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Key Criticisms of Six Sigma: A Systematic Literature Review

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Abstract

Six Sigma is one of the most popular initiatives to improve management processes in the last decade. Amidst the success stories on the Six Sigma, there exist some literature on the criticisms of Six Sigma. The purpose of this paper is to analyse the existing literature on the criticisms of Six Sigma through a systematic literature review. The criticisms need to be analyzed so that there is growth in the knowledge and understanding of Six Sigma. This study analysed literature through various electronic databases such as Academic Source Premier (EBSCO), Google Scholar, Business Source Premier (EBSCO), Emerald Insight, IEEE Xplore Digital Library, JSTOR, ProQuest, Science Direct, Taylor & Francis, PubMed, Wiley, Inderscience, Scopus and World Public Library. Sixty-one relevant articles were found and analysed in depth. This study finds twelve major themes of criticisms on Six Sigma. Based on the findings sixteen research directions are offered. Amidst the plethora of literature review on the success of Six Sigma, this is the first comprehensive systematic literature review on the criticisms of Six Sigma. The authors firmly believe that such criticisms will help the academicians as well as the practitioners to understand some of the rudimentary gaps in implementing Six Sigma as a business improvement strategy.

Keywords: Six Sigma, Systematic Literature Review, Critique, Six Sigma limitations,

I. Introduction

Six Sigma has been one of the most widely used quality improvement methodologies in both manufacturing and service organizations for over two decades [1]–[4]. Many researchers have devoted considerable attention to researching the various facets of Six Sigma. Previous research on Six Sigma have primarily focused on a) Evolution of Six Sigma[5]–[7] b) Six Sigma Theory[8], [9] c) Six Sigma Methodology[10], [11] d) Implementation frame works & methodology[12]–[14] e) Empirical observations [3], [15], [16] f) Impact of Six Sigma[17], [18] g) Six Sigma in service organizations[19]–[21] h) Critical success factors [22]–[24], i) Critical failure factors[25], [26] etc. Criticism in any field is an important component for the growth of knowledge, because, it challenges the basic assumption of the domain of knowledge[27], [28]. Six Sigma methodology has also been criticized by a number of authors[26], [29]–[32]. A systematic literature review in this domain is important because it will help in further developing the theory & understanding of Six Sigma which will help the researchers & practitioners in developing numerous facets of Six Sigma. There is yet to be a systematic literature review carried out on the criticisms of Six Sigma. Previous studies on the criticisms of Six Sigma needs to be analysed through the systematic literature review methodology to analyse the pattern in the criticisms of Six Sigma. In this study, we intend to extend the knowledge of Six Sigma by addressing the gaps in the literature regarding a need for a systematic literature review. The study will investigate a) *What are the common criticisms or limitations of Six Sigma?* and b) *How should future research proceed given our research findings?*

II. Background Theory

Many organizations are using Six Sigma to improve their product quality and service performance from the shop floor to health care systems. Six Sigma has been extensively used

for tackling defects or errors in business processes. The background theory is divided into two sections. The first section answers the question what Six Sigma and the second section is deals with the criticisms on Six Sigma.

I. What is Six Sigma?

Six Sigma is a project driven management approach which is intended to improve the organizations products, services and processes, by continuously reducing defects due to excessive process variation in organizations[33]. Schroeder et al (2008) defined Six Sigma as an organized, parallel-meso structure to reduce variation in the organizational processes by using improvement specialists, a structured method, and performance metrics with the aim of achieving strategic objectives. The two major perspectives on Six Sigma is 1) Statistical & 2) Business Improvement. From the statistical perspective, it is defined as having less than 3.4 defects per million opportunities or a success rate of 99.9997%. Here the term sigma is used to represent the variation about the process average[12]. From a business point of view, it is used to improve the effectiveness and efficiency of all operations to meet or exceed the customers' needs and expectations[33], [34].The initial applications of Six Sigma were focused on manufacturing sectors[35], [36] and subsequently it is applied in various service sectors such as education[37]–[39], public service [40] and health care [41], [42]. Six Sigma uses two types of methodology for tackling problems in organisations. The DMAIC (define-measure-analyse-improve-control) methodology is used for solving problems in existing processes where the solutions are unknown. The other methodology called DFSS (Design for Six Sigma) utilises DMADOV (define-measure-analyse-design-optimize-verify) for either redesigning existing processes due to fundamental problems in the design of products/services or designing Six Sigma concepts and principles into products and services in the product or service development stages. [43], [44]. Six Sigma is thus, likely to remain as

one of the key initiatives to improve the management of processes in organisations, rather than to be remembered as a management fad[1], [33].

II. Criticisms of Six Sigma

Although many companies have successfully implemented Six Sigma, a significant number of companies have failed to gain any benefits from Six Sigma[25], [45]. The results of a survey in the aerospace industry showed that respondents satisfaction with Six Sigma was less than 50%[14], [25], [46]. Six Sigma is prone to failure in organizations and ten major reasons for the failure of Six Sigma were elucidated[47].In a study on Six Sigma, it was reported that Six Sigma was expensive and failed to yield any benefits to the organization[48]. Companies like 3M and Home Depot though initially were advocates of Six Sigma, however, later abandoned Six Sigma initiatives due to the negative impact on customer and employee satisfaction [26], [49], [50]. Studies have also reported that benefits from Six Sigma programs are marginal and the cost of implementing Six Sigma is more than its benefits [26]. Nearly 60% of all corporate initiatives on Six Sigma have failed [29]. These criticisms of Six Sigma in literature warrant a systematic literature review analysis so that further understanding of the criticisms can be understood in a broad thematic sense. Besides, the thematic analysis will also lead to attempt in reducing the failure rate of Six Sigma initiatives and exploring future research areas. These future research directions will thus help to clarify the criticism on Six Sigma in a broader perspective.

