

Six Sigma in various industries: A literature review

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Abstract—The The present work is an attempt to capture the research gaps within the Six Sigma philosophy as well as to document notable research objectives through a systematic literature review. The methodology includes targeting relevant research publications, searching these using a wide range of keywords and phrases associated with Six Sigma and then reviewing each paper identified. The outcome of these reviews was to identify the research gaps within the Six Sigma philosophy so as to extend and update the previous work.

Index terms - Six sigma, manufacturing and service industries, SME's, critical success factors

BACKGROUND

Total Quality Management (TQM) is a sub-discipline of management science which aims to define, set, control and improve the effectiveness of an organization within its constraints. It has been named and labeled by different nomenclatures in its evolution over the last 60 years or so, such as quality control (QC), quality assurance (QA), total quality control (TQC), company-wide quality control (CWQC), TQM, or quality management systems (QMS). Since then, a paradigm shift in the core concept has occurred in the field of TQM by expanding the process of measurement, control and improvement from the testing/inspection departments to all departments in all types of firms, which may be manufacturing or service. Having implemented TQM, it means that the organization is essentially using the philosophy of standardization, customer satisfaction and continual improvement. For this purpose, this field uses many tools, methods, standards or programmes continuously being evolved by top class practicing companies, practitioners, or academicians. Six Sigma is the most recent entry in this field.

I. INTRODUCTION

All Organizations look for ways to improve their production and management processes in order to remain competitive in the market [1]. This can be achieved by reduction in production cost, improve product quality and enhance productivity. Therefore, organizations must utilize all the available resources to produce high quality products at low price and give the customer satisfaction. For above reasons, researchers all over the world proposed many improvement tools and technique to satisfy organizations needs. Now a day, Six Sigma is most popular tool which is used to reduce cost of product and enhance performance of an organization.

Six Sigma was originally introduced in the US by Motorola in the late 1980s and became popular elsewhere in early 1990s [2]. Some other organizations generated an

interest in Six Sigma after the successful implementation in Motorola. Since its inception at Motorola, Six Sigma has been defined by researchers or experts in many ways. As per earlier versions, Tomkins [3] defined Six Sigma as a program aimed at the near elimination of defects from every products, process and transactions. Harry [4] defined Six Sigma as a strategic initiative to boost profitability, increase market share and improve customer satisfaction through statistical tools that can lead to breakthrough quantum gains in quality. Six Sigma is one of the most important popular developments in the quality field [5]. It has improved quality of product and saved huge amount of money and improved the customer satisfaction for many organizations across the world.

Six Sigma is a well-established approach that seeks to identify and minimize defects in processes or systems by focusing on critical factors that are importance to customers [6]. Six Sigma provides best methods; tools and techniques to organizations which are needed for change. Six Sigma has been used to produce huge savings in many organizations.

Research questions for searching Research questions for searching

Researchers all over the world proposed several strategies and initial approach for this research was to answer the following questions:

- Q1. What is Six Sigma?
- Q2. What are the applications of the Six Sigma in any sectors?
- Q3. What are the main factors affecting the organizations?
- Q4. What are the critical success factors for implementation?

The main purpose of these questions was to provide guidance to search even if it was expected that existing literature might not be sufficiently developed to translate each question directly into a finding [7].

The present work is an attempt to capture the research gaps within the Six Sigma philosophy as well as to document notable research objectives through a systematic literature review. The methodology includes targeting relevant research publications, searching these using a wide range of keywords and phrases associated with Six Sigma and then reviewing each paper identified. The outcome of these reviews was to capture the research gaps within the Six Sigma philosophy.

II. LITERATURE REVIEW

Organizations are focusing on the ways to establish a sustainable business environment by using improvement methodologies which helps to minimize waste from various business processes [8]. Six Sigma is one of the best tool or technique which is used to reduce or minimize waste and improve the performance of an organization. Six Sigma is also using in many SMEs (small medium enterprises) and paper proposed a critique of quality management frameworks/models for SMEs [9, 50]. Research has shown that Six Sigma or other CI (continuous improvement) initiatives have failed either due to lack of understanding of how to get started or due to failure to link the initiative to strategic business goals and measurable objectives.

