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Quality & Productivity Improvement using Six Sigma – A literature Review

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Abstract – *There has been number of papers published related to Six Sigma applications in manufacturing and service organizations. However, very few studies are done on reviewing the literature of Six Sigma in all the areas including manufacturing, construction, education, financial service, BPOs and healthcare etc. Considering the contribution of Six Sigma in recent time, a more comprehensive review is presented in this paper. The following research is based on a Systematic Literature Review of 50 papers which were published on six sigma in the top journals in the field and other specialist journals, from 2003 to 2016. The authors have reviewed Six Sigma literatures in the way that would help research academicians and practitioners to take a closer look at the growth, development, and applications of this technique. The authors have reviewed various journal papers and suggested different schemes of classification. In addition, certain gap areas are identified that would help researchers in future research.*

A systematic approach needs to be adopted, which optimizes systems as a whole, focusing the right strategies in the correct places. The comprehensive review of shortlisted articles indicates that Six Sigma can be considered effective methods to support the conservation of resources, quality improvement and increasing efficiency. Various scholars provide evidence of this and as such, organizations should not only consider these methods to manage quality and improve operational performance but also meet environmental regulations. A set of research questions that demands future investigation has also been proposed based on the findings of this research.

This paper contributes to knowledge by providing an insight into the evolution of the Six Sigma. A very few literature are available related to analysis of boring machine using six sigma. Literature exploring the environmental/green impact of quality management methods commonly used in industry is limited. There is also a lack of studies aiming to investigate the green impact of Six Sigma in top operations and quality management journals. The study focusing on investigating the green impact of Lean, Six Sigma and Lean Six Sigma methods altogether is also a research first of its kind.

Keywords - Six sigma, DMAIC, boring machine, Productivity, Quality.

I. INTRODUCTION

In this competitive scenario, the markets are becoming global & economic conditions are changing fast. Customers are very quality conscious & demand for high quality product at competitive prices with product variety and reduced lead-time. Companies are facing tough challenge to respond to the needs of customer while keeping manufacturing & other related costs down .The companies are striving for their very survival. Companies can cut down their costs by reducing the production of defective parts.

Quality is a necessary characteristic for Industrial Engineers to observe, study, and understand. For organizations that offer products and services to customers, a system within this company is a process that produces, maintains, or supports a product or service. According to Kirkpatrick (1970), a system is a physical or conceptual entity comprised of interdependent parts that interact within boundaries established to achieve some common goal or goals. This definition of system aids a proper definition of quality within the realm of Industrial Engineering topics. According to El-Haik (2005), quality can be defined as .the degree to which the design vulnerabilities do not

adversely affect product performance. It is important to note that this definition is universally applicable to not simply products and product design, but also service and service process design. Also, the design vulnerabilities of a product or service can either be inherit in the type of product or services being created, or perhaps established by improper conceptual design. Regardless of which type of vulnerability may exist, the quality of a product or service is only decreased when it affects either the process that creates it by increasing costs, time, and constraints, or by affecting the end product or service that a customer uses. This implies that quality is not merely achieving the perfection of a product or service, but rather, high quality is achieving perfection of product or service performance, or getting as close to it as possible.

Productivity is an average measure of the efficiency of production. It can be expressed as the ratio of output to inputs used in the production process, i.e. output per unit of input. When all outputs and inputs are included in the productivity measure it is called total productivity. Outputs and inputs are defined in the total productivity measure as their economic values. The value of outputs minus the value of inputs is a measure of the income generated in a production process. It is a measure of total efficiency of a production process and as such the objective to be maximized in production process. Productivity measures that use one or more inputs or factors, but not all factors, are called partial productivities. A common example in economics is labor productivity, usually expressed as output per hour. At the company level, typical partial productivity measures are such things as worker hours, materials or energy per unit of production.

Six Sigma Methods -

Six Sigma is based on six basic principles that help the implementation of Six Sigma method to production companies or service industries. Six Sigma uses the base tools to improve the quality of products and processes as Measurement System Analysis (MSA), IPO Diagram (Input-process-output), Cause-and- Effect diagram (CE), Histogram, Pareto diagram, Define, Measure, Analyze, Improve, Control (DMAIC), Run chart, Control chart, Scatter diagram, Regression Analysis, Designing of Experiments (DOE), Failure Mode and Effect Analysis (FMEA), Standard Operating Procedure (SOP) and Quality Function Deployment (QFD).