III. Methodology

To achieve the study goal of adding to the extant knowledge on Six Sigma criticisms, the SLR methodology proposed by Tranfield, Denyer, and Smart [51] was employed in this review, as shown in Figure 1.

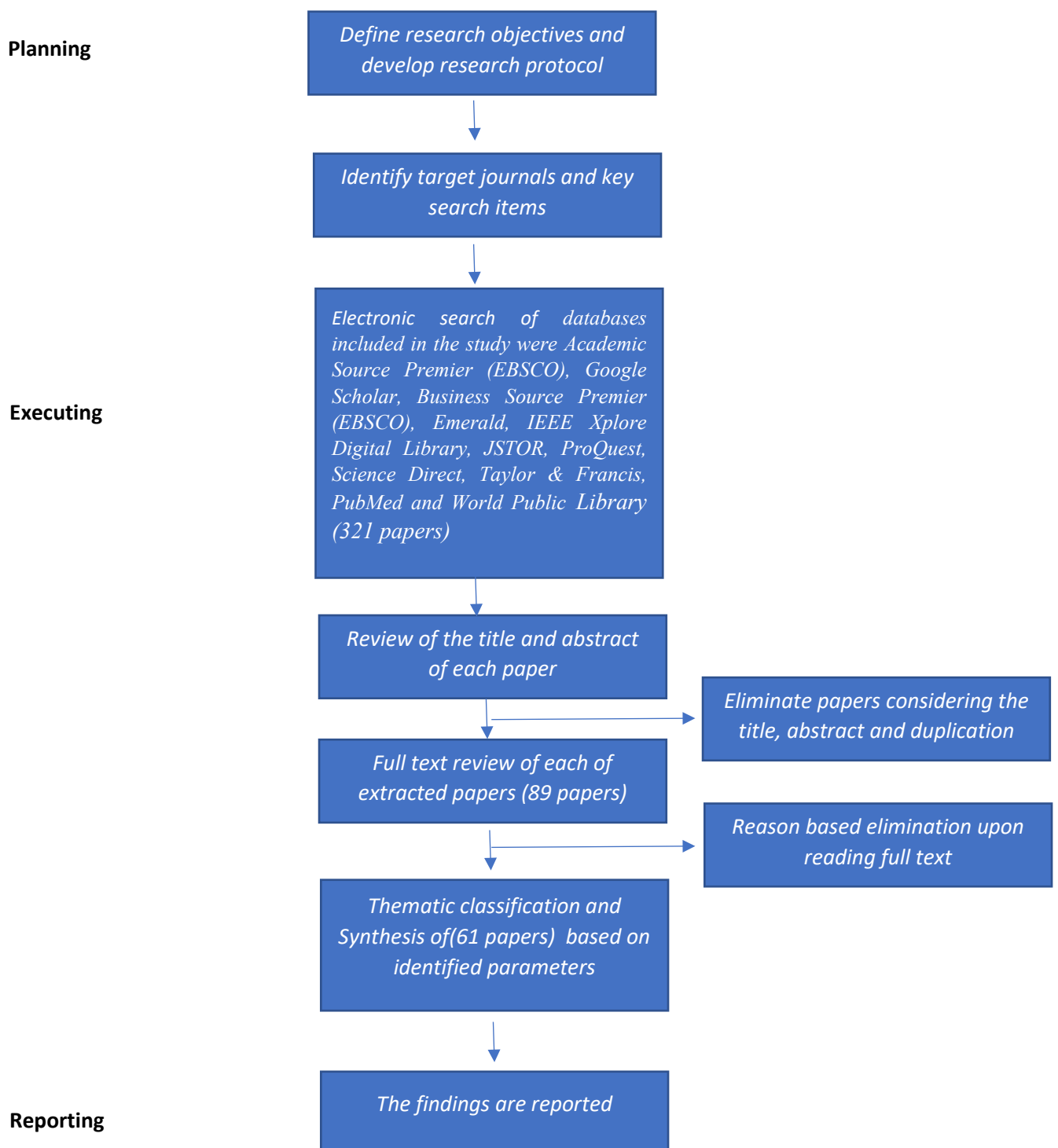
A. Data Sources

A systematic literature review process was undertaken. The first step was intended to search electronic databases. The search criteria employed for this research was *Six Sigma failures, Six Sigma failure rate, failure factors of Six Sigma, Six Sigma criticisms, Six Sigma failures, Six Sigma fad, Six Sigma criticisms, Six Sigma limitations, Six Sigma Challenges, Six Sigma disadvantages, Six Sigma issues, Six Sigma negative experience*. The scope of the study was restricted from any period to 2018. The databases which were considered in the study include: Academic Source Premier (EBSCO), Google Scholar, Business Source Premier (EBSCO), Emerald, IEEE Xplore Digital Library, JSTOR, ProQuest Dissertations and Theses, Science Direct, Taylor & Francis, PubMed, Wiley, Scopus and World Public Library. Though some authors have concluded that conference proceedings should be excluded[52], however conference proceedings and other grey literature offer some insights in an emerging research areas[53] such as Six Sigma criticisms. Hence, conference proceedings and other grey literature which were deemed to be appropriate for the research were included.

