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Industrial Applications and Practices of Six Sigma – A Literature Review

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Abstract: In recent years six sigma being widely adopted by various industries to achieve the expected goals, makes it an important subject of debate for quality management. This paper is an attempt to review the industries which are benefited by successful implementation of six sigma and explore the sectors where six sigma implementation should be emphasised. The review unveils that six sigma is largely implemented in manufacturing industry and emphasis should be given in successful implementation of six sigma in power industry as well.

Keywords: Six sigma, DMAIC, DPMO, Power industry.

I. INTRODUCTION

Six sigma is a disciplined and data driven methodology that was developed to enhance product quality and company profitability by improving manufacturing and business processes [1-2]. It is considered to be the latest and most effective technique in quality engineering. Implementation of six sigma in an organization results in substantial increment in their profit, minimizes all types of waste and maximizes customer satisfaction[3]. Six sigma improves the quality output of a process by identifying and removing the causes of defects and minimizing variability in manufacturing and business processes which reduces cost and increases profit [4-5]. It uses a set of quality management methods, mainly empirical and statistical methods. It creates a special infrastructure of people within the organization who are experts in these methods. It is a business strategy that allows companies to apply scientific methods to improve their performance drastically by designing and monitoring everyday business activities in a way that minimize waste and resources while increasing customer satisfaction [6].Six sigma is a powerful business improvement strategy which enables companies to achieve and sustain operational excellence by using simple but powerful statistical methods. The term Six sigma originated from terminology associated with manufacturing, specifically terms associated with statistical modelling of manufacturing processes.

Six sigma indicates standard deviations from mean. The maturity of a manufacturing process can be described by a sigma rating. When a process reaches six sigma level it is said to be running at near perfection and it produces a mere 3.4 defective parts per million opportunities (DPMO) [1]. One of the basic reason due to which six sigma became very popular all over the world is that it is considered to be a fresh quality management strategy by which TQC (Total Quality Control), TQM (Total Quality Management) and other can be replaced. The most vital part of six sigma is that it is the integration of customer, process, manpower and strategy [7]. Six sigma is a new paradigm in the area of manufacturing strategies to achieve various quality goals.

Six sigma is adopted worldwide in manufacturing industry to increase productivity and to make a process robust to quality variations [3].

II. OBJECTIVE

The objective of this paper is to review the significance of applying six sigma methodologies in various industries and how it helps an organization to yield better products and services. The paper also aims to identify those sectors where successful implementation of six sigma need to be further explored, validated and recognised.

III.LITERATURE REVIEW

Six sigma has been the subject of interest to many researchers over the years. Six sigma methodologies improve quality and produce large cost savings. Many researchers studied six sigma programs and identified six sigma as an important tool to enhance product quality and company profitability. For example, in a paper researchers signify implementation of six sigma DMAIC (Define-Measure-Analyze-Improve-Control) methodology in a small size furnace manufacturing industry. Itwas identified from the Pareto chart that overall performance of the shell and tube heat exchanger (an integral component of furnace) is mainly affected by the effectiveness of the heat exchanger. Circular fins over the bare tubes of the heat exchanger were introduced to increase the effectiveness of the shell and tube heat exchanger from 0.61 to 0.664. It is worth mentioning that saving of INR 0.34 million per year was achieved by improving sigma level from 1.34 to 2.01[8].

In another paper initiative was taken to apply six sigma in auto sector manufacturing firm to reduce the level of defects. Initially define phase was applied and statistical tool such as Pareto chart was also used [10]. Another attempt was made for finding the implication of six sigma methodology in small scale industries (SSI), taking a specific case of Hydraulic jack manufacturing industry. Six sigma methodology application control high rejection

rates of pump head of hydraulic jack set. In this case sigma level was improved from 2.21 to5.64 and cost saving of INR. 0.01929 million per annum was achieved [4].Kaushik et al. try to review the implications of Six sigma methodology in a bicycle chain manufacturing unit, which falls in an SME environment.

By applying DMAIC methodology bush diameter variation is reduced in the process of bicycle chain bush manufacturing, which results an increase in sigma level from 1.40 to 5.46. This increase in sigma level resulted in monetary savings of INR 0.288 million per annum [11].

In a paper Srinivasan et al. try to reduce the high rejection rate in the painted damper outer tube of shock absorber in a leading shock absorber manufacturing company by applying six sigma DMAIC methodology. It was clear from the Pareto chart that Peel off and Blisters are the two major reasons behind high rejection rate. Fish bone diagram was used to identify the various causes which results in the formation of peel off and blisters. It was observed that major causes which influence the peel off and blister are cleaning temperature, phosphate PH and phosphate temperature. From response diagram for peel off and blisters it was clear that both blisters and peel off can be optimised effectively by setting cleaning temperature, phosphate PH and phosphating temperature at 700C, 3.5 and 600C respectively [9].

In paper Desai and Shrivastava tabulated the process yield of SAW boom machines for a period of one year and the Saw boom machine having lowest process yield have been considered for improvement. Pareto chart analysis identified the major cause of low process yield as lack of work which is mainly dependent on the scheduling of the activities. Various input variables were identified and actions were taken to optimize these inputs to improve the process. It was observed that sigma level improved from 1.8 to 3 and corresponding process yield improvement is 61.8% to 93%. This increased sigma level results a cost saving of INR. 1.2 million Per annum [3].

In a paper Youssouf et al.[13] focused on the optimizing maintenance of industrial systems with the help of lean six sigma [13]. Brun in his paper elaborates the results of a research project which was focused on six sigma implementation in the typical Italian companies with a purpose to drive the attention of the scientific community towards such issues [12].

