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Impact of Six-Sigma DMAIC approach on Manufacturing Industries

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Abstract: The concept of Six-Sigma has dominated the management scene for some decades. Six-Sigma is a rigorous, disciplined, data-driven methodology that was developed to enhance product quality and company profitability by improving manufacturing and business processes. Many organisations all over the world have tried to use Six-Sigma DMAIC (Define, Measure, Analyze, Improve, and Control) approach and its tools to get optimised organisational achievements. The present work is an attempt to study the impact of Six-Sigma DMAIC approach in manufacturing industries of Ludhiana. This study is to explore the level of usage and level of difficulty of different tools of DMAIC approach. Barriers in implementing Six-Sigma DMAIC approach and the benefits achieved after successful implementation of DMAIC approach have also been identified. A well designed questionnaire has been used to collect data from 23 manufacturing industries. The results from the analysis of data have shown that, the manufacturing organizations have less educated man power (Mean=2.8260 significant at 5% level) and also they are lacking in to provide adequate training to them for effective implementation of Six-Sigma tools. Furthermore, the results have shown that maturity phase of DMAIC approach enhances the improvements as compared to initial and developing phase, yet it can be concluded that Six-Sigma DMAIC approach is still growing in manufacturing organizations. Also, the results of correlation analysis indicate that DMAIC approach is significantly used to improve the quality (r=0.443122 significant at 5% level) of product.

Keywords: D-Define, M-Measure, A-Analysis, I-Improve, C-Control.

I. INTRODUCTION

Six-Sigma: An overview

The foundation of the Six-Sigma program is statistics; sigma stands for standard deviations from the mean of a data set in other words a measure of variation, while Six-Sigma stands for six standard deviations from the mean. When a process reaches the Six-Sigma level that process will be running close to perfection, producing a mere 3.4 defects per million. By using statistical and analytical tools firms can reduce the amount of variation in a process by removing the causes of variation therefore increasing the output quality of the process. The primary objective of the Six-Sigma methodology is the implementation of a measurement based strategy, which focuses on process and sub-processes improvement through the application of Six-Sigma best practice such as DMAIC and DMADV. The Six-Sigma DMAIC (Define, Measure, Analyze, Improve, and Control) approach is applied for improving existing processes and looking for incremental improvement. The Six-Sigma DMADV (Define, Measure, Analyze, Design, and Verify) approach is applied for developing new processes or products at Six-Sigma quality levels. The success of this methodology within an organization has significant momentum that can only lead to fundamental organizational cultural transformation. **The research objectives of this study** –(1) To assess the current status of Six-Sigma DMAIC approach by determining level of usage and level of difficulties of various tools used in DMAIC approach (2) To determine the barriers in implementing DMAIC approach and benefits achieved from Six-Sigma implementation.

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II. REVIEW OF LITERATURE

Review of literature related to Six-Sigma – Review of literature is done to understand the concept of Six-Sigma, to understand the various phases of this approach, to find out the tools used in all phases and to investigate the barriers in implementation.

Harry (1998) claimed that people in industries from manufacturing to service are witnessing the growth of a strategic continuous improvement concept called Six-Sigma.