B. Screening

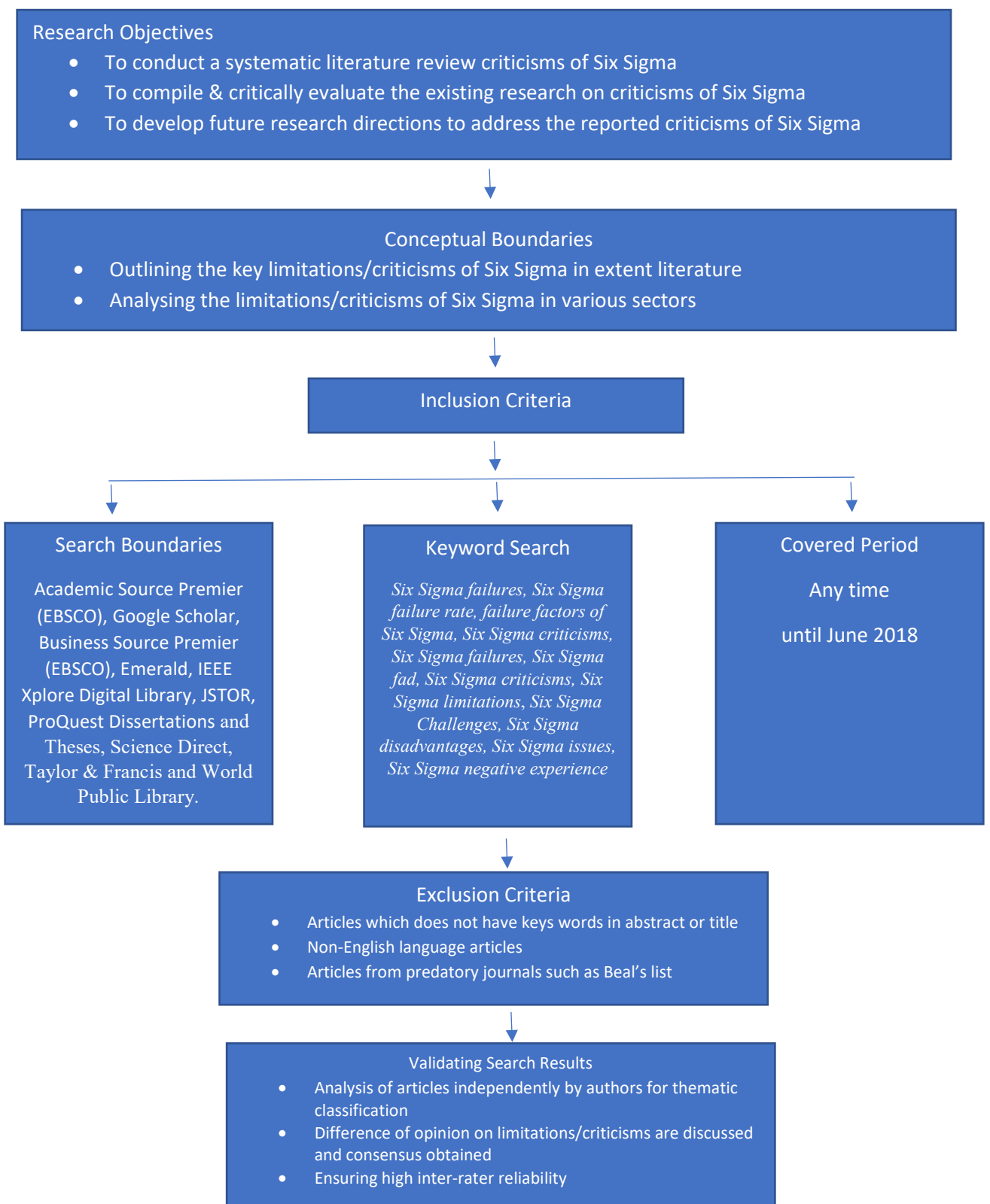
A literature review protocol based on Popay et al. [54] was developed to limit systematic error and bias in the screening of papers for review. This protocol, which summarized the scope, strategy, and data extraction method for the review, is detailed in Figure 2. The present research used the protocol to obtain its final sample of articles. The first step was a broad search to find abstracts that met the screening criteria, *Six Sigma failures, Six Sigma failure rate, failure factors of Six Sigma, Six Sigma criticisms, Six Sigma failures, Six Sigma fad, Six Sigma criticisms, Six Sigma limitations, Six Sigma Challenges, Six Sigma disadvantages, Six Sigma issues, Six Sigma negative experience* in the title or abstract of the article. Case studies that claimed the successful implementation of Six Sigma were excluded; however, if failure factors were considered then these were taken in. The titles and abstracts were then analysed. This helped in removing duplicates. The remaining abstracts were

screened using the inclusion/exclusion criteria stated earlier. The full articles were then read to meet the inclusion/exclusion criteria. The reference list of articles was read to further improve the search criteria. The total number of articles that came up initially and a breakdown of each stage is given in Figure 1.



C. Data Analysis

As the primary goal of this research was to explore six sigma criticisms, it was decided to identify the patterns, directions, similarities, and differences in six sigma implementation within the sampled articles [55]–[58]. Sixty-one articles were extracted after review considering the research objective of the study. These articles were analysed and the themes of criticisms which emerged from the analysis are organized. The data from the final group of articles were condensed to a controllable complete form as follows. The Editorial/opinion and theoretical articles were summarized in writing. After that, they were then synthesized and coded by themes to reduce data and establish patterns and themes in a comprehensive and systematic manner. As regards to the empirically based articles, they were read, coded, summarized and synthesized to determine types of research studies completed to date. The theoretical, opinion and editorial articles were read for themes and ideas were then categorized and synthesized to determine patterns among the group[56]. The entire sample was then critically analysed to gain an understanding of the state of overall knowledge in relation to Six Sigma limitations. After studying all the papers, sixty-one articles that were relevant were compiled. The articles were then critically analysed and following themes of criticisms emerged from the analysis.