Management in organizations is weak and often involved in fire-fighting, paying inadequate attention to softer issues such as leadership, culture change, employees training and education, etc., characteristics evident in SMEs. If Six Sigma is only considered as implementation of statistical tools and techniques to solve complex problems in the organization, it is doomed to fail due to its very weak linkage to strategic business objectives. In case studies found that strong leadership, management commitment, communication, education, and training were critical in introducing and driving any culture-change initiatives such as Six Sigma within SMEs and has attempted to perform a comparative analysis of quality management practices in Six Sigma and non-Six Sigma SMEs by conducting multilevel case studies in four SMEs [10].

Six Sigma has been implemented with success in many large corporations; there is still less documented evidence of its implementation in smaller organizations. Due to growing importance of supply chain management issues in global market environment, large firms are heavily dependent on small- to medium-sized enterprises (SMEs) for the provision of high quality products and/or services at low costs. The increasing demand for high quality products and highly capable business processes by large organizations has left no choice on the SMEs to consider the introduction of Six Sigma business strategy [11].

The DMAIC (Define, Measure, Analyze, Improve, and Control) methodology and various tools and techniques are utilized to streamline processes and enhance productivity. SMEs produce high quality products with low price [12]. The project goals and the Six Sigma method can compensate for one another. It also suggests that adherence to the Six Sigma method becomes more beneficial for projects that create a lot of knowledge [13].

The results from an empirical investigation of Six Sigma status in Indian industry presented, especially to highlight critical success factors (CSFs) of Six Sigma implementation in a developing economy like India [14]. The research reflects the status of Six Sigma application and implementation in the software industry, identifies the commonly used statistical and non statistical and software engineering tools and frameworks used within software business; and determines the critical success factors (CSFs) for a successful Six Sigma initiative in the software/IT industry [15]. The status of Six Sigma

implementation in Indian industries examined. The details, such as, how long companies have been using Six Sigma, their implementation process, the tools and techniques that have been employed, and common Six Sigma metrics used by Indian companies and also identifies the critical success factors (CSFs) for Six Sigma implementation in the Indian industries, followed by the key benefits derived from Six Sigma implementation and the common barriers encountered [16].

Identify the specific requirements for implementation of Six Sigma based on a sample of SMEs in Germany. This also examines how Six Sigma has to be modified to be applicable and valuable in an SME environment. This is the first study of its kind to be carried out on Six Sigma survey in SMEs [17]. Six Sigma deployment alternative models proposed that allow SMEs to implement Six Sigma at a pace where they can digest the methodology and achieve benefits, without significant resource commitment and overhead structure of the traditional Six Sigma. As a result, SMEs are sometimes able to achieve faster and more impressive benefits than their large customers and also recommended an eight-step methodology for successful deployment of Six Sigma within SMEs [18]. There is nothing inherent in Six Sigma that makes it more suitable for large companies and suggested that the greatest barrier to implementation in small companies to date has been the way the major Six Sigma training providers have structured their offerings. More recently, as more and more sets of deployment guides and training materials have become available, the pricing structures have begun to change. Today, it is much easier for SMEs to obtain good external resources without a large up-front payment [19].

To justify the highly useful role of quality management techniques like Six Sigma for SMEs which are normally presumed to be in the domain of large industries. Six Sigma methodologies have been applied to a small unit manufacturing bicycles chains with dwindling productivity levels. After applying Six Sigma it was found that the chain manufacturing firm can increase its profit by controlling high rejection rate of cycle chain bush [20].

