



# Six Sigma: Literature Review and Implications for Future Research

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## ABSTRACT

*There has been considerable 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 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 further research. The paper has been categorized in four sections. Section one & two present introduction to Six Sigma and preamble to literature review respectively. Section three presents classification of Six Sigma papers based on research methodology & research contents. Section four presents key findings, conclusion and areas for future research.*

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## 1. Introduction And Overview Of Six Sigma Methodology

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

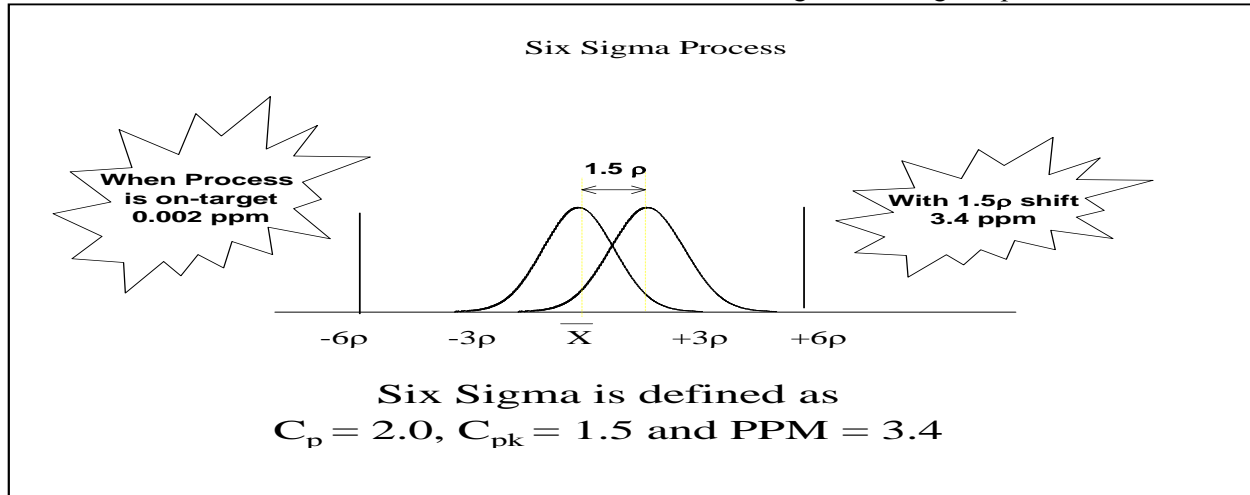
the production of defective parts. This is what Six Sigma is all about. Six Sigma is disciplined, focused and scientific problem solving technique, which uses statistical and non statistical tools integrated with methodology to bring down number of defects to 3.4 defects per million opportunities in any process. Six Sigma is a quality management program to achieve 'Six Sigma' levels of quality. Six Sigma stands for six standard deviations (sigma is a Greek letter used to represent standard deviations in statistics). Motorola pioneered it – in mid 1980s, which began seeing, benefits just two-year later. Six Sigma was developed by Mikel Harry. The program gained publicity when Motorola won the Malcolm Baldrige award (MBNQA). Some of the pioneering companies, which used Six Sigma at

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very beginning, are ABB, General Electric (GE), and Allied signal, Texas Instruments. General Electric spent \$500 million on Six Sigma in 1995 & gained more than \$ 2 billion from that investment. In 2000, Fort Wayne, Indiana became the first city to implement the program in city government. Figure 1 shows basic definition of Six Sigma process. Harry and Schroeder[1999]Six Sigma is a disciplined

method of rigorous data gathering and robust statistical analysis to pin point sources of error and ways of eliminating them. Paul[1999] Six Sigma is a comprehensive, statistics-based methodology that aims to achieve nothing less than perfection in every single company process and product Six Sigma is a formal methodology for measuring, analyzing, improving, and then controlling or “locking-in” processes.



**Fig.1. Six Sigma definition**

## 2. Preamble To Literature Review

The authors have reviewed various research papers from various international journals and have made both hard copies search in established libraries and electronic search in World Wide Web. The three websites searched were: www.sciencedirect.com, www.Inderscience.com, www.ieeexplore.com.