D. Descriptive Analysis

The descriptive analysis of articles revealed that most of the articles on limitations or criticism were published from the US followed by the UK. As Six Sigma originated in the American corporations and later was adopted by other countries, that may be reason for such a large number of articles emanating from the US. Though Six Sigma originated way back in 1985, the first articles stressing the limitations surfaced in the 1993. The reason could be that since limitations or criticisms evolve over a time period. That too when large number of organizations have implemented Six Sigma. The analysis of research method reveals that most of the articles on the limitations or criticism were conceptual and case study. This trend suggests, that this field is evolving and there is an imminent need for further research to be carried out to investigate the limitations on Six Sigma. The investigation transpired that most articles were from the Emerald, Google scholar and Elsevier database. Additional scrutiny depicted that large number of articles were either one and two authored, suggesting a need for studies where there are collaborations among authors to address the issue of criticisms of Six Sigma. Sector wise comparison suggests that most papers were concentrated most on the manufacturing compared to service sector. Nevertheless, papers which neither concentrated on any sector were in large numbers, suggesting that limitations studies need to focus the criticism or limitation in a specific sector for deep understanding of the phenomenon. The Figure 3 depicts the summary of the descriptive analysis.

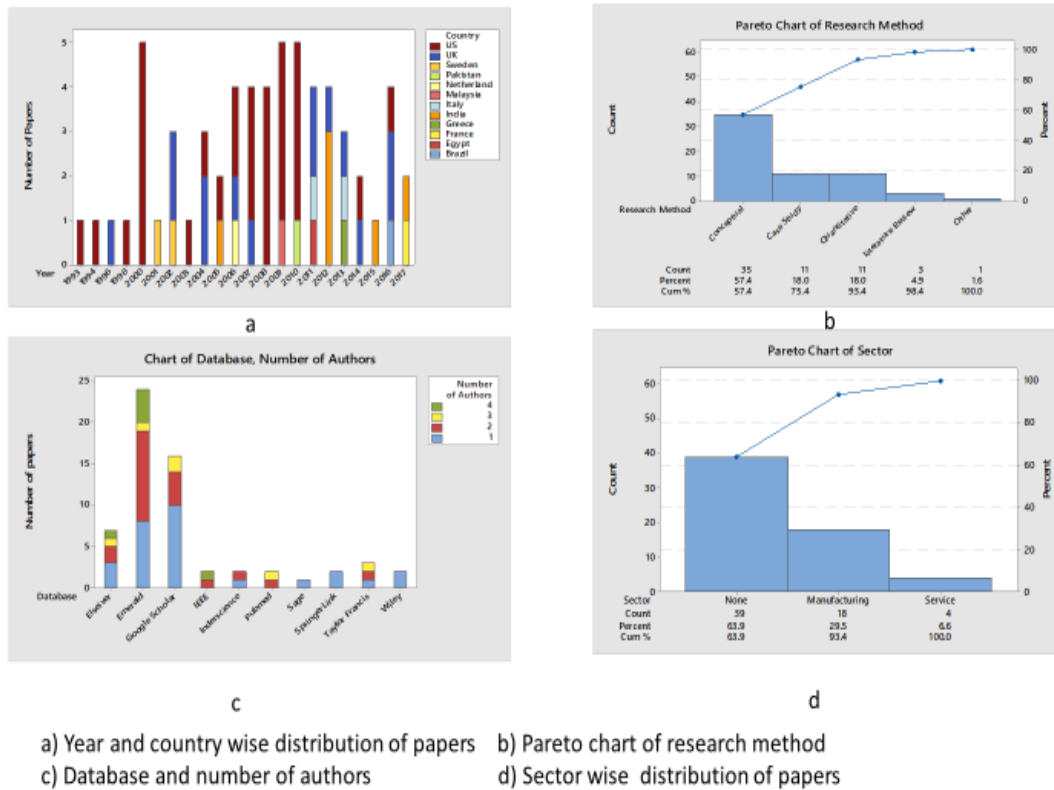


Figure 3: Descriptive Analysis of Research articles

IV. Thematic Analysis of Six Sigma Criticism

Criticism 1: The failure rate of Six Sigma like any other organizational change initiatives is very high.

The success rate in quality management studies was a cause for concern. In a study in the healthcare sector, it was estimated that 62% of Six Sigma initiatives have failed [25], [59]. Six Sigma like any other quality improvement initiatives starts off well, but, as time progresses it fails to have a lasting impact. As a result, the motivation drops and organizations fall back into the same old habits [60]. Around 60% of all corporate Six Sigma initiatives fail [14], [26], [29], [61]. Due to these high failures, more corporations across multiple industry sectors are now pulling back on their Six Sigma initiatives. It is felt that the methodology by itself is not the cure-all for corporate ills [14], [29]. In the healthcare

companies, a national survey indicates that 54% of the companies do not intend to implement Six Sigma[62]. The criticism of poor success rate needs to be investigated.

Many companies abandoned Six Sigma projects because they were not achieving positive net results within a specific period of time. In addition, “it is generally believed that only a small number of organizations that start this program succeed, where a large number of them fail”[63], [64]. The critical success factors for the successful Six Sigma implementation reported in previous studies are a) management involvement and commitment b) cultural change c)organizational infrastructure d) communication e) education and training f) project management skills g) project prioritisation and selection h) understanding six sigma methodology, tools and techniques i) linking six sigma to business strategy j) linking six sigma to customer k) linking six sigma to human resources l) linking six sigma to suppliers[12], [33], [65]–[67]. There were very few studies on critical failure factors (CFF’s). It is important to distinguish the importance of CFF’s, as it is those the key aspects or areas where ‘things must go wrong’ for the Six Sigma implementation process to achieve a high level of failure. The most common CFF’s elucidated in a previous study on LSS, which is the only study of CFF’s are a) lack of top management attitude, commitment and involvement b) Lack of training and education c) Poor LSS project selection and prioritisation d) A weak link between the CI projects and the strategic objectives of the organisation e) Lack of resources, such as technical, human and financial resources[25]. The successful implementation of six sigma also requires disciplined and systematic application of tools and techniques. The strength of Six Sigma lies in the application of tools and techniques within five stages of methodology. The key ingredients for the successful application of tools and techniques in Six Sigma are a) uncompromising support and commitment from top management b) well-designed education and training programmes c) co-operative environment d) backup from facilitators e) availability of resources f) rigorous project management approach and a