In respect to the Six Sigma implementation in service processes, the idea of using the tool in service processes such as transportation and distribution. He also indicated that reducing the lead time and providing faster delivery as two customer value goals are considered when selecting a Six Sigma project. This supports the idea of using Six Sigma methodology to reduce delivery lead time for a food distribution SME [21] and demonstrates the efficacy of proposed methodology by its application in a small and medium-sized enterprise (SME) manufacturing die-casting product. The example provided is a real-life case study conducted by the authors in an organization embracing the Six Sigma business strategy within their day-to-day functioning and is to focus on the importance of the project selection process and its role in the successful deployment of Six Sigma within organizations. The best Six Sigma projects begin not inside the business but outside it, focused on answering the question: How can we make the customer more competitive?

What is critical to the customer's success? Learning the answer to that question and learning how to provide the solution is the only focus we need [22].

The study presents the results of the survey conducted in UK manufacturing SMEs to investigate into their quality practices and measure its impact on the organizational performance of SMEs. Results of the survey revealed that factors critical to success of quality initiatives are equal in importance, irrespective of type of initiatives implemented by the firm. Management Commitment and Strong Leadership is required to make any change initiatives successful in the organization. It should also be linked to employees in terms of training, making resources available and establishing good communication with them [23].

A. Reasons for not implementing Six Sigma in SMEs

Large organizations have been implementing and reaping the benefits of Six Sigma in the last two decades. However, its application in SMEs is still less evident in the literature. It is important to understand the perception of Six Sigma and factors hindering its implementation from the SMEs perspective. Firms were asked to state the reasons for not implementing Six Sigma as an initiative to drive continuous improvement efforts within their firms.

The majority of the firms were discouraged to implement Six Sigma due to lack of knowledge of the system to start the initiative. This was followed by other reasons such as lack of resources, not sure if relevant, never heard, and cost issues.

B. Six-Sigma in process and service industries

Six Sigma is also playing very important role in process and service industries. An attempt is being made to apply Six Sigma methodology to a process industry taking a specific case of a thermal power plant. DM (de-mineralized) water in thermal power plants is an expensive input material. A DM water make-up cycle is required to compensate for the losses incurred in the water steam cycle due to evaporation, start-up and shut-down, venting, valve passing and blow downs. Six Sigma applications, is to reduce the consumption of DM water in a thermal power plant [24] and developed theory for Six Sigma implementation in service organizations. The study involves a questionnaire survey and case studies to understand and build a conceptual framework. The survey is conducted in service organizations in Singapore and is exploratory [25].

C. DMAIC Methodology

The purpose of study was to develop a Six Sigma approach for integrated solutions of products and services. Although such integrated solutions are becoming increasingly prevalent in a range of industries and although the new "services-dominant logic" has underlined the growing importance of services in integrated solutions, this paper has presented an integrated approach for only the first ("Define") phase of the Six Sigma cycle, the activities of this phase are fundamental to the application of proposed approach; moreover, the "Define" phase is the phase that is most relevant to the new "services-

dominant logic" [26]. Pointed out relevant aspects related to the professionals involved with the program, the number of projects developed per year, as well as the return on investments made by companies [27]. To critically evaluate the contributions of Six Sigma methodology to the improvement of service quality, since its development in the late 1980s, Six Sigma has been extensively applied in manufacturing and quasi-manufacturing settings and explored the challenges of Six Sigma in reaching a much wider field of application [28].

To light some characteristics of problem tasks for which DMAIC may be a suitable method. DMAIC is applicable to empirical problems ranging from well-structured to semi-structured, but not to ill-structured problems or pluralistic messes of subjective problems. DMAIC is suitable for rather extensive problem solving tasks, requiring all of the components of problem definition, diagnosis, and the design of remedies. It is less suited for problem tasks of a smaller scope [29]. The study attempts to simulate Six Sigma and offer the improvement methods of Six Sigma: DMAIC (Define, Measure, Analyse, Improve, and Control) to the case company in order to provide it with a strategic solution involving information systems integration to manage and/or improve the performance of the production planning procedure. After an analysis of the five phases of Six Sigma, the performance of the production planning procedure actually improved through information systems integration [30]. Paper focused on implementing the DMAIC based Six Sigma approach in order to optimize the radial forging operation variables. The authors have kept their prime focus on minimizing the residual stress developed in components manufactured by the radial forging process [31] and developed a framework for effective Six Sigma implementation and addressed the need for the utilization of a structured methodology for Six Sigma implementation [32]. DMAIC process, goals and usual tools is shown in figure 1.