The search was carried out in all the journals of these websites with key word as ‘six sigma’. In addition, www.delnet.ac.in was searched for Six Sigma books. Authors have done their best to collect and review all the existing Six Sigma papers. However, they do not claim that their list is complete or completely exhaustive in nature. During classification the papers in various categories, authors have found that, few papers

were representing more than one category. Therefore, there may be certain overlaps in categorization for a few papers.

The objective of literature review is:

1. To update the database and to ensure that it contains literature as current as possible.
2. Arranging the publications in an orderly manner to enable easy and quick search
3. Classification of literature based on Research methodology, content, journal, year and further sub classification
4. Scrutiny of the outcome of the papers
5. Identifying gaps and providing hint for future research

## 3. Classification Of Six Sigma Literature

The classification scheme proposed in this paper includes a categorization of publications that highlights the growth of literature from time to

time. The authors have classified Six Sigma literature based on the criteria of research methodology as well as research contents. Figure 2 & 3 illustrate classification of number of research papers according to research methodology where as Figure 4 & 5 represent the classification according to research contents. Figure 6 presents number of the publications in chronological order updated up to July 2011. It is rational that very strict demarcation in

classification is not possible since there are few overlaps in categorization.

### 3-1. Classification Of Literature Based On Research Methodology

Based on research methodology Six Sigma papers have been classified in five categories as case studies, conceptual papers, literature review, general review and research papers (Figure 2 and 3).

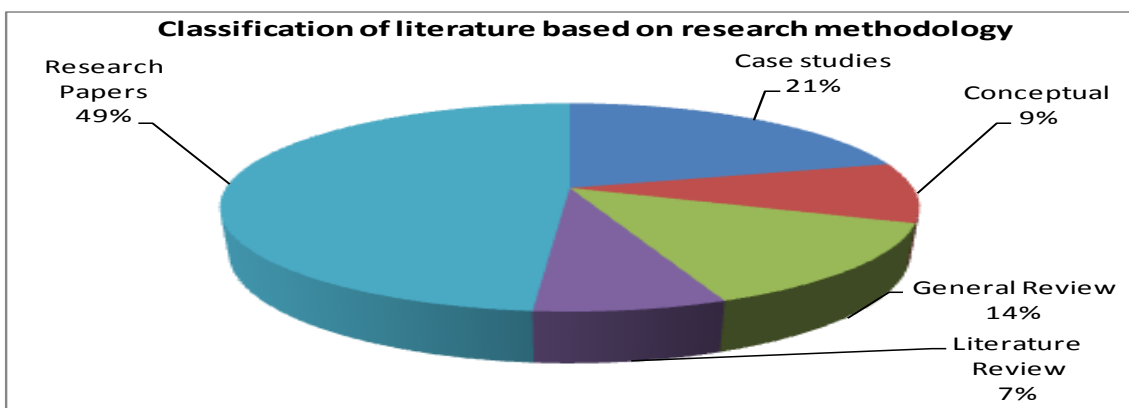


Fig.2. Pie chart representing percentage of Six Sigma papers based on research methodology

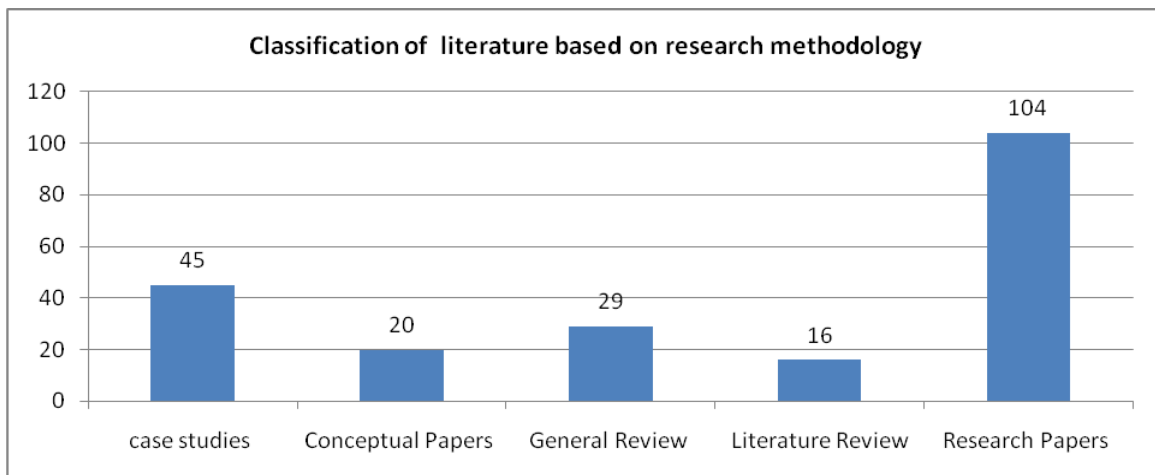


Fig.3. Bar chart representing number of Six Sigma papers based on research methodology