framework to indicate which tool or technique to use and when[19]. Consequently, it is imperative to conclude that successful implementation of Six Sigma in an organization is the successful tackling of critical success factors, critical failure factors and implementing the six sigma tools and techniques in a systematic and disciplined manner. Therefore, Six Sigma can be compared to change initiative in an organization. It is estimated that almost 70% change initiatives in the organization fail [68], [69]. When you compare Six Sigma with any change initiatives, it can be inferred that failure rate is almost similar around 60-70%. Thus, Six Sigma like any other change initiative is prone to high failure rate.

Criticism 2: The initial cost of implementing Six Sigma in an organization is very high.

The cost of implementing Six Sigma initiatives in an organization is very high compared to its benefits[48]. The initial cost for institutionalising Six Sigma in corporate culture can be a substantial investment[70]. Because of this many small and medium-size enterprises are discouraged from the introduction, development, and implementation of Six Sigma strategy[71], [72]. Six Sigma warrants use of a parallel meso structure and use of Six Sigma experts. The cost of training and implementing a parallel meso structure within an organization is a high. In the implementation of parallel meso structure, the employees are usually drawn from various departments[9], [14]. Consequently, there is a shortage of employees who must be recruited from the parent departments.

Criticism 3: Six Sigma, if not implemented properly, may have a negative impact on customer satisfaction

Customer satisfaction is the fundamental requirement for any industry to be successful. At two major companies like 3M and Home Depot, they abandoned the Six Sigma program because it had a negative impact on customer satisfaction [26], [49], [50]. At 3M, the creative and innovative culture that had always driven the company's success took a back seat to cost

cutting, process improvement, and efforts at improving business efficiency[50], [73]. An organization that is creative and innovative delivering products and services are well liked by the customer. For improving the customer satisfaction, organizations have to be creative and innovative in ways they deal with customers [74]–[76]. There are also studies which suggest that proper implementation of Six Sigma promotes customer satisfaction and innovation [77]–[79]. Thus, it is proposed that Six Sigma is implemented to promote customer satisfaction.

Criticism 4: Poor measurement system for Six Sigma may erode employee motivation. Also, Six Sigma creates a culture of command, and culture associated which may stifle the employee creativity and innovation.

The efficiency programs like Six Sigma are designed to identify problems in work processes. Once found then a rigorous measurement system is put in to reduce variation and eliminate defects[11], [80]. If the measurement system is not perfect, it creates a lot of motivation problem for the employees[81]. When Six Sigma type of initiatives become ingrained in a company's culture, creativity can easily get squelched. After all, a breakthrough innovation is something that challenges existing procedures and norms [73], [82]. Employees are at the receiving end while implementing Six Sigma programs because of the structured and procedural nature of Six Sigma. In addition, Six Sigma is associated with a culture of command control much like a mechanistic structure within an organization. In other words, Six Sigma promotes a perceived superiority of technical and rational knowledge over the interaction of human knowledge[81], [83]–[85]. The mechanistic organization structure is predisposed to resist organizational change and it will stifle employees creativity and innovation[86].

Criticism 5: The benefits due to Six Sigma improvement for companies are minimal with respect to the efforts

The benefits associated with Six Sigma are minimal compared to the efforts and cost associated with it. Being a statistical and data-driven methodology, the efforts required in the implementation of Six Sigma is very high in terms of resources and documentation. Compared to the efforts, the benefits of Six Sigma programs are minimal [26]. A fortune article is supposed to have stated that of 58 companies that announced Six Sigma implementation, 91% have trailed S&P 500 since then. Many of the huge success stories of Six Sigma saving huge money are anecdotal and without evidence [87]. There is a need for a study which will longitudinally monitor the success of Six Sigma for a long period.

Criticism 6: The technical criticisms of Six Sigma like 1.5σ shift needs to be addressed to instil confidence in Organizations to implement Six Sigma.

The prominent technical criticism of Six Sigma is 1.5σ shift. The argument that argue to assume the process mean to be 1.5σ shift is ridiculous[88]. If the six-sigma process mean were centered on the target value, the process would produce defectives at a rate of two parts per billion. When the process mean shift by 1.5σ the defective rate would increase to 3.4 ppm defectives. This discussion has a theme that standard deviation can be arbitrarily modified as per process user's convenience. In most cases, the standard deviation cannot be further reduced without capital investment that is also not guaranteed. Six Sigma approach implies that operator further controls standard deviation. The concept of shift is rejected in mid- 1980's[89]. Such technical criticisms of the Six Sigma methodology should be studied in detail, else many organizations will be discouraged from implementing Six Sigma.

Criticism 7: Implementing a structured improvement method like Six Sigma may hinder Organization Innovation.

The three components of Six Sigma i.e. Six Sigma role structure, Six Sigma focus on structured improvement methodology and Six Sigma focus on metrics were studied on Organizational Innovation. It was shown in the previous study that Six Sigma focuses on structured improvement methodology was negatively related to Organizational Innovation i.e. both technical and administrative innovation[2], [29]. For the business to survive in the modern world, innovation is the key[90], [91]. Some writers claim that six sigma has started to develop towards a technology based statistical process approach, rather than broad business improvement approach[77], [92]. To maintain a long-term success organization, should produce innovative products and services[93]. However, the structured improvement methodology of Six Sigma may hinder the organizations for innovations(Inman, Buell, & Inman, 2003; Sony & Naik, 2012).