Edgeman (2000) defined that Six-Sigma of today speaks the language of management: bottom-line results.
Henderson and Evans (2000) pointed out seven components of successful Six-Sigma implementation as upper management support, organizational infrastructure, training, tools, link to human resource based actions measurement system and information technology infrastructure.
Williams (2001) highlighted that continuous improvement techniques are the recognized way of making significant reduction to production costs.
Tennant, Geoff (2001) concluded that the objective of Six-Sigma is to reduce the variation in the process and also defects of the final product.
Coronado and Antony (2002) conducted a review of the literature related to the critical success factors (CSF) that lead to effective implementation of Six-Sigma.
Antony (2002) concluded that Six-Sigma methodology aims to reduce the number of mistakes/defects in a manufacturing process and hence the manufacturing costs.
Goh (2002) concluded that Six-Sigma as a quality improvement framework has been gaining considerable attention in recent years.
Thomas (2003) reviewed that the Six-Sigma is a financial improvement strategy for an organization and now a day it is being used in many industries. Basically it is a quality improving process of final product by reducing the defects
Kuei and Madu (2003) argued that quality leadership among top managers is one of the key drivers of successful completion of the DMAIC project cycle.
Antony et al. (2005), based on their study of 11 success factors in small and medium manufacturing industries of UK, it revealed that management involvement and participation, linking Six-Sigma to customers and linking Six-Sigma to business strategy of the organization are the most important factors for success of Six-Sigma.
Sokovic et al. (2005) discussed the application of Six-Sigma methodology in process design. **Bendell (2006)** reviewed and compared Six-Sigma and the lean organization approaches to process improvement.
Camgoz (2007) has defined Six-Sigma on the basis for a best-in-class philosophy and a long-term business strategy that measures quality improvement.
Cheng (2008) reviewed the literature related of TQM and Six-Sigma, and then constructed and explored the conceptual framework via an empirical study.
Yang et al. (2008) concluded that Six-Sigma is a fashionable method of management, but if organizations want to obtain dramatic benefits from the implementation, they must enhance the implementation of the critical success factors but the more problematic area issue is presence of a barrier, as barriers pull down the organization in negative direction. There are relatively less reported studies about barriers.
Mandal et al. (2008) used statistical techniques to analyze significant relationship among key parameters for success of US manufacturing sector based on empirical data.
Desai and Shrivastava (2008) performed a case study by applying Six-Sigma DMAIC (Define–Measure-Analyze-Improve-Control) methodology in an industry which provides a framework to identify, quantify and eliminate sources of variation in an operational process to optimize the operation variables, improve and sustain performance and found that Six-Sigma improves the process performance (process yield) of the critical operational process, leading to better utilization of resources, decreases variations & maintains consistent quality of the process output.
Pranckevicius et al. (2008) discussed the application of the Six-Sigma DMAIC model to improve the plastic cup manufacturing process.

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Antony(2008) carried out a survey in manufacturing and service organisations to understand the status of Six-Sigma and presented essential ingredients which are required for the successful deployment of Six-Sigma and concluded that Six-Sigma is now increasingly applied to a variety of processes ranging from manufacturing to service and variegated transactional processes.

Preeprem and Hendry(2008) explored the areas of weakness in Six-Sigma implementations that may require enhancements in the methodology and investigated critical success factors.

Pulakanam and Voges (2010) investigated that organizations are increasingly adopting Six-Sigma in a bid to improve the quality of their processes and products, and thus achieve competitive advantage.

III. RESEARCH WORK

As field survey provides economies for doing research, it also has number of potential weakness like no control over who fills out the questionnaire. To overcome this disadvantage of sending the questionnaire to different organizations, it has been decided to distribute and collect the questionnaire from the respondents personally. Also it has made possible to collect responses in a very small span of time saving the precious time.

Survey Instrument and its Content Validity

For conducting survey, a questionnaire on four point scale has been designed which consists of four different sections (Section-A, B, C and D). Section-A includes questions related to general information about the company, respondent characteristics, size of the industry, main products of the company, whether they are using Six-Sigma or not. Section-B indicates the level of use of tools of Six-Sigma DMAIC approach in an organization. The extent of use is determine on four point scale (1= Not applicable, 2= immature , 3= developing, 4= mature) and level of difficulty also determine on four point scale (1= Not at all, 2= To some extent, 3= To moderate extent, 4= To a large extent).

Section- C represents the various barriers faced by the companies during Six-Sigma implementation. Section-D shows Benefits achieved after the implementation of Six-Sigma DMAIC approach. The survey instrument is pre tested for content validity, ambiguity and clarity by professionals.

To check the content validity of questionnaire advanced statistical software SPSS is used**.** In statistics, Cronbach's α (alpha) is a coefficient of internal consistency. It is commonly used as an estimate of the reliability of a psychometric test for a sample of examinees.

Types of manufacturing Organizations surveyed

A total of 40 manufacturing organizations have been surveyed in Ludhiana. Different types of manufacturing organizations surveyed based on the products manufactured.

Respondent Characteristics

Different persons at different levels of organization have participated in this survey. Survey respondents are divided to eight (5) categories. Survey shows that majority of respondents that have participated in this survey are at Management Representative(15%) Manager level (40%), Senior Engineer level (25%) and Engineer level (20%) from different departments of the organizations.

Out of these 40 manufacturing organizations surveyed, twenty three (23) organizations are applying Six-Sigma DMAIC Approach and seventeen (17) are not applying this technique.

Types of organizations applying Six-Sigma approach

Out of 23 organizations applying Six-Sigma approach, Auto Parts =13, Multi products=6 and Cycle Parts =4.

Respondents of Organizations apply Six-Sigma technique

Out of 23 respondents, Management Representatives (4), Managers (6), Assistant Managers (3), Senior Engineers (6), and Engineers (4) have participated in this survey. Heads of different departments included in Manager.

