

# Six Sigma: Literature Review Analysis

Bibhuti B Pradhan

***Abstract---** Six Sigma (SS) methodology is now one of the most used methods in quality management since it benefits from enhancing process performance efficiency by recognizing and reducing the causes of production and business process defects and variability. Thus, literature on the SS topic has increased exponentially over the past decades; the large number of works on the SS field represents a good opportunity for a structured literature review of the articles to understand the evolutions of the concept, the fields of its application and possible development for further studies. The literature review was performed using a retrospective analysis of the key SS methods developed for both large and small companies to highlight specific aspects of the SS literature and some SS technique implementations. The assessment of the papers contained in literature is carried out by means of a test of Strengths Weaknesses. In addition, an assessment was carried out for those dealing with the application of the SS methodology to both large companies, Small & Medium Enterprises (SMEs), based on the compliance with some milestones identified as necessary for each SS system. Finally the paper argues as to the research field's potential future developments.*

***Keywords---** Histograms, DMAIC, DMADV, SMEs and SixSigma.*

## I. INTRODUCTION

The use of Total Quality Management (TQM)[1] as an overall quality program is still prevalent in modern industry, but many companies are extending this kind of initiative to incorporate strategic and financial issues. After the early 1980s TQM hysteria, Six Sigma, building on well-proven TQM concepts, can be seen as the latest evolutionary stage although there are some philosophical variations between TQM methods and Six Sigma programs, the change from the first to a Six Sigma method is a key to effectively implementing a quality management system. Six Sigma is a business strategy aimed at identifying and eliminating the causes of errors or defects, defined as anything that might lead to customer dissatisfaction or failures in business processes by focusing on outputs that are critical to customers, it uses the normal distribution and a strong relationship between product Non-Conformities or defects, and product yield, reliability cycle time, inventory, schedule, etc the activities of Six Sigma are not limited to process or operation levels, but extended to all the levels of an enterprise to reduce cost and produce high quality products.

Six Sigma[2] has been widely adopted as a validated management engineering technique in a variety of industries for producing high-quality products and reducing costs at all levels of an organization. General Electric and Motorola are the Six Sigma implementation's two most well-known success events. In addition, the Six Sigma concept is also gaining acceptance in organizations in health care, marketing, engineering, financial and legal services, in addition to achieving major advantages in the manufacturing sector. Many studies have been conducted on the implementation of the technique

in large enterprises; however, very few studies have been published on the successful application of Six Sigma in Small and Medium Enterprises (SMEs) representing the lifeblood of modern economies. This article aims to provide a concise overview of the SS topic discussed in the literature and provides a first classification of the works based on three different approaches: applying the SS technique in large companies and small and medium-sized enterprises; evaluating the strength weakness of the papers reviewed for review; and determining some milestone of importance, defined by the authors as the fundamental aspects.

## II. RESEARCH METHODOLOGY

Review of the literature review started from the compilation of articles on the subject of interest. The author's methodology has been developed using the ISI Web of Knowledge databases. In the main topics, the writers were searching for posts with the key-word "Six Sigma." The main field of application of the SS methodology[3] is the chemical sector as predicted but with general applications in the world of physics. In the other manufacturing enterprises a smaller number of articles have been published, even though the number of works is increasing among different sectors and field of application. The authors then narrowed the review to a smaller number of articles chosen because of their importance to the research. The remaining papers were chosen as suitable for review from the authors, and divided into four groups:

- GROUP 1- regarding general Six Sigma methodology: they deal with general Six Sigma definition, including DMAIC/DMADV models and belt systems
- GROUP 2- on general Six Sigma implementation: the key factors for a successful implementation of Six Sigma are treated
- GROUP 3- about Six Sigma methodology in SMEs: they explain the main guidelines to adapt the main Six Sigma features to a SME context
- GROUP 4- presenting Six Sigma implementations in SMEs: the main approaches to implement Six Sigma in SMEs, including statistical tools, and the importance of integration with other quality management methods.