Criticism 8: Variance reduction should not be the only goal of Six Sigma implementation.

Six Sigma is a powerful philosophy, strategy, and methodology for understanding, quantifying and reducing variation in all business processes[96], [97]. Many companies around the world have built entire cultures upon this foundational concept[98]. However, variation reduction is not the only evil the organizations have to deal with. A flourishing organization must grow; hence, the focus should be on growth and speed of growth[99], [100]. The companies which have stopped growing has hit the wall[100]. There have many stories of successful companies which have suddenly stopped growing[101]. Hence, in addition to variance reduction, the companies should also pursue other goals for its success in the long run like growth and speed of growth.

Criticism 9: Six Sigma bend towards Correction System

There has been some mention of Six Sigma bending towards a correctional system philosophy. In other words, it is a system which is bending towards correcting a system, rather, than preventive or proactive approach towards quality improvement[88], [95]. This criticism may have arisen due to the manner in which organizations have implemented Six Sigma as a philosophy, rather than Six Sigma as a problem-solving methodology itself. Training & Education are essential components of Six Sigma implementation[23]. Organizations should use Six Sigma as a philosophy for prevention of errors and defects in a proactive manner rather than a corrective manner.

Criticism 10: What is new in Six Sigma?

There is nothing new about Six Sigma, it is the same old quality improvement tools rebranded in a new methodology. In order to successfully implement Six Sigma, an expert requires in-depth knowledge of tools and techniques of Six Sigma, inferential and descriptive statistics, capability to convince and manage people[31], [102], project management skills[12], visionary leadership and uncompromising commitment from senior management team ([22], [103], [104] and organisational infrastructure (i.e., Belt system)[9]. The authors argue that Six Sigma places a clear focus on measurable bottom-line results which makes it unique from other initiatives we have witnessed in the past. Moreover, Six Sigma methodology integrates the tools and techniques in a cookbook fashion within the problem-solving methodology.

Criticism 11: Non-Standardisation of Curriculum

Training is the key to the implementation of Six Sigma within an organisation[23]. However, non-standardisation of curriculum of Six Sigma training for the Yellow Belts, Green Belts and Black Belts training has been a constant problem. The skills of different belt systems have been used in the industry without any knowledge indiscriminately, without an understanding

of the skills and responsibilities, as the training and requirements are mostly tailored to different industries and/or companies[105]. An education system which is non-standardised creates a lot of different learning pattern which may be detrimental to the implementation of Six Sigma. Different countries follow different standards for training and this will lead to greater confusion among the practitioners while implementing Six Sigma. Another cause of concern is that there is no standardisation of certification criteria for different belts is another major issue. Such a controversy causes a total havoc while implementing Six Sigma. Although ISO 13053 was developed in 2011[106], not all organizations are implementing this education system around the world like ISO 9001:2015 standard. The differences were huge between the requirements of ISO 13053 and the actual practices followed by a sample of 107 European large companies when implementing Six Sigma[107].

Criticism 12: Other Limitations of Six Sigma

There are other criticisms of Six Sigma as regards to the challenges it will face due to the Big data revolution. However, the big data has to be used in the right way if we have to make a meaningful analysis through Six Sigma[108]. The environmental aspects are neglected in Six Sigma implementation. Most of the companies does not take into account green concepts while implementing Six Sigma[109]. In the wake of a new revolution of Industry 4.0, the integration mechanism with Six Sigma will possess a great challenge[110].The success of Six Sigma in SME's industries are well documented[111], however, there is hardly a study of Six Sigma in micro-enterprises.

V. Discussion & Future Research Directions

Six Sigma is possibly one of the most widely used quality improvement methodologies of the last three decades. Along with success stories of implementation of Six Sigma in various sectors today, there are also criticisms of Six Sigma Methodology. In order to understand the

concept of Six Sigma, the criticisms have to be also considered. This study through systematic literature review analysis and compiles the literature criticising Six Sigma. Below, discussion on the criticisms and the corresponding future research directions are given.

Research direction 1: High failure rate

Previous literatures have suggested that the failure rate of Six Sigma implementation is very high. The average failure rate of Six Sigma literature is around 60-70% [25], [29], [59]. Future research should explore the high failure rate of Six Sigma implementation across different industries. The failure rates may also be classified between manufacturing and service industries and across different countries. In order to ascertain the reasons for the failure rate a qualitative or multiple case study research may be conducted. The authors argue that failure rate of Six Sigma programs at the project level as well as firm level should be studied and analysed separately. Perhaps the development of a framework in reducing failures of Six Sigma initiatives could be extremely invaluable for many senior managers in organisations at a global level.

Research direction 2: High initial cost

The second criticism of Six Sigma revolves around the initial cost of implementation of Six Sigma[48]. The cost of manpower, training, and education of employees, allocating resources to the execution of projects, etc adds to a huge additional investment for the organizations. Future research may look at the cost of implementation of Six Sigma in terms of fixed cost and variable costs for the different type of organizations ranging from manufacturing, service to even public sector organisations and small and medium-sized enterprises. Some mechanisms for reducing high start-up cost may be also researched so that small and medium scale industries may be assisted.

Research direction 3: Reduced customer satisfaction

Implementing Six Sigma has resulted in reduced customer satisfaction due to the lack of innovative products and services. Customers are satisfied with the organizations if there are innovative products and services from the organization at competitive pricing strategies. Efficiency-driven organizations may result in producing products or services which may not be useful for the customers. Researchers may look at how to develop innovative products or services using structured improvement methods like Six Sigma[29], [60].

