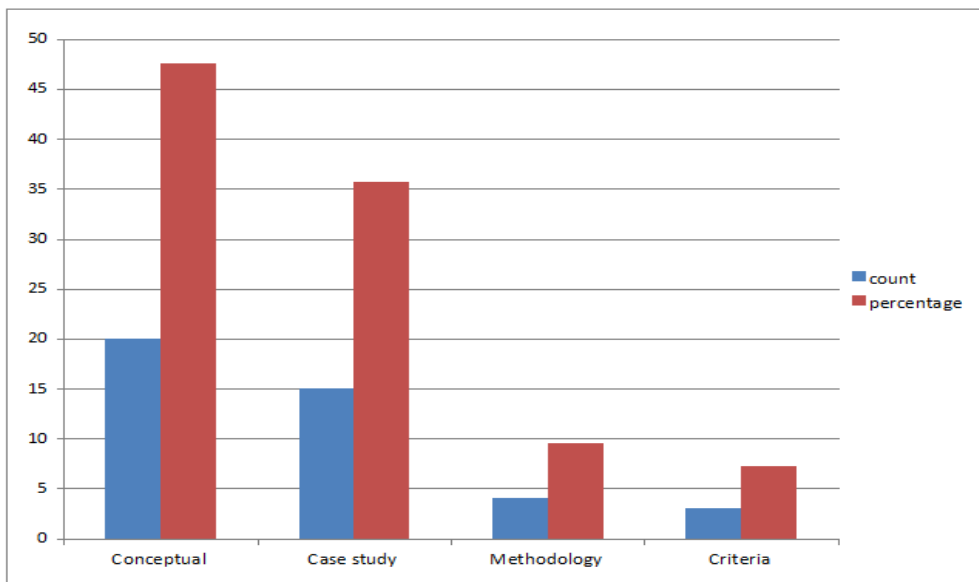


Figure (1) - Bar chart for classification of literature

Fig.1 shows the detail bar chart for the classification of literature on the basis of its content. The count of number of articles as well as their percentage contribution is shown for all the four broad classifications.

#### IV. METHODOLOGY

The Methodology is then classified mainly into five phases effective for all target elements. Which are define phase, measure phase, analyze phase, improve phase and control phase. These are to be executed while implementing any of the classified elements.

The paper has chosen to concentrate upon six sigma(DMAIC) methodology:

- **Define Phase:** In order to implement the Six Sigma Methodology and Management System it is crucial to define:
  - The Customer – who is the customer, what do they want and what are their expectations? This will involve looking at quality control issues and core business processes
  - The project boundaries – Where does the process begin and end?
  - The process to be improved
- Tools used in the phase are as follows:
  - Project charter
  - Project Schedule
  - CTQ(Critical to Quality)
  
- **Measure phase:** In order to apply the Six Sigma Methodology and Management System it is essential that you measure the performance of Core Business Processes. You will need to –
  - Develop a plan for the collection of data for the process
  - Gather data to identify types of defects and metrics
  - Compare evidence to customer survey results
- Tools used in the phase are as follows:
  - Data Collection
  - Gage R&R(Gage Repeatability and reproducibility)
  - SIPOC
  
- **Analyze Phase:** The next step in the DMAIC model is to analyze the data and process map to establish causes of defects and where you can improve:
  - Current performance and goal performance are compared to identify gaps
  - Opportunities for improvements are prioritized
  - Sources of variation are identified
- Tools used in the phase are as follows:
  - Pareto Chart
  - Fishbone diagram
  - Regression Analysis
  - FMEA(Failure Mode and Effect Analysis)
  
- **Improve Phase:** Using the data from the implementation of the above it is now possible to improve the process by designing creative solutions to fix and prevent problems. This is achieved by
  - Using discipline and technology to develop innovative solutions
  - Develop and implement a plan
- Tools used in the phase are as follows:
  - Brainstorming
  - Design Changes
  - DOE(Design of Experiment)
  
- **Control Phase:** Control and sustain improvements over time by –
  - Preventing the instinct to return to the old ways of doing things
  - Developing, documenting and implementing an ongoing monitoring plan
  - Integrating the improvements throughout the company through the use of training, staffing and incentives.
- Tools used in the phase are as follows:
  - Control Charts
  - Process Capability Six pack
  - Hypothesis Testing
  - Process Sigma Calculation

## V. AVENUES OF FURTHER RESEARCH

The review of literature leads us to believe that there are still several avenues of research that need to be addressed. The following are some of the salient ones:

1. The Societies like ASQ, ISSSP are conducting various certified program for individuals in Industries. Similarly various certified workshops should be customized to promote the Group Training Program to the six sigma team in different organizations. Extra efforts should be made in forming the Strategic Plans for Need-based Training Program for different sized six sigma Teams in the Different-sized Organizations. This will help the organization to gain success in a ruthlessly competitive global environment.
2. Some Standard Process Tools to be followed in various Product manufacturing, Project executing, Plant running or Process Industries should be established using Six Sigma methodology. These six sigma Process Tools should accommodate various processes, their functions, applicability, efficiency improvement and running cost saving modules for the complete and continuous adaptations for the overall improvement of the organizations.
3. Product Development: Product development needs to be done with Valuable inputs for both at prime design level and at an existing design. Continuous database updating tool should be developed to acquire existing and advanced techniques of manufacturing, machining and processing the various components of the Product being assembled or manufactured. This database can be fed into Decision making Matrix for the Alternate, cost saving, more efficient and valuable manufacturing technique to be employed.

## VI. CONCLUDING REMARKS

This paper gives brief but incisive insight into the existing literature. As shown above new avenues for the further research can be opened. The imperative of six sigma methodology in all kinds of activities globally everywhere is solicited strongly. It is assumed that the said avenues can be greatly taken care for exploiting the six sigma Techniques. It is also presented that the literature would help businesses visualize what quality and process events will occur given various situation and ultimately help them in their overall development.

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