### 3-2. Classification Of The Papers Based On Research Contents

Based on research methodology, Six Sigma papers have been classified in six categories; Six Sigma general aspects and fundamentals, Six

Sigma tools techniques and frame work, Six Sigma applications in manufacturing organizations, Six Sigma applications in service organizations and Six Sigma project selection & implementation strategies and Six Sigma& its

linkages with other quality improvement initiatives (Figure 4 and 5).

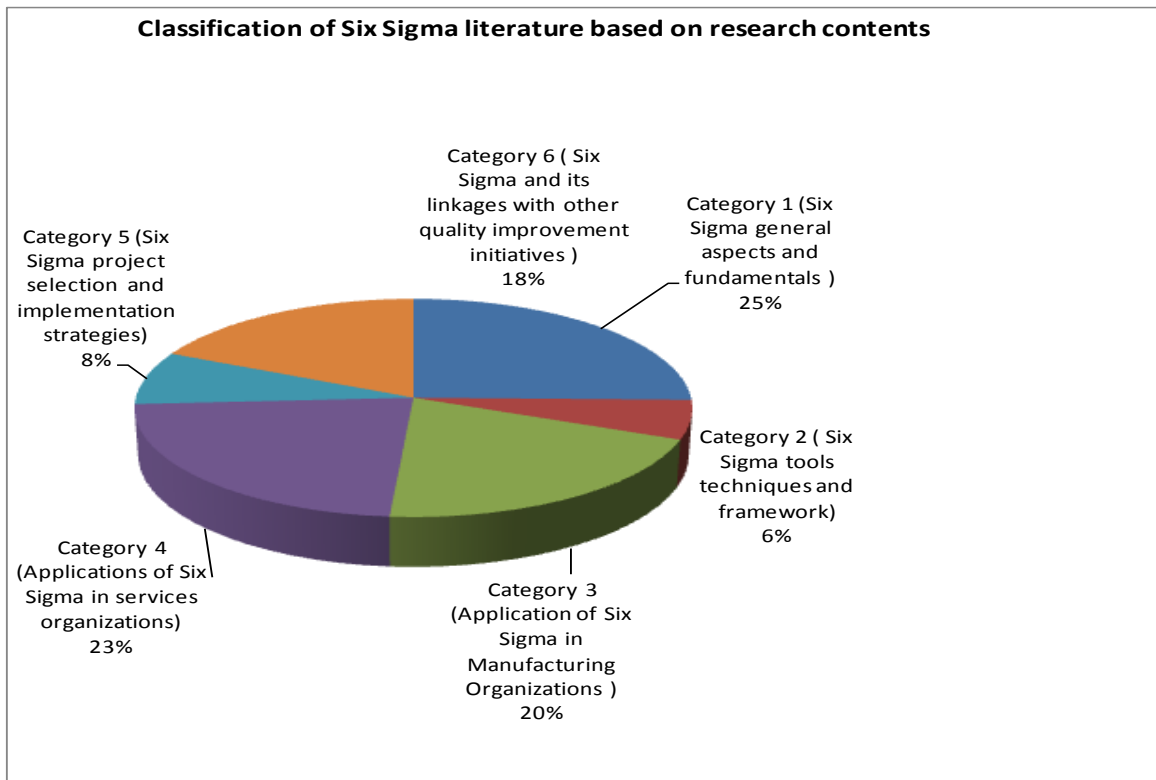


Fig.4. Pie chart representing the percentage of each category in based on research contents