Research direction 4: Reduced employee motivation for creativity and innovation

It is often mentioned that the typical mechanistic organization structure for Six Sigma implementation may stifle employee motivation for creativity and innovation. This is definitely a future research topic for Six Sigma promotion in the right direction. Building a new culture for quality management including Six Sigma is important in the era of the fourth Industrial Revolution (Park et. al, 2017). Some strategies to motivate employees for creativity and innovation should be studied and the role of leadership in creating an environment for fostering innovation should also be further explored. An innovative feature like the marriage of Six Sigma with TRIZ[112], [113], may be considered for promoting innovation using Six Sigma. Six Sigma may be implemented with other creativity inculcating techniques within organizations. The impact of Six Sigma on the satisfaction of employees is documented in literature[2], [26], [29]. The structured improvement process sometimes inhibits the creative temperament of employees because it instils a culture of command and control. Researchers may explore the relationship between Six Sigma and creativity. Though there are some studies on creativity and Six Sigma [95], however, there are only a few qualitative and empirical studies which are conducted to clarify the relationship between these two important variables e.g. [114]. Future research in different context, different industry setting will help in understanding this relationship.

Research direction 5: Six Sigma improvement benefits

Another criticism of Six Sigma is that the benefits derived out of Six Sigma is minimal[26]. Implementing Six Sigma within a company requires some time, effort and cost[115]. There are frustrations that benefits given by data are expensive and small part is implemented in the end[32]. Initial results of Six Sigma are attractive, however, in the long run many organizations fail to sustain the Six Sigma results and benefits in the long run[116]. Therefore, in the long run when the benefits of Six Sigma, are compared with the efforts required to implement and sustain Six Sigma, the results are inconclusive[14], [61], [116]. Future research should explore in a different context and setting, the long run benefits of Six Sigma implementation. Also, case studies research may be carried out in different sectors, to conduct the cost-benefit analysis using longitudinal data for a long period e.g. ten years. This will help in analysing the sustainability of the benefits of Six Sigma in the long run. The case study is a preferred method, as it will help to capture a large number of variables of Six Sigma implementation and the corresponding improvement benefits.

Research direction 6: Technical criticism of Six Sigma on 1.5 σ shift.

The prominent technical criticism of Six Sigma is the controversy around the 1.5 σ shift[88]. It is reported that Motorola without formal empirical verification has devolved the concept of 1.5 σ . and the shift in process mean will also have implications for the distribution of process outcomes. Therefore, one should also question the assumption that the entire process distribution shifts by 1.5 σ [117]. This particular issue 1.5 σ should be the major thrust for future research, as a small shift in sigma could lead to erroneous defect calculations[32]. The followers of Deming have rejected Six Sigma on the grounds that Six Sigma 3.4 ppm is a numerical goal and the 1.5 σ shift is arbitrary[118], [119]. Such controversies need to be addressed by the researchers as it will help many organizations while implementing Six

Sigma. Research should be conducted in this area to find the veracity of 1.5σ claims. Also, guidelines may be offered with regard to the nature of shifts for different types of processes.

Research direction 7: Six Sigma and Organization Innovation

A recent study in China empirically finds that Six Sigma management, infrastructure, and core practices have a positive relationship with product, process, and administrative innovation[120]. However, numerous case studies at various organization also show a negative impact on Organizational innovation[29]. DMAIC for example, and employs rigorous, analytical methods, it leads to people blindly following a rigid process, and turning off their brains[73], however, such an argument can come from people who have never implemented Six Sigma. Creativity is an integral part of the DMAIC process. However, it is not the best method for identifying opportunities for disruptive innovation which is critically needed for businesses to succeed in the long-term[95]. Six Sigma due to its structured improvement methodology may have a negative impact on the organizational innovation[2]. In view of these academic debates, it is important that future research should be conducted in various sectors to ascertain the nature of the relationship between the Six Sigma and Organization Innovation.

Research direction 8: Significance of variation reduction

Organizations to be competitive in the modern market should keep growing and the companies which have stopped growing has hit the wall. The organizational growth is not due to one factor[100]. There have many stories of successful companies which have suddenly stopped growing[121], [122] leading to negative firm performance. Therefore, continuous involvement in variation reduction should not be the only motto of Six Sigma, other organizational benefits like growth opportunities etc should be considered in tandem. One size of variation reduction does not fit all parts of the organization. In a manufacturing

such kind of rigor may be required, however, when it comes to research or design department, variation may not be the only thing to look to. Hence, customization of Six Sigma may be topologized among different elements in an organization. Thus, future research should identify various factors like growth strategy, innovation strategy[123], product expansion[124], market penetration[125], diversification etc which should be considered in tandem with variation reduction so that Six Sigma can be implemented effectively.

Research direction 9: Six Sigma as a prevention or proactive methodology

The proactive or preventive aspects should be considered while implementing Six Sigma[88]. Many organizations are concentrating only on the correctional system while implementing Six Sigma[115] and hence it will not be beneficial for the organization to sustain the results in the long run. Proactive or preventive and correctional system will help the organizations to sustain the best practices for a long-term organizational growth[126]. Therefore, the future research should concentrate on how to integrate preventive or proactive systems in equal proportions while implementing Six Sigma.

Research direction 10: What's new in Six Sigma?

Six Sigma as a methodology is questioned for its uniqueness compared to other quality improvement initiatives like TQM etc. Many argue that the tools and techniques are of previous quality management systems given a new name[31], [102]. Though previous research has delineated about the uniqueness of Six Sigma compared to other initiatives[9], [21], [22], [98], there exist still misperceptions about its uniqueness. Future research should study why Six Sigma is seen as a similar initiative when compared to its predecessors. The perception – expectation gap formations of the stakeholders will be interesting to explore so as to understand the mechanisms for perceiving a new improvement initiative.