Size of the Organizations under study: Out of these 23 organizations applying Six-Sigma technique, fifteen (16) are medium scale and seven (7) are large scale. The size of the organizations under study based on medium scale (69%) and large scale (31%).

Number of years since Six-Sigma adoption

On the number of years since Six-Sigma adoption, four groups are formed. These four groups include the organizations where years since Six-Sigma adoption are less than 2 year, between 2-4 years, between 4-6 years and more than 6 years. Out of 23 manufacturing organizations applying Six-Sigma technique, thirteen (13) organizations are between 2-4

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Vol. 3, Issue 5, May 2014

years, four (4) organizations are between 4-6 years and six (6) organizations more than 6 years. It reveals that 57% of the organizations under study had adopted this technique since 2-4 years, 17% between 4-6 years and 26% above 6 years.

IV. EXPERIMENTAL RESULTS

Analysis of Questionnaire

For the analysis of questionnaire, the following categories have been made:

1) Level of usage of DMAIC approach by calculating TPS and PPS.
2) Level of difficulty in implementation
3) Barriers in implementing Six-Sigma approach
4) Benefits achieved after successful implementation of approach

Level of usage of DMAIC approach by calculating TPS and PPS

The questionnaire filled by the manufacturing organizations applying Six-Sigma has been analyzed at each phase level i.e. Analysis is done on the basis of five (5) phases. Value of Total Points Scored and Percent Point Scored has been calculated for each tool of five phases. The level of usage each tool has been calculated on the value of PPS.

Level of difficulty in implementing DMAIC approach

Analysis for determining the degree of difficulties in implementing DMAIC approach is done on each tool and each phase level. The mean, standard deviation and *t*-statistics has been calculated for each tool and hypothesized mean for each phase. The degree of difficulties in implementing various tools of DMAIC approach has been calculated on the value of mean and the level of significance has been tested on the basis of *t*-test. Further degree of difficulty at phase level has been calculated on the basis of hypothesized mean.

Level of difficulty in implementing phases of DMAIC approach

Level of difficulty of various phases has been calculated on the basis of hypothesized Mean (μ). The result reveals that analyze phase (hypothesized Mean (μ) =2.434783) has maximum degree of difficulty and control phase (hypothesized Mean (μ) = 1.973913) is least difficult to implement.

Barriers in implementing Six-Sigma approach

Analysis for determining the barriers in implementing Six-Sigma approach is done on the basis of fourteen (14) barriers related to organizations. The mean, standard deviation and *t*-statistics has been calculated at each element level. The severity of a barrier has been calculated on the value of mean and the level of significance has been tested on the basis of *t*-test.

Benefits achieved after successful implementation of approach

Analysis is done on the basis of six (06) main benefits including Production, Quality, Cost, Safety, Delivery and Morale and also on the basis of other sub benefits of Six-Sigma. The important benefits achieved from Six-Sigma implementation are determined from the value of mean and level of significance has been tested on the basis of *t*-test

Limitations of the Study

- The sample size of this survey is relatively small. For more precise results, large sample sizes may be considered.
- The selection of manufacturing organizations has been done on the basis of convenient sampling technique.

Scope of Future Work

- This survey can be extended to service organizations as well.
- The survey can be expanded by taking into consideration the reasons for the difficulties in implementing this technique.
- The study has been conducted by collecting the empirical data through questionnaire and using various statistical tools. The results obtained through questionnaire can be further validated by performing case studies on selected manufacturing industries.

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V. CONCLUSION

From the results and discussion, the following conclusions are drawn:

- It is concluded that Process mapping (PPS=78.84), Pareto Charts (PPS=91.80), Sampling Plan (PPS=86.40), Kaizen (PPS=84.24) and Check Lists (PPS=90.72) are highly used tools of DMAIC approach.
- The tools including Benchmarking (Mean=2.243478), Affinity diagrams (Mean=2.521739), ANOVA (Mean=3.086595), Taguchi's experiment (Mean=2.652174), Standard operating Procedure (Mean=2.214235) are highly difficult to implement. Manufacturing organizations are facing maximum degree of difficulty in implementing analyze phase and least degree of difficulty in implementing control phase.
- Less educated workforce due to inadequacies of training (Mean=2.82608) is the most important barrier in implementing DMAIC approach.
- The results of correlation analysis indicate that DMAIC approach is significantly used to improve the quality (r=0.443122) of products.
- It has been also concluded that maximum benefits are achieved in maturity phase as compared to developing and introductory phase which shows that Six-Sigma DMAIC approach is still growing in manufacturing organizations of Ludhiana.

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International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 3, Issue 5, May 2014

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