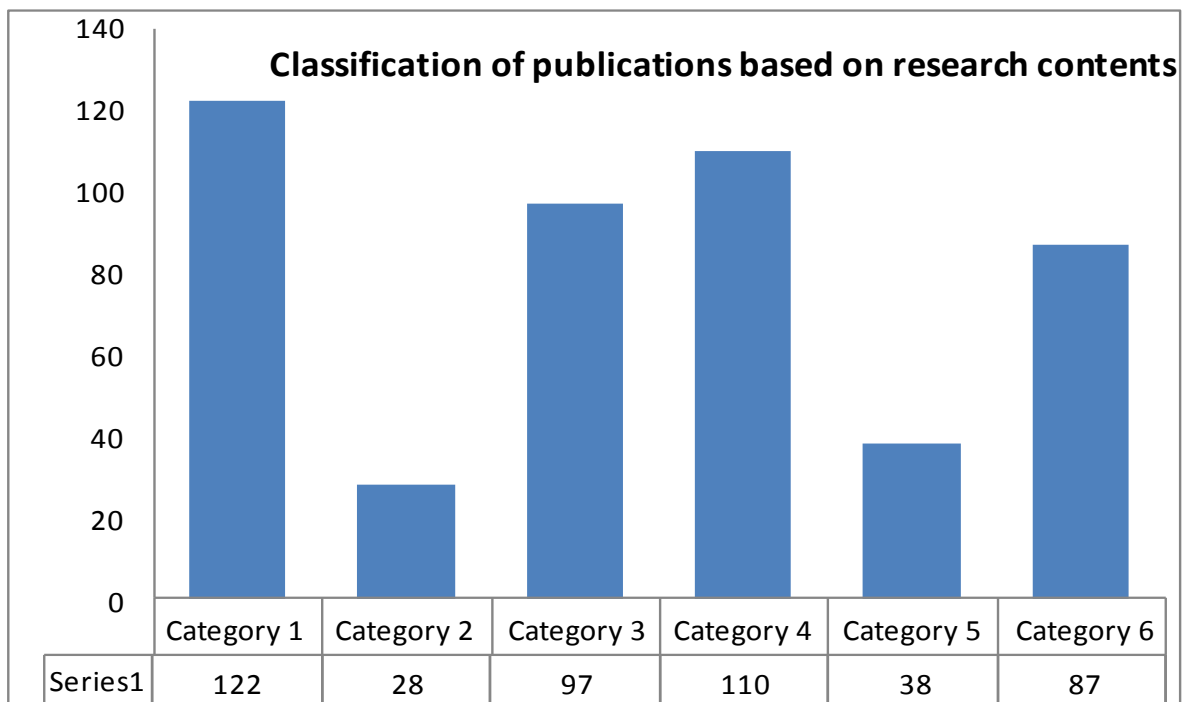


Fig.5. Bar chart showing number of publications based on the Categories

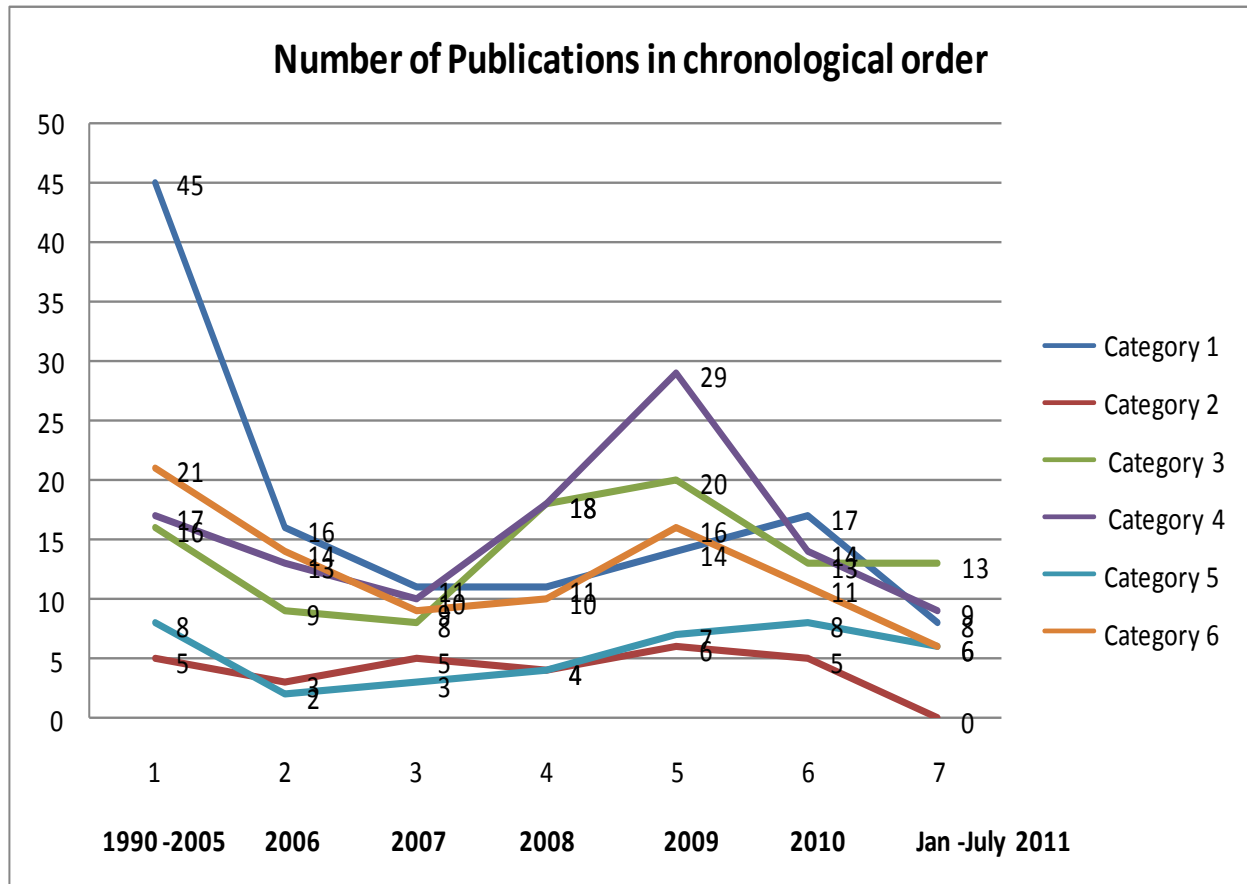


Fig.6. Number of the publications in chronological order

### Category1: Six Sigma General Aspects And Fundamentals

This category includes publications on Six Sigma evolution, concepts, methodology, and performance matrices & employee perceptions. There are 45 publications on this category from time span of 1991 to 2005. The numbers of papers are highest in this category corresponding to time span of 1991 to 2005 as papers belonging to this category represent basic concepts of Six Sigma. Due to quantum growth of Six Sigma deployment in various other sectors, there is no sharp rise in numbers of papers belonging to this category in previous five years. Few of the papers pertaining to above-mentioned category are;

Majoomdar [2002] has worked on the problem of process variation in the industries. He has

suggested that variation are single largest enemy of the industries and suggested the tools to deal with short term and long term variation. He has further suggested that statistics is a key ingredient in successful implementation of Six Sigma program. Man [2002] has linked Six Sigma with adult learner characteristics. He has presented a model that enable adult learner to engage in lifelong learning within their organization. He has further stressed that model enables learning throughout in their personal lives also. Antony [2004] has examined pros and cons of Six Sigma in a detailed manner. In addition, applications of statistical & non-statistical tools and techniques to tackle process variability have been described. He has stressed that applications of Six Sigma will grow in forthcoming years due to presence of