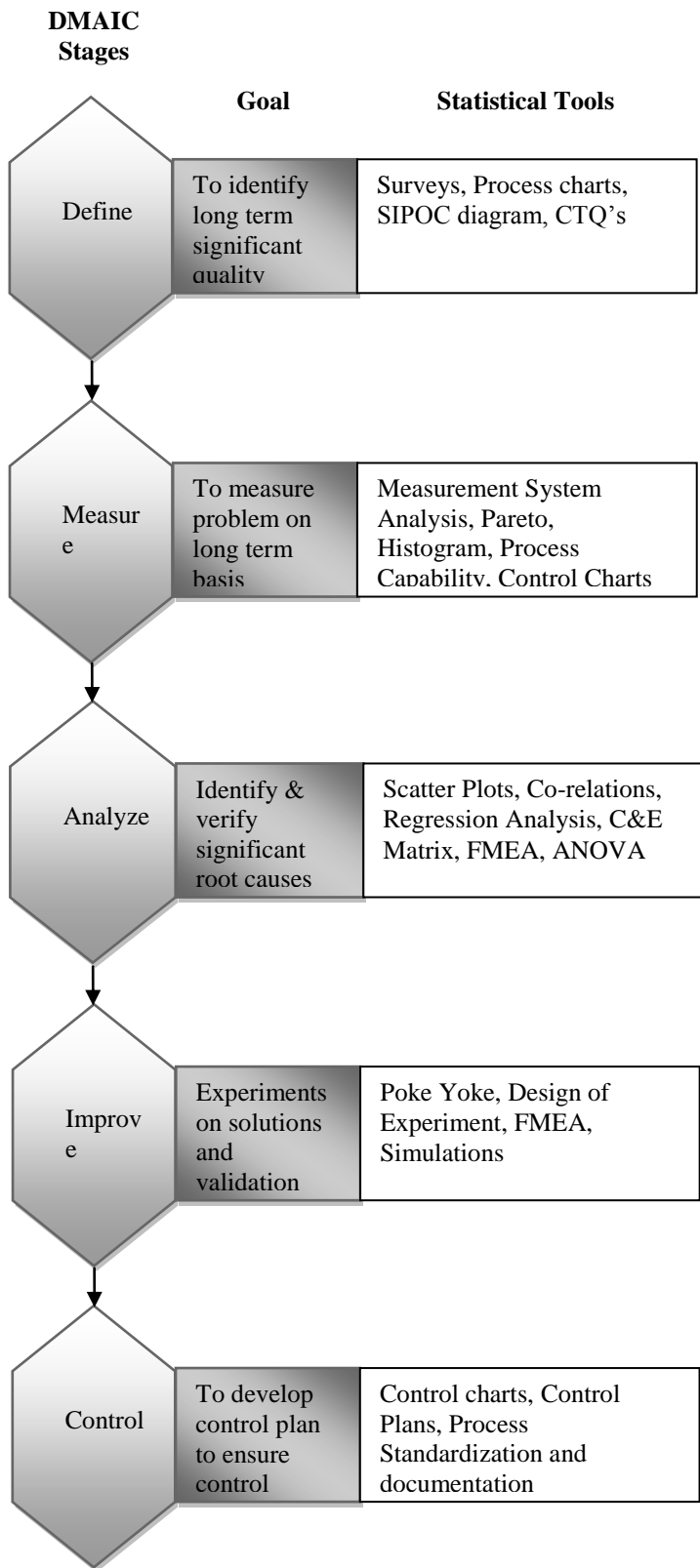


Figure 1 DMAIC process, goals and usual tools

D. Six-Sigma implementation

To examine the implementation of Six Sigma in Saudi Arabia, Six Sigma has evolved into a powerful business excellence strategy that provides several benefits to organizations such as increasing business profitability, reducing operational costs, reducing process variability, reducing cycle time and reducing number of customer complaints. Despite its proclaimed benefits and the wide interest expressed by both academics and practitioners, the rate of implementation in developing countries has been disappointing [33]. In Six Sigma strategy, there is a well-known system of expertise, which is identified as the champions hierarchy; Master Black Belts (MBBs), Black Belts (BBs) and Green Belts (GBs). The literature recommends a minimum of 30 MBBs in large firms, and 1 BB and 5 GB for 100 employees. The striking results indicated that the number of professionals is below the recommended numbers. The Six Sigma improvement strategy has been gaining considerable popularity recently as a method that reduces cost by eliminating variability in the processes which leads to improved process capability and enhanced process throughput [34]. To develop an effective implementation model, it consists of six steps [35]

- The first step is to perform strategic analysis driven by the market and the customer.
- The second step is to establish a high-level, cross-functional team to drive the improvement initiative.
- The third step is to identify overall improvement tools.
- The fourth step is to perform high-level process mapping and to prioritize improvement opportunities.
- The fifth step is to develop a detailed plan for low-level improvement teams.
- The sixth step is to implement, document, and revise as needed.

Implementing the Six Sigma methodology has resulted in significant benefits, such as no more re-tooling or rework, no more scrap, and valuable time saving, which illustrates part of the positive impact attained. Large variation in the production process found at the beginning of this project [36]. An integrated model proposed to explain process improvement implementation success through specific learning activities under taken by Six Sigma project teams. Drawing on two streams of research, team learning and operations management, the model explains implementation success through two types of organizational learning:(1) Knowing-what, facilitating the project team to understand the current process and its input factors (process characterization) and (2) Knowing-how, helping the team identify how these factors affect the process outcome and generate optimal solutions by changing or modifying input factors for improved process outcome (process optimization) [37].