The main classification is between big companies and small and medium sized enterprises, and the second is between theoretical models and practical implementation in case studies. The authors then performed a force-weakness analysis. The key findings of this review are that many works have been published in the papers on Six Sigma in large companies over the past decades, yet very few of them provide a well-structured approach with a description of the results achieved. In addition, a part of them shows the application of Six Sigma approach in real case studies, but on the other hand they don't explain the methodology used in detail. One of the main weaknesses of the papers on the Six Sigma approach and implementation in SMEs[4] is the lack of an adequate theoretical framework or model, whereas there are much empirical documented evidence, such as surveys and interviews. From the analyzed literature, the authors have identified four main milestones for a quality system, as described in the next paragraph. Through this analysis, the authors have been able to draw the conclusion that very few methodologies found in literature contemporarily respect all the four milestones.

### III. LITERATURE REVIEW ANALYSIS

- Six Sigma: concepts, applications and key factors

From the statistical point of view, the term “Six Sigma” is defined as having less than 3.4 defects per million opportunities or a success rate of 99.9997%, where sigma is a term used to represent the variation about the process average, in the same way, in the business world Six Sigma is defined as a business strategy used to improve business profitability, to improve the effectiveness and efficiency of all operations to meet or exceed customer’s needs and expectations. At the operational level, Six Sigma[5] is building on a collection of well-established traditional methods and resources, as well as new techniques to set priorities for change and quantify monetary benefits; these new tools will ensure that the additional goal of increasing productivity can be accomplished. Six Sigma peculiar characteristics are applied by means of two simple models: DMAIC (Define-Measure-Analyze-Improve-Control), used when a goal can be achieved by improving the goods, processes and services (PPSs) already owned by the company and DMADV (Define-Measure-Analyze-Design-Verify) used when the PPSs are not already realized by the company and it needs to be created and implemented.

Accordingly, the key factors for the successful implementation of SS systems are: managing involvement and dedication, knowing the SS theory, linking it to a business strategy, linking it to consumers, project prioritization and selection, organizational infrastructure, cultural change, project management skills, linking it to suppliers, training and linking it to employees.

One of the Six Sigma key innovations is also the professionalizing of quality management functions; for this reason, Six Sigma methodology[6] identifies several key roles for its successful implementation: executive leadership (CEO and other members of top management); champions (they have the responsibility for Six Sigma development inside the organization); Master Black Belts or MBB (Black Belts and Green Belts’ guides with the projects development responsibility); Black Belts or BB (they apply Six Sigma methodology to specific projects); Green Belts or GB (as black belts, they have a good methodological preparation, although they work part-time to the project development, due to other responsibilities inside the organization); DMAIC, DMADV and belt system represent the core elements of a Six Sigma organization.

- Six Sigma implementation in SMEs vs. Big Companies

SMEs are much more agile than large ones and therefore improvements can be made fairly quickly; SMEs also have a highly visible top management and managers are more likely to be directly involved with customers; SMEs also have a greater pre disposition towards the final consumer, which is one of the fundamental bases. This close relationship and the high degree of communication with key customers appear to be significant advantageous for SMEs in opposition to large corporations. Nevertheless, SMEs[7] also present particular needs and limits, especially about the lack of financial resources and consequently the impossibility to carry on advanced methods for quality management.

The DMAIC procedure is still widely used, although with some differences: as a matter of fact, due to the impossibility to meet high costs and the unavailability of full-time experts, SMEs are often forced to use just simple statistical tools, like process mapping, cause and effect analysis, histograms and FMEA (Failure Modes and Effects Analysis), missing out more complex techniques (run charts, non-parametric tests) that large companies use instead. In addition, decisions

are generally made for short-term profitability and in many cases there are no incentives or reward programs due to budgets and resources constraints. Another typical lack of SMEs is the unavailability of trained experts: for example, the usual criterion for having a full-time Master Black Belt is one per 1000 employees; the cost for extensive training may be prohibitive, and sparing personnel to become Black Belts is often unrealistic. Actually, basing on the definition of SMEs given by EC, it would not have sense to keep it, since the maximum number of employees for a SME is 250; for this reason the attention for training programs must be focused on BBs (one per 100 employees) and above all GBs, since their costs are sensibly smaller and they are not full-time working on a single projects as they have other regular jobs inside the organization. Six Sigma can be also integrated with other quality management models; in fact it is a quite common error considering Six Sigma as a completely replacing model: many companies are apathetic about Six Sigma because they believe their existing culture and system, such as ISO 9000 and continuous improvement, are sufficient to meet their needs. Thus Six Sigma[8] should not replace the already existing quality management methods, but it could improve them by getting into the organization; final result is a quality approach that includes both traditional features of TQM both Six Sigma quality philosophies.