Measurement system analysis

Diffusion of the watched commodities' parameter can be connected by the commodity itself or the system of measuring. The system of measuring is made by operator, benchmark and the method of measuring. Measuring System Analysis (MSA) is a tool for the evaluation of accuracy and advisability of the measuring system. It goes with testing or measuring the chosen parameter by the operator. It monitors the influence of repentance and reproducibility of the total variance. The goal of MSA is to estimate how the system of measuring contributes to the total variance of watched parameter. Most of the time, analysis of the measurement system is used in the phase of Measurements.

Analysis of the causes and consequences

CE is a tool to solve problems through finding the cause of their occurrence. It helps to find all possible causes, to split causes into categories and organize their relationships and impact on output, and to identify opportunities for improvement. In general, these categories are commonly known as

7 M causes:

- Man -people, job;
- Methods and mechanics, process;
- Machine – machines, equipment;
- Measurement;
- Management- system of organization and management;
- Material; and
- Mother Nature - environment.

Histogram

Histogram is a perfect tool for visualization of the frequency of the watched phenomenon in process. It is a bar chart made from number of categories, showing their splitting. Customer tolerance can be added (LSL, USL) to watched process.

Pareto diagram

Pareto diagram is a bar chart for discrete data, indicating the frequency of non-digital data. These categories are arranged in descending order. The tool that allows determining the impact of input factors to an endpoint.

DMAIC

It is the common option for the model of improving the process based on Deming's circle Plan-Do-Check-Act (PDCA). DMAIC is in the Six Sigma methodology being used as the standard routine for planning and implementation of the project.

II. SOURCE OF LITERATURES

Numerous articles dealing with theory and application of six sigma have been published over last 15 years, but topic is still under considerable development and debate. We have examine the work related to six sigma published in referred journals. The distributions of articles in various journals.

Table 1 - Distribution of reviewed articles

A) Journal
International Journal of Engineering Research and Application
International Journal of Industrial Engineering and Production Research
ISBN
International Journal of Modern Engineering Research (IJMER)
Interdisciplinary Journal of contemporary Research in Business
International Journal of Scientific and Engineering Research
International Journal of Scientific and Research Publication
IEEE
International Journal of Production Economics
IJQRM
International Advanced Research Journal in Science, Engineering and Technology
International Journal on Emerging Technologies
International Journal of Lean Six Sigma
Journal of Information, Knowledge and Research in Civil Engineering.
International Journal of Engineering Technology and Advanced Engineering
International Journal of Engineering and Technology
International Journal of Project Management
Journal of Economic Literature
International Journal of Quality Research
International Journal of Mechanical Engineering And Robotics Research
Journal of Business and Management
International Journal of Advanced Research, Ideas and Innovation in Technology
B) Conferences
Proceeding of the International Multi-conference of Engineers and Computer Scientists
International Conference on Manufacturing Research (ICMR)
1st Logistics International Conference
International Conference of Innovative Computing Technology
IEEE International Conference on Management of Innovation and Technology

III. SIX SIGMA APPLIED IN VARIOUS FIELDS

The concept of six sigma is applied in various fields of application, calibration, as well as measurement and decision making process. The reviewed literatures are classified on the basis of application. The literature shows that maximum work is related to the mechanical application and basic terminologies are as shown in figure.

Table 3 - Application wise break up of literature

Field	Number of papers	Percentage(%)
Manufacturing	14	29.78
Food	1	2.127
Health Care	3	6.382
Engineering & Management	20	42.553
R&D	8	17.021
Finance	1	2.127

Manufacturing sector

Motorola was the first organization to use the term six sigma in the 1980s as part of its quality performance measurement and improvement program. Six sigma has since been successfully applied in other manufacturing organizations such as General Electric, Boeing, DuPont, Toshiba, Seagate, Allied Signal, Kodak, Honeywell, Texas Instruments, Sony, etc. The reported benefits and savings are composed and presented from investigating various literatures in six sigma.

Financial sector

In recent years, finance and credit department are pressured to reduce cash collection cycle time and variation in collection performance to remain competitive. Typical six sigma projects in financial institutions include improving accuracy of allocation of cash to reduce bank charges, automatic payments, improving accuracy of reporting, reducing documentary credits defects, reducing check collection defects, and reducing variation in collector performance. Bank of America (BOA) is one of the pioneers in adopting and implementing six sigma concepts to stream-line operations, attract and retain customers, and create competitiveness over credit unions. It has hundreds of six sigma projects in areas of cross-sel ling, deposits, and problem resolution. BOA reported a 10.4% increase in customer satisfaction and 24% decrease in 368 *Int. J. Mech. Eng. & Rob. Res. 2013 Suryakant Sharma et al., 2013* customer problems after implementing six sigma . American Express applied six sigma principles to improve external vendor processes, and eliminate non-received renewal credit cards. The result showed an improved sigma level of 0.3 in each case. Other financial institutions including, GE

Capital Corp, JP Morgan Chase, and SunTrust Banks are using six sigma to focus on and improve customer requirements and satisfaction.