Delays, rejections, errors, mistakes, losses, and inefficiencies are all problems of not just an organization as a whole but are found in every department or section of an organization. When problems are created regularly by one department, they become a regular feature of others' processes. Say for example, regular delays by a Purchase Department in purchasing is not just a problem but a cause of many problems of other departments: planning errors, production delays and long stoppages, maintenance delays and long shut-downs, broken promises by the Sales department, customer complaints, employees irritation and dissatisfaction, for example. In return, all of these problems further aggravate and create more problems: such as customers' dissatisfaction and disloyalty, vendors' dissatisfaction and disloyalty, employee's dissatisfaction and lower retention rates. The Six Sigma is a positive approach to make breakthrough improvement by involving managers at all levels in any organization. However, it is not magic which will happen by hiring any good trainer, black belt or consultant. It requires good vision of the top management, appropriate strategies based on experiences, practical and hands on training to managers that actually takes them through the use of advance statistical tools using the DMAIC processes; effective coordination through proper project management in the first 1–2 years; and leadership of quality which demands effective accountability, motivation and teamwork from managers. Any initiative in the right direction with the right approach and right tools is a guarantee for success [38].

Author proposed that Six Sigma projects enhance technological innovation of the firms; however, they are beneficial for firms in stable environments. Since Six Sigma programs are focused on variance reduction and efficiency. These initiatives are not very effective in dynamic environments, where the rate of technological change is dramatic [39]. The tension between goals and quality management investigated in the Six Sigma context and find empirical support that goals can be effective in Six Sigma improvement teams when teams adhere to the Six Sigma tools and method [40]. In small organizations, if one visible and important person is actively against Six Sigma, then this attitude must change or the initiative must be a non-starter. In other words, in small companies, the top management team needs to be visibly supportive of every aspect of Six Sigma initiative and they must demonstrate by their active participation, involvement and by their actions that such support is more than lip service [41]. Identify the following advantages for small-businesses embarking on Six Sigma initiative [42]:

- Stronger, more intimate relationships with customers.
- A limited number of sites.
- Fewer layers in the management hierarchy.
- Faster and effective internal communication.
- Strong owner influence.