Sharma and Rao used statistical process control (SPC) as a quality assurance tool to improve the quality of manufacturing. SPC was used to record the key quality characteristics (KQCs) of the manufacturing of connecting rod of an internal combustion engine.

Applying the DMAIC approach the estimated standard deviation was reduced from 0.408 to 0.048 and also process performance capability index was increased from 0.12 [14]. In a paper Chowdhury et al. 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) [15].

In case of aviation industry most of the research concerned with the mitigation of risk. Stolzer et al. attempted to enhance the current FOQA (Flight Operational Quality Assurance) methodology by implementing six sigma. Mean and standard deviation were varied to explore the effect on process sigma and it was asserted that Six sigma can be effectively used in FOQA programs [16].

An attempt was made by Vassilakis and Besseris to identify the causes behind the defects detected during maintenance process (assembly) 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 (Total Quality Management) policy and a new statistical quality control scheme should be deployed [17].

A model was established by Al Muhareb and Graham-Jones based on the six sigma DMAIC approach to apply in the departure area at KKIA (King Khalid International airport). The application of the proposed model results in a decrease in waiting time of passengers and also improves the level of different services in the departure area [18].

Sectors such as health care, power generation are also not left far behind in six sigma practices. In recent years 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. Yeh et al. established a model which developed a suitable structure of Lean Six sigma to improve service delivered to AMI (acute myocardial infarction) patients [19].

In a paper Bandyopadhyay and Coppens explains how six sigma can be implemented successfully in healthcare industry to improve quality of services offered to the patients and reduces healthcare cost [20].

An initiative was taken by Kaushik and Khanduja to implement six sigma in Thermal Power Plant. It has been observed that an increase of 0.1 % in DM (De-mineralize) make up water consumption resulted an increase of INR 82.82 lakhs per annum in generation cost.

Fish bone diagram was used to find out the causes for consumption of more DM water during the combined cycle. The implementation also helped to reduce the DM-make up water consumption from 0.90% to 0.54% of MCR (maximum continuous rating), which resulted in energy savings of INR 304.77 lakhs per annum [21].

IV. REVIEW ANALYSIS

Table I shows the implementations of six sigma across various genres of industries. The relevance of six sigma implementation amongst these institutions can be well understood from Fig. 1. As evident from the figure that six sigma is implemented largely in manufacturing industries as compared to other sectors. Also power industry is having the least six sigma implementation

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TABLE I INDUSTRY WISE IMPLEMENTATION OF SIX SIGMA

Industry / sector	**Six sigma implementation**
Manufacturing	Improve effectiveness of a shell and tube heat exchanger.
	Reduction in the rejection rate of pump head of hydraulic jack set.
	Reduce brush rejection rate in a bicycle chain manufacturing unit.
	Reduce of high rejection rate of the painted damper outer tube of shock absorber.
	Improve connecting rod manufacturing process.
	Analyze the production defects in case of manufacturing of thermoformed refrigerator liners.
	Optimize maintenance process for industrial systems by using six sigma.
	Reduce level of defects in auto sector manufacturing firm.
Aviation	Enhance the FOQA (Flight Operational Quality Assurance) methodology.
	Minimize defects of maintenance process (assembly) in an aerospace company.
	Improve level of service in the departure area.
	Decrease waiting time of passenger.
Healthcare	Improve quality of services offered to the patients.
	Reduces healthcare cost.
Power	DM make up water reduction in thermal power plant.

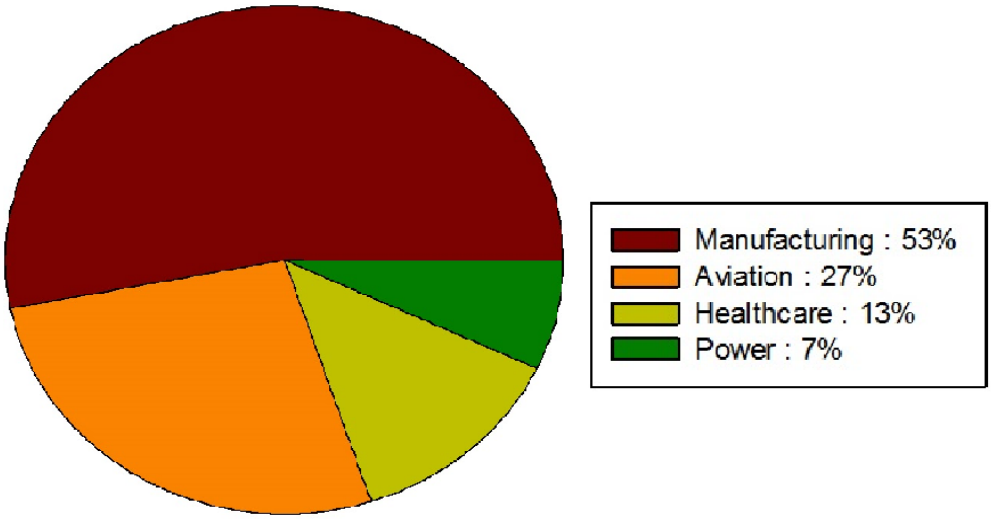

Fig. 1 Sector wise distribution of industries where six sigma is implemented.

V. CONCLUSION

The study shows different industries which are being benefited by increasing overall profit, productivity and reducing cost of poor quality by successful implementation of Six sigma. This review also discloses that six sigma implementation is maximum in case of manufacturing industries while power sectors the least. As electricity is required to perform day to day activities smoothly and efficiently as well as for running of almost all industries, it plays a vital role in the socio-economic development of the country. So it is asserted that initiative should be taken to implement six sigma methodology in power sector to ensure that desired power is generated in an efficient way at a minimal cost with minimum resource requirements, similar to the way it is being implemented successfully in manufacturing industries.

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