Research direction 11: Standardisations of Six Sigma Education

Non-Standardisation of Six Sigma education has been a huge problem[105]. Though ISO 13053 has been developed its status of implementation throughout the world is a matter of great importance and study[107]. Future research may study the status of its implementation in various countries. In addition, the extent of implementation of this standard will moderate the relationship between Six Sigma and Organizational performance e.g. firm performance. Therefore, future research should be conducted in this area. The qualitative study on how organizations perceive this standard will also be an important area for research. Similarly, barriers or implications for standardising Six Sigma education will also be an important area to explore.

Research direction 12: Six Sigma and Big data

Big data are large data sets where in the traditional data processing are inadequate to deal with [127]. The challenge of Big data sets includes capturing data, storing data, analysing data, searching data, sharing data, transferring the data, visualizing the data etc[128]. Big data offers huge opportunities that can unlock infinite efficiencies and savings when it is used in the right way[108]. Most of the observation data are passive and observational, thus needs to be utilised with care and caution for improvement initiatives. Therefore, future research in Six Sigma should explore this area further to develop tools for conceptualisation & visualisation of big data. In addition, a step by step methodological analysis plan will help so that big data issues can be addressed.

Research Direction 13: Six Sigma and Green

The integration of Green and Six Sigma has been conceptualised in the literature. Green Six Sigma is the assessment of direct and eventual environmental effects of all processes and products of an organization[109]. The environmental concerns have made organizations to

develop cleaner manufacturing processes and services as well as designing recyclable products. Green is an initiative that tends to reduce the negative environmental impact of production and consumption of products and services through utilisation of methods which helps in improving the environmental footprint of the organization [129], [130]. Integrating the concepts of Green and Six Sigma would be beneficial to further improve and sustain the environmental footprint of the Organisation. The future researchers may develop integration frameworks for Green- Six Sigma for products and services. The implementation model also should be developed for Green Six Sigma, so it will be guide to the practitioners in terms of any precedence relationship to be followed so that Green Six Sigma can be implemented successfully.

Research Direction 14: Six Sigma and Industry 4.0

Industry 4.0 merge the real and virtual worlds into an Internet of Things (IOT) in order to exploit the full potential of the synergy between the information and communications technology (ICT) sector and the production sector [110], [131]. The Cyber-Physical-Systems (CPS) will be the platform for achieving it. This will comprise not only the objects, devices and facilities, but also production plants and logistics components with systems which are called sensors and actuators will be able to communicate with each other and utilise services provided via the internet [132]. Smart manufacturing calls for the integration of IOT with CPS for creating cyber-physical-production-systems (CPPS's) [133]. This will generate a high volume of data and Six Sigma can make use of it. In addition, the DMIAC model of Six Sigma will be enhanced with capability modelling and thus, Six Sigma can be used as the guideline for capability modelling [110]. The future processes will become smarter by embedding various technologies and the flood of data will have to be incorporated into Six Sigma. The predictive and self – learning measures of modern machines, smart materials, and

objects will also need new analytical tools, which may be used in tandem with existing Six Sigma tools and future research may explore these areas.

Research direction 15: Six Sigma and Public Sector Organisations

The public sector in most of the countries provides a wide variety of services. These services are used by a large number of customers. There are many unique characteristics of public service like public accountability, multiple objectives, lack of equity ownership, Governance structures etc[134]. However, there are very few studies done on the implementation of Six Sigma in public services. An important question to address in a public service would be how public sector should work together to maximize benefits, reduce duplication, and deliver a customer-focused and integrated service[40]. Therefore, the impact of Six Sigma on local councils, higher education, ambulance and fire services, police forces, municipalities etc should be further researched for its suitability in the long run. The critical success factors for implementing Six Sigma in public services will have to be re-examined in two different setting i.e. developing and developed countries. The implementation model is an important research because public services cannot afford to pay huge consultant fees. Therefore, a research which depicts a step by step implementation model will have a deep impact on its implementation in public utilities.

Research direction 16: Six Sigma and micro enterprises

The microenterprises play a major role in the development of a developing country[135]. Micro-enterprises are defined as those with fewer than ten employees. In a developing country this can account for fifty percent of new job opportunities. A study in a developing country states that three out of five business of micro nature fails. There are many reasons for its failure, some of the main reasons are the ability to provide quality product or service, unable to handle more than one critical project, low levels of productivity, poor quality

products, serving small localised markets etc [136], [137]. Six Sigma can be an important methodology for the micro-enterprises and it changes the way they do business. However, the initial cost of Six Sigma implementation is high. Future research may be directed on how to implement Six Sigma in micro-enterprises. Such a research direction will create a huge impact on the lives of new and existing micro-entrepreneurs.

VI. Conclusion, limitations and agenda for future research

Six Sigma is one of the most popular process excellence methodologies used in the organizations today. Many organizations have benefitted from the implementation of Six Sigma. Despite its success, Six Sigma is also criticised by many academicians and practitioners. It is important to collate and analyse these criticisms for enlarging the body of knowledge on Six Sigma. This study through a systematic literature review method analysed the criticism of Six Sigma in detail through a thematic analysis. Twelve predominant criticisms in the literature have been analysed and sixteen research directions are given to help the future researchers. The systematic literature review gives an overview and critique of the field of Six Sigma. The review is limited by the databases accessed, the search criteria's, method of searching, inclusion and exclusion criteria and the time constraints. Due to Big data revolution and Industries 4.0 integration with Six Sigma, the horizons of Six Sigma are expanding. Hence, it is pertinent that given our findings the future research in Six Sigma should focus on the sixteen research directions elucidated in the paper. Each of the directions will help to repudiate the criticisms of Six Sigma in the long run.

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