The new technologies developed to implement the knowledge retrieval evaluation mechanism. The evaluation mechanism is an effective tool to facilitate the knowledge retrieval process more robust and, hence, ensure satisfactory

performance in support of problem solving, decision making, and knowledge innovation [43]. Using logistic regression analysis, we disentangle the unique effects of individual experience, organizational experience, team leader experience, and team familiarity on the likelihood of improvement project success over time. It indicates that team leader experience is the key factor associated with project success, followed by the level of organizational experience [44]. Practical insights about the influence of practices offered that project managers use to create new knowledge by capturing explicit and tacit knowledge, and seeks to advance theoretical understanding of process improvement [45]. Highlight the key role of soft impediments, i.e. knowledge and support, and hard impediments, i.e. professionals and finance, as the most influential barriers to Six Sigma implementation. The analysis clearly shows that only specific barriers are significantly influencing Six Sigma implementation in relation to dimensions of organizational factors [46, 47]. It is examined the operating performance effects of early versus late adoption of Six Sigma process improvement. It developed hypotheses describing the advantages of late adoption, and factors that affect a firm's ability to benefit from Six Sigma either as an early or late adopter [48].

Six Sigma concentrates on measuring product/service quality, reducing variation, driving improvements and saving the cost. The original application was to eliminate assembly line defects, but since then it has expanded into almost every corporate operation. Six Sigma is described as a philosophy, methodology and breakthrough strategy to solve problems [49].

III. RESEARCH OBJECTIVES & METHODOLOGY

A. Research objectives

The fundamental objective of research is to “examine the extent to which Six Sigma is being implemented within Indian manufacturing SMEs”. In order to do this effectively, the general objective is further divided into a number of specific research questions as follows:

- To what extent is Indian manufacturing SMEs implementing Six Sigma?
- To what extent are the Indian manufacturing SMEs familiar with the tools and techniques of Six Sigma?
- To what extent do Indian manufacturing SMEs actually use the tools and Techniques?
- What benefits have been brought to the Indian manufacturing SMEs through Six Sigma implementation?
- What are the Critical Success Factors for implementation of Six Sigma in Indian manufacturing SMEs?
- What are the common barriers in the implementation of Six Sigma in Indian manufacturing SMEs?

B. Research methodology

To achieve objectives, a survey questionnaire can be constructed on the basis of literature. It can be developed to

provide a baseline for Six Sigma practices by SMEs in India. It consists of four parts:

- (1) Surveyed SMEs' demographic information.
- (2) SMEs experience with Six Sigma program.
- (3) Tools and techniques of Six Sigma used by SMEs.
- (4) Critical success factors for Six Sigma implementation in Indian SMEs.

Research methodology adopted in this paper is a critical review of the subject of Six Sigma from a research, as well as an application, point of view. It is the result of extensive literature study as well as few case studies Six Sigma implementation processes and observations. An exhaustive review of Six Sigma application phenomenon was carried out in order to identify key factors or critical success factors involved in it. It mainly identifies research gaps which are not considered by researchers so far. These will help other researchers to plan their researches.

IV. CONCLUSION

In recent few years there has been a lot of interest in the application of Six Sigma principles. Many papers have been presented / published on this subject substantiating the importance of adopting Six Sigma to improve performance. This research is carried out to identify the various approaches, latest trends, tools and techniques by carrying out a systematic literature review.

Although there are many numbers of publications about Six-Sigma and therefore a lot of different points of view, the main goals of Six Sigma, however, remain unchanged, i.e. improving efficiency, profitability and capability in the process. Existing literature also traditionally categorizes these Six Sigma tools under DMAIC but classification of tools under other alternative approaches such as DFSS, DCOV or DMADV is lacking.

This literature review also focuses on performance and implementation frame work of many enterprises in different countries and identify critical success factors for successful Six Sigma implementation. The outcome of these reviews was to identify the research gaps within the Six Sigma philosophy so as to extend the work.

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