Healthcare sector

Six sigma principles and the healthcare sector are very well matched because of the healthcare nature of zero tolerance for mistakes and potential for reducing medical errors. Some of the successfully implemented six sigma projects include improving timely and accurate claims reimbursement, streamlining the process of healthcare delivery, and reducing the inventory of surgical equipment and related costs. The radiology film library at the University of Texas MD Anderson Cancer Centre also adopted six sigma and improved service activities greatly .Also in the same institution's outpatient CT exam lab, patient preparation times were reduced from 45 min to less than 5 min in many cases and there was a 45% increase in examinations with no additional machines or shifts.

Engineering and management sector

In 2002, Bechtel Corporation, one of the largest engineering and construction companies in the world, reported savings of $200 mn with an investment of $30 mn in its six sigma program to identify and prevent rework and defects in everything from design to construction to on time delivery of employee payroll. For example, six sigma was implemented to streamline the process of neutralizing chemical agents, and in a national telecommunications project to help optimize the management of cost and schedules.

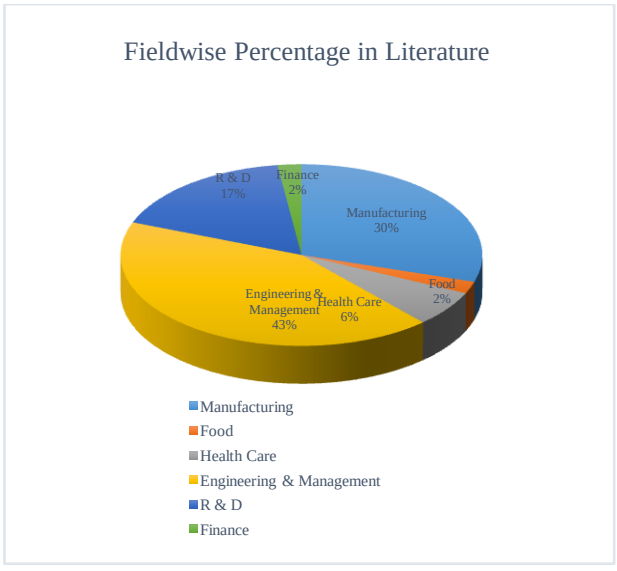

Fig.1 - Field wise percentage in literature

Research and development sector

The objectives of implementing six sigma in R&D organizations are to reduce cost, increase speed to market, and improve R&D processes. To measure the effectiveness of six sigma, organizations need to focus on data driven reviews, improved project success rate, and integration of R&D into regular work processes. One survey noted that as of 2003 only 37% of the respondents had formally implemented six sigma principles in their R&D organization reported that the development and manufacturing of the new prototype at W R Grace (Refining Industry) was cut to 8-9 months from 11-12 months by implementing.

IV. DEVELOPMENT IN SIX SIGMA

Six sigma is likely to remain as one of the key initiatives to improve the management process than just being remembered as one of the fads. The primary focus should be on improving overall management performance, not just pinpointing and counting defects. Researchers and practitioners are trying to integrate six sigma with other existing innovative management practices that have been around to make six sigma method even more attractive to different organizations that might have not started or fully implemented the six sigma method. Integrating and comparing principles and characteristics of six sigma with Total Quality Management, Human Resource Functions, Lean Production, ISO 9000 , ISO 9001, the capability maturity model are all part of the quality community's effort to maximize the positive effect of the six sigma method. The concept of UOM is applied to calibration as well as measuring process. The year wise developments in the field of six sigma as shown in table 2.

V. METHODOLOGIES IN SIX SIGMA

The various researchers have applied different methodologies for the estimation of six sigma. The literatures are classified on the basis of methodology applied for the particular applications. From the literature it is proved that DMAIC are very popular in the field of six sigma. Lean six sigma is a modern and advance concept. As compare to DMADV is also familiar in the field of six sigma.