statistical science within Six Sigma. Kwak and Anbari [2004] have stressed upon the key factors like management commitment & involvement, training, cultural changes, linking Six Sigma to business. Authors have also described obstacles, challenges, and future of Six Sigma methodologies. Authors have suggested that primary focus should be on improving management performance rather than just pinpointing and counting defects. Authors have further concluded that effective implementation of Six Sigma principles are more likely to succeed by refining the organizational culture continuously. Senapati [2004] has suggested Six Sigma DMAIC approach through deming cycle, TQM, MBNQA, and Dorian shanin's statistical engineering. He has suggested Six Sigma as improvement initiative, which does more than any other existing plan. Kumar, M. et al. [2008] has found that Six Sigma is neither a fad nor just another quality initiative. It has base of factual data coupled with hard work & is a disciplined, focused, scientific, and structured problem solving methodology. He has suggested that Six Sigma should not be viewed as advertising banner for promotional purposes. The organizations implementing Six Sigma have benefits from it in three major ways like reduced defect rate, reduced operational cost, and an enhanced customer satisfaction. Six Sigma should be adopted as a way of life. Authors have suggested that right training and implementation will help people to understand that Six Sigma methodology is significantly different from other quality initiatives. It contains many concepts & philosophies that have been taught for years but

then again it is different because it teaches practical method of achieving results. Schroder et al. [2008] have provided definition & underlying theory of Six Sigma and discussed structural control and structural exploration of the same.