- Classification and evaluation of the Articles

After the first distinction between SS[9] for big companies and SS for small and medium sized enterprises, the 43 papers chosen for conducting the research were assessed using two other criteria: a strength-weakness evaluation of the articles and a similar milestone methodology. For this second point, as defined in this article, the authors established the milestones which should be respected by every SS approach. The 43 papers illustrated strengths and weaknesses under different perspectives for the first method. In particular, the most important strengths highlighted from the review are the large use of case studies 51 per cent of the articles to test the researcher's theories. In this way, the real cases have been used to illustrate the most important emerging achievements or issues; a second strength of the 21% of the total papers is the thorough application / illustration of the SS methodology, through particular the implementation of the DMAIC / DMADV phases; in addition, a detailed overview of the relevant statistical and non-statistical methods (23%) in supporting them.

On the other side, the most important weaknesses encountered during the review process could be summarized in the absence of case studies presented in the remaining part of the articles (49%), without any practical documentation regarding the theories developed during the researches; a not explicated/deepened description of the concrete utilization of the SS methodology (42%); too high complexity or contrarily incompleteness of the statistical tool description (19%) presented in the articles; non holistic approach or not complete applicability in different type of companies, sectors and sizes (37%). For the second evaluation criterion the authors have identified the most important milestones that respond to the specific company's needs and characteristics for successfully implementing the SS methodology. Four milestones have been identified as follows. They refer to 4 characteristics that a SS system should present:

- Simple: Methodologies and tools used in the SS projects have to be easy to understand and quick to use.
- Universal: The SS approach has not to be referred to a particular type of enterprise, but it must be applicable to every company that intends to implement it

- Holistic: If an enterprise already owns a quality management system, the SS approach does not have to replace it, but rather it must gradually integrate each other: generally speaking, the SS project doesn't have to distort enterprise's nature.
- Developable: Other solutions and tools should be developed from the adoption of the SS approach indeed Six Sigma is a continuously innovative technique and therefore maintaining a static approach to the methodology would be reductive.

#### **IV. DISCUSSION**

There are a number of key research gaps in literature, which this paper aims to address:

- The existing weaknesses in SS implementation both for big companies both for SMEs are still not well understood
- The link between SS and small businesses is not well explored in terms of real benefits coming from the implementation of the methodology
- There is no clear and detailed description of the used tools and of the methodology adopted for the successful case studies
- There is insufficient empirical evidence to verify and further explain the six sigma CSFs identified
- The SS systems does not respect simultaneously the milestones required.

In further research all of these issues need to be addressed. The following key exploratory research questions are drawn from the research gaps and problems found in the literature review, which constitute a research agenda for further work.

- What are the areas of weakness in six sigma[10] implementations, if any, which could be addressed by research into potential enhancements to the methodology?
- What are the difficulties and issues in the six sigma implementation process and how do they differ between SMEs and big companies?
- What are the CSFs for six sigma implementation? And how do they impact six sigma?

#### **V. CONCLUSION**

The article presents a review of the literature on the research topic Six Sigma. The authors' analysis was developed using three distinct approaches: the first aim was to investigate the differences in SS implementation between big companies and SMEs; the most important result is the identification of ten major differences in the implementation of SS methodology in the two different environments.

this paper provide a kind of key ingredient list for a successful implementation of SS, but no article provided either quantitative findings or substantive effects on the efficiency of the company. The second aspect examined wanted to

highlight the incompleteness of the literature available, as almost every article reviewed addressed very important strengths from one hand, but contemporarily major shortcomings from the other. In general, articles that, for example, presented a successful case study lacked a clear description of the statistical tools used or considered the SS approach as a stand-alone system that was not perfectly integrated into the company's strategy. Other examples are articles presenting a detailed description of several statistic and non-statistic tools, probably with a too high complexity for applicability to other industrial contexts. Finally, part of the articles was focused in illustrating the Critical Success Factors for a successful Six Sigma.

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