The phase of Six Sigma implementation

In order to reduce process variation and the associated high defect rate, Six Sigma focuses on improvement methodology application, then the DMAIC is mentioned most frequently now and a lasting improvement method (Starbird, 2002). The representative's meanings of five English letters are as follows:

Define
The top management shall identify the problem according to customer feedback, strategy and mission of company, define customer requirements, and set goal.
Measure
Measurement is a key transitional step on Six Sigma road, one that helps the project team refined the problem and being the search for root causes which will be the objective of Analyze step in DMAIC. Therefore, the project team needs to validate problem/process, refine problem/goal, and measure key steps/input.

Table 2 - Development of literature

Sr. No.	Researchers	Year	Contribution to Research
1	Yewande Adeyemi	2003	Larger Companies need time to implement Six Sigma
2	Obaidullah Hakeem Khan	2005	Implementation of Six Sigma in UK organization
3	Ayon Chakrabarty and K.C.Tan	2006	Six Sigma for future research
4	Hongbo Wang	2008	Six Sigma for future research in Quality Management
5	Kifayah Amar and Douglas Davis	2008	Implement Lean Six Sigma Indonesian SMEs in manufacturing
6	Wollongong	2008	Evolution of Lean Six Sigma
7	Matthew McCarthy	2008	Establish a Six Sigma training program for academic course
8	Rosnah Mohd. Yusuff	2008	Implementation of Six Sigma in manufacturing of Automobile component
9	Luca Cagnazzo and Paolo Taticchi	2009	Identification of implementing the SS methodology
10	Weiyong Zhang, Arthur V. Hill and Glen H. Gilbreath	2009	A Retrospective and Prospective study on Six Sigma
11	Mohamed Gamal Aboelmaged	2009	A structured review and implications for future research in Six Sigma Quality
12	Mahour Mellat Parast	2009	Six Sigma effect on innovation and firm performance
13	Benny Tjahjono and Peter Ball	2010	Future Scope in Six Sigma Research
14	Shweta Sareen, Chad Laux and Brandeis Marshall	2010	Suitability of Six Sigma for small, medium and large scale firms
15	Vijayendra Singh Sankhla and Saurabh Tege	2010	Future Research in Six Sigma
16	Sophie Thi Quynh Nga Ngo	2010	Relationship between Six Sigma and Organizational Performance
17	Hsiang-Chin Hung and Ming-Hsien Sung	2011	Applying Six Sigma to manufacturing processes in the food industry to reduce quality cost
18	Miroslav RUSKO and Ruzena KRALIKOVA	2011	Application of Six Sigma method to EMS Design
19	Thomas J. Zugelder	2012	Lean Six Sigma literature review and agenda for future research
20	Xiaoning Zhu and Mahmood Hassan	2012	Research on Lean Six Sigma
21	Nilesh V Fursule and Swati N Fursule	2012	Benefits and limitations of Six Sigma Methodology
22	Jeroen de Mast and Joran Lokkerbol	2012	Analysis of the Six Sigma DMAIC Method
23	Lateef Ur Rehman Ateekh-ur-Rehman	2012	Safety management in manufacturing company by six sigma approach
24	Karin Schon and Bjarne Bergquist	2012	The consequences of Six Sigma on job satisfaction

25	Ricardo Pires de Souza,Helio Roberto Hekis	2012	Implementation of a Six Sigma project in a 3M division of Brazil
26	Muhammad Imran Qureshi	2012	Customer Satisfaction Measurement and Analysis Using Six Sigma in Telecom Sector
26	Saja Albliwi and Jiju Antony	2013	Implementation in Manufacturing Sector
27	Ana Mijajlevski	2013	Six Sigma DMAIC methodology in Logistics
28	Sunil V. Desale and Dr. S.V.Deodhar	2013	Lean Six Sigma Principal in Construction
29	Md. Enamul Kabir and Mostafa Lutfi	2013	Productivity Improvement by using Six Sigma
30	Ripon Kumar Chakrabortty, Tarun Kumar Biswas and Iraj Ahmed	2013	Reducing Process Variability by using DMAIC Model
31	Suryakant Sharma, Deepak Bhardwaj and Vinay Kumar	2013	Application and Benefits of Six Sigma Approach
32	Mehul Mayatra, N.D.Chauhan and Parthiv Trivedi	2013	Implementation of Lean Manufacturing Techniques
33	Virendra Narula and Sandeep Grover	2015	Implications for Future Research in Six Sigma
34	Saad A. Shaikh and Javed Kazi	2015	Six Sigma DMAIC Methodology
35	Ganesh P. Jadhav, Sandeep B. Jadhav and Amol Bhagat	2015	DMAIC methodology used in manufacturing industries
36	Georgiana CIOANA and Catalina RADU	2015	Future Scope in Lean Six Sigma
37	Riddhish Thakore, Rajat Dave, Tejas Parsana and Amit Solanki	2016	Six Sigma Implementation Practice in Manufacturing
38	Sanjib Biswas and Barnali Chowdhury	2016	Industrial Applications of Six Sigma
39	Navy Gera and Er. Harvinder Lal	2016	Productivity Improvement using Lean Six Sigma
40	Chugani and Garza-Reyes	2016	Green impact investigation on Six Sigma
41	Andrea Sujova, Lubica Simanova and Katarina Marcinekova	2016	Sustainable Process Performance by Application of Six Sigma Concepts