### **Category2: Six Sigma Tools, Techniques And Framework**

This category includes publications on Six Sigma tools, techniques and frame works. There are five publications from 1991- 2005 belonging to this category. Few of the papers pertaining to above mentioned category are; Henderson and Evans [2000] have reviewed the basic concepts of six sigma, its benefits, & successful approaches for implementation & benchmarked the practices of General electric company. Authors have done study of Six Sigma DMAIC methodology in GE and found key factors for successful implementation of Six Sigma include upper management support & involvement, training, infrastructure, tools and linking HR based action like promotions, bonuses etc. Rowlands and Antony [2003] has presented the application of design of experiment (DOE) in order to find out the key process parameters which affect the tensile strength of welded joints. Statistical analysis was carried out to identify process parameters that influence mean strength and variability in welded joint strength. The result of analysis may be applied to a manufacturing company to extend the application of DOE to other core processes. Lazreg and Gien [2009] have linked Six Sigma and maintenance excellence with quality function & deployment. The authors suggested that linking maintenance

excellence & Six Sigma leads to an improved model of organization maintenance function, eliminate the occurrence errors, and reduces the cycle time of maintenance. Authors have claimed that these two approaches can be coupled using quality function deployment. Yeung [2009] has explored the use of supplier, input, process, output, and customer (SIPOC) in Six Sigma to monitor product and services provision for customer satisfaction. A case of integrating SIPOC of Six Sigma into social, responsible, & ethical retail shoe shop has been demonstrated in this paper. The author has suggested carrying out further research on use of quality concept in analyzing relationship between consumer behavior & business performance.

### **Category3: Six Sigma Applications In Manufacturing Organizations**

These publications illustrate the application and implementation of Six Sigma in manufacturing industries. Case studies of actual implementation of Six Sigma in manufacturing organizations are also presented in these papers. In addition, research papers from this category include general papers of Six Sigma in manufacturing, application of Six Sigma in jobbing industries, small and medium scale industries, application of Six Sigma in construction, chemical and process industries. There are 16 publications from 1991- 2005 belonging to this category. There is considerable increase in publication belonging to this category. Few of the papers pertaining to above-mentioned category are; Antony et al. [2005] has presented the application of Six Sigma Define-Measure-Analyze-Improve-Control (DMAIC) methodology

to reduce engine-overheating problem in an automotive industry. The experimental data collected during DMAIC project will provide a greater scope for the wider application of Six Sigma methodology across the automobile companies in future. Doble [2005] have compared Six Sigma methodology and chemical plant safety methodology for the chemical process safety. Kumar and Sosnoski [2009] has examined one of the shop floor chronic quality issue during heat treatment process through Six Sigma DMAIC methodology. Radha Krishna and Dangayach [2007] has presented the implementation of Process level Six Sigma in auto component manufacturing plant. Gerhorst et al. [2006] have worked on Design-For-Six-Sigma (DFSS) in product development at ford motor company through computational fluid dynamics and experimented design technique. Sahoo et al. [2008] has implemented DMAIC in order to optimize radial forging operation. The authors had the prime focus on minimizing the residual stresses developed in the components manufactured by radial forging. Antony and Desai [2009] have accessed the status of Six Sigma implementation in Indian industries. The authors have presented the results for exploratory empirical study. The questionnaire survey was applied in UK industries and adapted so that it could be applied in Indian industries. Awad et al. [2009] has worked on DFSS approach to improve the expectancy of track roller & idlers for an off road machine through CAE model. Aggogeri, F. et al. [2009] have worked on implementation of DFSS project in SME to improve performance of extrusion process.