Analyze

In analyses stage, the project team shall use data analysis tools and process analysis techniques to identify and verify root causes of the problem. For the reason, the project team needs to develop causal hypotheses, identify vital few root causes, and validate hypothesis.

Improve

The goal of the improve stage is to find and implement solutions that will eliminate the causes of problems, reduce the variation in a process, or prevent a problem from recurring. So the project team needs to develop ideas to remove root causes, test solutions, and standardize solution/measure result.

Control

Once the improvement has been made and results documented, continue to measure the performance of the process routinely, adjusting its operation. It is very important for the project team needs to establish standard measures to maintain performance and correct problems as needs. Without control efforts, the improved process may well revert to its previous state.

DFSS Process

Design for Six Sigma (DFSS) is a systematic methodology utilizing tools, training and measurements to enable the organization to design products and processes that meet customer expectations and can be produced at Six Sigma quality levels. DFSS is potentially far more effective than DMAIC as its application is in the early stage of new product/process development, thus the papers under this category aim to provide an explanation of DFSS and why it is different from DMAIC [12-15]. For example, Mader explains the

DFSS methodology, its key aspects and how it enhances the design process, improving New Product Development (NPD).Antony presents DFSS using the Identify, Design, Optimize and Validate (IDOV) approach. Treichler et al. discusses the use of DFSS in the design function of major US corporations and Koch et al. explain DFSS in detail, using as an example the application of DFSS in automotive crashworthiness under an engineering design context. All of these studies of DFSS have been undertaken in a manufacturing context. Hence, there is a need for more extensive study to consider new areas of DFSS application, such as how DFSS can be applied to nonmanufacturing processes. (DFSS) is a systematic methodology utilizing tools, training and measurements to permit the association to design products and processes that meet customer expectations and can be produced at Six Sigma quality levels.

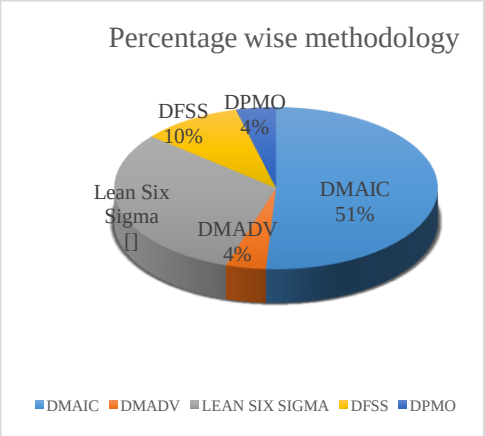

Fig. 2 - Classification of literature based on research methodology

Lean Six Sigma

Lean Six Sigma is not new, it is a combination of Lean Management and Six Sigma methodologies which were first integrated in 1986 in the US-based George group. The term 'Lean Six Sigma' did not appear in literature until 2000 (Timans et al. 2012), and LSS teaching was not established until 2003 (Kubiak 2011). Since that time, there has been a noticeable increase in LSS popularity and deployment in the industrial world; especially in large western organizations such as Motorola, Honeywell and General Electric (Timans et al. 2012; Laureani and Antony 2012) and in some small and medium size manufacturing enterprise (SMEs) (Kumar et al. 2006). *Albliwi and Antony* LSS is "a methodology that focuses on the elimination of waste and variation, following the DMAIC structure, to achieve customer satisfaction with regards to quality, delivery and cost. It focuses on improving process, satisfying customers and achieving better financial results for the business" (Salah et al. 2010). Organizations give many reasons for implementing LSS; to improve business performance and operational efficiency for example, especially given the growth of global markets, to improve product quality, reduce production costs and so improve customer satisfaction (Antony 2008; Snee 2010; Laureani and Antony 2012; Jayaraman et al. 2012). The history of LSS and notable success stories of LSS implementation in the industrial world can be seen in many academic papers by authors such as Chakravorty and Shah (2012) and Thomas et al. (2009). On the other hand, not all organizations can gain real benefits from LSS implementation; a poor attempt at LSS implementation can actually render it ineffective (Jayaraman et al. 2012).