#### **Category4: Six Sigma Applications In Service Organizations**

These publications present overview of Six Sigma DMAIC methodology in service organizations. In addition, case studies related to Six Sigma applications in services including financial organizations, education and health care have been discussed. The research papers in this category include general papers on six sigma, Six Sigma in education, Six Sigma in health care services, Six Sigma in e-business & financial services. During the time interval of 1991- 2005 number of publications corresponding to this category are 17. In this category, there is substantial increase in number of publications, because now a days service organizations like financial services, health care, e commerce, and logistics are playing a very vital role for economy of developed countries. Few of the papers pertaining to above-mentioned category are; Hensley and Dobie [2005] has presented Six Sigma model in an urban public transit company. The model includes analysis of the transit company's readiness for Six Sigma. The survey analysis was used to identify the differences in perceptions between service employees and customers. He has suggested that Six Sigma programs work best in the organizations that are prepare to apply them. One of the limitations of study was that it was implemented in single organization. Antony [2006] has studied basic features of Six Sigma methodology for implementation in service organizations. He has investigated tools and techniques used within Six Sigma methodology for service processes performance. Key factors for successful

implementation of Six Sigma in service organizations include strong leadership and management commitment, organizational culture change, selection of Six Sigma team members and teamwork, Six Sigma training, linking Six Sigma to customers etc. Antony et al. [2007] have studied the UK service organizations and found out that average level of companies in UK was around 2.8 sigma. Authors have suggested key factors for successful deployment of Six Sigma in service organization include management commitment and involvement, customer focus, linking Six Sigma to business strategy, organizational structure, & project management. Macarty and Fisher [2007] have described as how to get started and to overcome the resistance for service organizations. Authors have suggested that with guided implementation & disciplined used Six Sigma yields tangible results in service environments. Jenicke et al. [2008] has identified several aspects that differentiate an academic environment from manufacturing setting for Six Sigma application. He has proposed a three-tier framework for academic institutions where Six Sigma may be used as used by administrators, faculty, staff, and students as an implementation guide. He has suggested that role of management is very critical if Six Sigma is to be implemented successfully. He has further encouraged college and departmental heads to participate in Six Sigma training that will in turn encourage faculty and staff to participate in Six Sigma initiative. Behnam nakhai et al [2009] have found that extreme drive for adopting Six Sigma in service organizations has led both to limited field of application & unrealistic expectation as to what



Six Sigma is truly capable of achieving particularly in service organizations. Authors have presented the service quality model and described the gap between Six Sigma and service quality. Kay Chan Tan et al [2009] has done qualitative & quantitative analysis of Six Sigma organizations in Singapore and found out that application of Six Sigma in service sector is concentrated in a few services. He has provided parameters to be considered for successful implementation of Six Sigma. He has done a questionnaire survey of Singapore service organizations to understand the status of Six Sigma in Singapore.

The survey shows that 23% of responses are not aware of Six Sigma methodology, 23% find it is not relevant. 15.38%, 17.95%, & 17.95% percentage of responses find that it is not relevant, not interesting, time consuming and difficulties in identifying process parameters.

### **Category 5: Six Sigma Project Selection & Implementation Strategies**

The research papers pertaining to this category include papers on Six Sigma project selection, Critical Success Factors (CSFs) affecting its implementation and Six Sigma implementation strategies. There has been eight papers belonging to this category corresponding to time interval of 1991- 2005. The number of papers corresponding to 2006 were two & numbers of papers corresponding to 2010 were eight. The trend shows that there has been sharp increase in publication belonging to this category.

It is due to the large growth of Six Sigma implementation in service as well as manufacturing organizations. Few of the papers

belonging to this category are; Antony and Banuelas [2002] have reviewed critical success factors for deployment of Six Sigma in organizations. Banuelas et al [2006] have used survey as method to investigate that what measures are to be considered to select Six Sigma project and how potential projects are identified. He has concluded that Six Sigma converts quality improvements into bottom line financial benefits and selection of appropriate project is a key factor to success.

Chakravorty [2009] has commented that Six Sigma program fails because an implementation model to effectively guide the program is lacking. He has recommended six steps implementation model for effectively implementing Six Sigma projects. Kumar, M. et al [2009] have focused on the importance of project selection and its role in successful deployment of Six Sigma within the organizations. Authors have presented the methodology linking the project selection process to successful deployment of Six Sigma within the organization. Büyüközkan and Öztürkcan [2010] has presented a combination of ANP (Analytical Process Network) & DEMATELC (decision-making trail & evaluation laboratory) techniques to help companies to determine the critical Six Sigma projects & identify the priority of these projects especially in Logistics Company. Desai and Patel [2010] have commented that Six Sigma is not being explored in Indian Industries to its full potential.

Authors have presented two real life cases highlighting Six Sigma implementation difficulties in Indian industries.

### **Category6: Six Sigma And Its Linkages With Other Initiatives**

Under this category literature on Six Sigma and its linkages with other initiative such as systems thinking, lean, ISO 9001: 2008, supply chain management, and Design for Six Sigma are considered. Few of the papers pertaining to above-mentioned category are; Antony [2002] has stressed that during journey of excellence of any firm, they often need to redesign the products and processes in order to reduce defects and improve quality. Author has explained the underlying statistical concepts and methodology of design for Six Sigma (DFSS) for a firm moving toward the realization of Six Sigma quality. Banuelas and Antony [2003] have examined the similarities & differences in Six Sigma methodology and compared it with DFSS approach. Banuelas and Antony [2004] have stressed importance of DFSS to design and redesign processes to ensure achievement of high levels of quality. Authors have tested suitability of a multi criteria decision-making technique and the analytical hierarchy process to make a choice between Six Sigma and DFSS in two multinational companies. Michel.O Leill [2004] has reviewed the post occupancy evaluation research methods and discussed how this can be deployed within the Six Sigma quality frame work. Raisinghani et al [2005] have done conceptual study and found out that immediate goal of Six Sigma is reduction of defects. Reduced defects lead to process improvements and which enhance customer satisfaction. Authors have also described evolution of quality initiatives like TQM, Quality circles, kaizen, ISO 9000, and MBQNA. Authors have further conducted case

studies on few organizations like GE, allied signal etc and suggested that Six Sigma project can have negative consequences if applied in wrong project. Makrymichalos et al. [2005]. have demonstrated the vital linkage between Six Sigma and statistical thinking. Authors illustrated key characteristics required for statistical thinking & common barriers in implementation of key principles of statistical thinking.. Klefsjo et al. [2006] have commented on both the TQM and Six Sigma. Authors have stressed that TQM has lost some of its charm before quality approaches such as Six Sigma and Lean enterprises. Yeung [2007] have stressed upon the integration of ISO : 9001 and Six Sigma in organizational culture. Pranckevicious et al. [2008] has worked on application of 5S technique in improve phase of DMAIC methodology. Antony [2009] has presented the fundamental and critical difference between TQM & Six Sigma philosophies of quality management. The author has presented the viewpoint of the nine leading practitioners and academicians in countries such as USA, Singapore, India, UK, & Korea. The viewpoint of this type would help a lot to set out a research agenda in the future. Etienne [2009] has presented that Six Sigma can be used to analyze the quality system of company.

### **4. Conclusion And Areas For Future Research**

The objective of review was to understand the status of Six Sigma as on yesterday, today and tomorrow. The conclusion is based on the review of 482 publications from 1991- 2011. The trend implies that Six Sigma research activities have

increased significantly after 2005. The 77% of the total Six Sigma publications are from 2006 to 2011. Six Sigma research has scattered in a wide range across various journals domains and fields has attracted the attention of academics and practitioner. During last decade, Six Sigma has achieved a reasonable maturity and there has been substantial contribution made in Six Sigma framework to extend application from manufacturing to services context. Although the review does on claim to be exhaustive, it does provide reasonable insight in to state of art Six Sigma research. Based on the literature review presented in the paper, we identify following directions of future research:

1. There has been a considerable research on Six Sigma fundamentals in last decade. Instead of discussing much about the Six Sigma basics and comparison of Six Sigma with other quality initiatives, more focus should be on how to integrate other quality efforts in to Six Sigma to achieve quantum gains.
2. There is a need to have more case studies clearly presenting the application of Six Sigma within each domain in a proposed framework.
3. More research is to be conducted on user experiences reflecting pros and cons of Six Sigma in such context.
4. There is great potential for research on Six Sigma and its linkages with other initiatives, Six Sigma and Statistical thinking, Six Sigma in Supply Chain Management.
5. 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.

6. The areas for further 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.

In Six Sigma projects true and quantum gains can be achieved by customizing the problem and paying attention to each and every variable which is responsible for manufacturing the desired product/services at minimum possible cost. The integration of Six Sigma with lean manufacturing and supply chain management and other innovative management techniques will be ideal solution for achieving maximum productivity. Six Sigma will be prevailing in industries as long as Six Sigma projects yield measurable or quantifiable bottom line results in financial or monetary terms.

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