VI. LOCATION WISE AWARENESS IN FIELD OF SIX SIGMA

In the era of globalization, market is totally open on the basis of selective assembly and interchange ability. All manufacturing industries are using ISO norms for manufacturing of the products, testing of the samples for various application are performed using six sigma. The concept of six sigma is used in all most all part of countries for quality improvement.

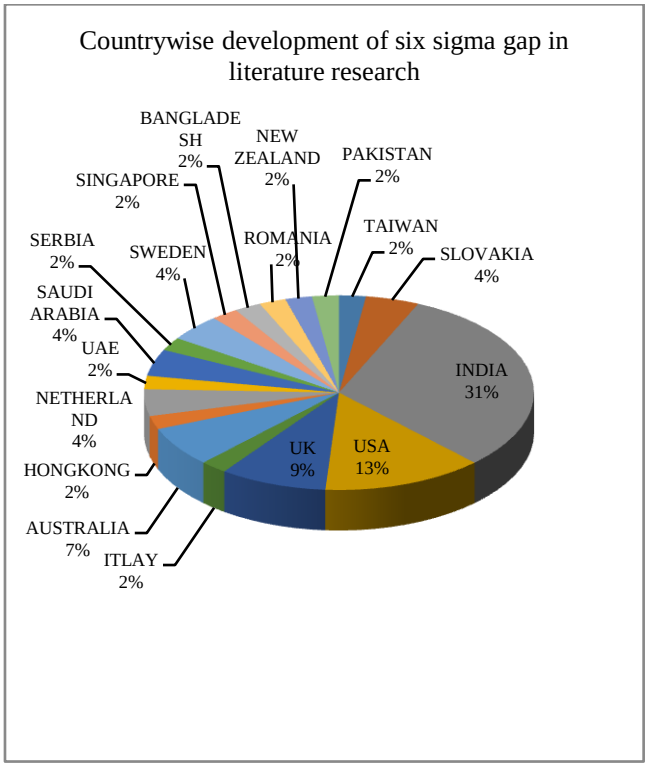

Fig.3 - Country wise development of six sigma gap in literature research

The literatures are classified on the basis of country wise contribution in the development of six sigma. From the literature reviewed, it is proved that the India is having more awareness in the field of quality aspects and six sigma followed by USA, UK & Australia. The growth of six sigma in developing country like Taiwan, Pakistan, Bangladesh, Serbia, Romania & Slovakia is very slow. Even growth of six sigma in Developed countries like Italy, Singapore, UAE, Neither land, New Zealand & China is very slow. Now awareness is continuously increasing towards six sigma.

VII. GAPS IN LITERATURE RESEARCH

The following are few research gaps in the literature

- The methodologies used by different authors are difficult to understand and to apply.
- The simplified and precise methodology for training and application purpose was not available.
- In service sector education and healthcare are two major are areas where Six Sigma is either not visible or is at very nascent stage. Six Sigma implementation strategies and critical success factors for successful deployment of Six Sigma project are other areas for future research. Applications of Six Sigma projects in Indian states and central government run organizations and administration have also not been explored.
- Year wise in the past decade there is a growth & need of six sigma analysis in various sectors.
- Country wise developing as well as developed countries need to improve the use and application of six sigma.
- Methodology wise DMAIC is most popular among the authors. Whereas other Methodology have limited application hence, there is a good scope of improvement.
- In manufacturing field there are number of papers available but very few papers are available in the field of boring machine.
- The areas for future research can be summarized as Applications of Six Sigma in manufacturing & service sectors areas which are not explored yet with full potential, areas of Six Sigma enhancement and integration of Six Sigma with other quality initiatives, critical success factors for successful deployment of Six Sigma and Six Sigma implementation strategies.
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VIII. OBJECTIVE OF RESEARCH PAPER

- To study the concept of six sigma.
- To present simplified way of application of six sigma.
- To apply the concept of six sigma in case of automated assembly. Example, TATA Motor bus assembly.
- Country wise distribution of scope of need & development is studied & analysed.
- Year wise distribution helps in future need of six sigma analysis.
- Sector wise distribution helps in various scope of application in the field of six sigma.

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