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Systematic Literature Review of Six Sigma Philosophy in Manufacturing Operations

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Abstract

Processes in manufacturing and service organizations are regularly improved upon for better operational performance. Six Sigma is one of the management philosophies required to achieve improved quality and process performance in systems. Consequently, this study aims to investigate the existing literature that focused on Six Sigma philosophies in process industries and exposition on the future of Six Sigma approach in manufacturing. For the first time, this research focused on the recommendation of the fourth industrial revolution for process improvement and offer foreseeable decisions in every phase of the Six Sigma technique. Other aspects covered in this review include Six Sigma developments, metrics and capabilities, Six Sigma and quality management approaches; Six Sigma integration and innovation; Six Sigma and organizational sustenance and benefits of Six Sigma philosophies; confrontational concerns on Six Sigma Improvement Strategies and the future of Six Sigma. Future research directions focused on the Six Sigma philosophy and innovative technologies to support philosophy have been highlighted with effective recommendations.

Keywords

Six Sigma Techniques, Hybrid Philosophies, Six Sigma Improvement Strategies

1. Introduction

Six Sigma is one of the most useful management philosophies that is capable of reducing defects while improving the efficiency of processes in systems (Kwak and Anbari 2006). It is a business strategy that seeks to identify and eliminate causes of defects or failures in processes by focusing on factors critical to the customer (Snee 2010). This management philosophy has gradually stretched effectively to other sectors, product and service-based (Chakrabarty and Chuan 2007). In recent times, the management philosophy is noticed to gain more improvement from state-of-the-art digital technologies thereby maintaining the quality of the product in industries. Six Sigma tread the path of the rigorous project approach and extensive use of analytic and quality tools. Its structured team approach to solving problems has introduced in its formation a platform that breeds and diffuses knowledge.

However, the research on Six Sigma philosophy irrespective of its impressive track records in practices is still at the low level (Zhang et al. 2009). This is because of divergent views and set perceptions on the Six Sigma subject. The concern of Six Sigma being perceived as a management fad, according to Zhang et al. (2009), has prevented many scholars from conducting rigorous research on Six Sigma. The research territory to date on Six Sigma subject has been found only within the North American region with only a few studies in Europe and Asia (Wang et al. 2004). Therefore, this paper seeks to systematically review Six Sigma and its methodologies, explore integration possibilities of Six sigma with other techniques, and discuss future possibilities of six sigma.

2. Six Sigma Development

Six Sigma is a methodology introduced by Motorola in the late 1980s and it is widely used in manufacturing production to guarantee quality and several factors facilitate its success (Garcia-Alvarez et al. 2018). Companies, such as General Electric, Allied-Signal, Honeywell, and many others, followed shortly after and also made it an integral part of their leadership development activities (Henderson and Evans 2000). Linderman et al. (2003) defined Six Sigma can as an organized and systematic method for strategic process improvement as well as new product/service development that utilizes statistical techniques in causing defect reduction. The concept of Six Sigma is based on achieving a quality standard of fewer than 3.4 defects per million opportunities (DPMO) (Bothe 2002). Six Sigma defines defects as anything that is not within customer expectations (Planettogether 2020). The special thing about Six Sigma compared to other process improvement methods is its connection between output, process, and input. Although the original focus of Six Sigma was on manufacturing, it has been applied in a non-manufacturing context with minor adaptations (Does et al. 2002). Six Sigma has its origin in quality engineering, which has traditionally had a strong emphasis on statistical methods (Demast and Lobberkol 2012) and does provide an effective means for deploying and implementing statistical thinking.

The Sigma (σ) is a parameter of the distribution function, which expresses the variability of given quality characteristics compared to the expected value of the mean (μ). The smaller the σ , the smaller the risk that a portion of the measurement variable will fall outside the given limit values. Six Sigma means to produce such small variation around the process mean so that within the tolerance range, there will be exactly 12 units of σ . This quality improvement program was developed by Motorola engineers in 1986, and their quality improvement goals were set such that process variability is at ± 6 Standard deviations from the process mean, signifying that customer specifications are met and can only produce 3.4 non-conforming products. These 3.4 DPMO computations assume a 1.5 sigma shift in the process mean and are based on the assumptions that the process output follows a normal distribution, and the process means may in the long term shift up to 1.5 standard deviations. "Six Sigma" comes from the bell curve used in statistics, where one Sigma symbolizes a single standard deviation from the mean (Kumar, 2021). According to Omar et al (2012), a standard deviation is a statistical way to describe how much variation exists in a set of data, a group of items, or a process. Any process that is at Six Standard deviations is highly capable, signifying that customer specifications are met. Figure 1 and 2 shows a standard normal distribution of 68.26% of values are within 1 standard deviation of the mean; 95.46% of values are within 2 standard deviations of the mean, 99.73% of values are within 3 standard deviations of the mean and respective DPMO. A Six Sigma process has a process mean that is at six standard deviations from the nearest specification limit, thus providing enough shields between the process natural variation and the specification limits.

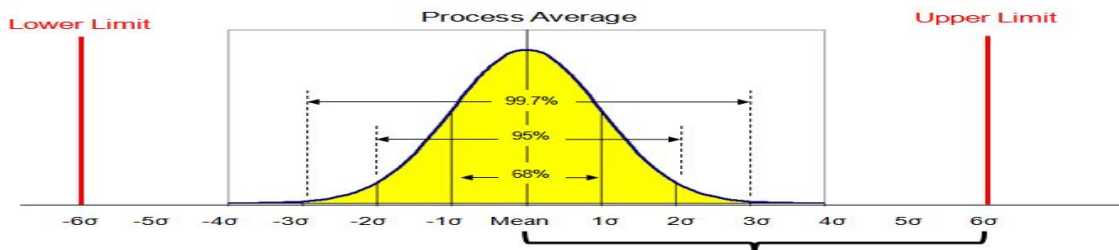


Figure 1. Six Sigma definitions (Source: <http://leansixsigmadefinition.com/glossary/six-sigma/>)

Table 1. Sigma Levels and DPMO (Adapted from <http://leansixsigmadefinition.com/glossary/six-sigma/>)

Sigma Level	Defects per million	Yield
One	690,000	30.85%
Two	308,000	69.15%
Three	66,800	93.32%
Four	6,210	99.38%
Five	230	99.977%
Six	3.4	99.99966%

2.1 DMAIC and DMADV Six Sigma

Six Sigma structured improvement procedure have two known methodologies, DMAIC and DMADV; these two Six Sigma methodologies are employed under different circumstances and problem areas. DMAIC is an acronym for

Define, Measure, Analyze, Improve, and Control, and is a structured problem-solving procedure for an existing process as shown in Figure 2. The Six Sigma-DMAIC (SS-DMAIC) concept has provided an applicable framework to satisfy the requirement for critical to quality (CTQ) characteristics. Its potency in process improvement studies cannot be overemphasized and its integration advantage and applications in various fields, are fast gaining wider recognition. The essence of the DMAIC method is to reduce variation in a process, in order to achieve high-quality conformance in customer's terms (Smetkowska and Mrugalska 2018). DMAIC is a revised version of well-known problem-solving methods such as Plan-Do-Check-Action (PDCA) and Plan-Do-Study-Action (PDSA) (Zhang et al. 1999). SS-DMAIC steps are basically used for any process improvement project. This approach comprises five steps and each step addressed certain tools and techniques. It offers a structured approach to solving problems and improving results. DMAIC is concerned about removing variability out of the existing processes. Typical DMAIC projects are selected based on their expected contribution to improving efficiency, cost, or customer value (Pande et al. 2000).

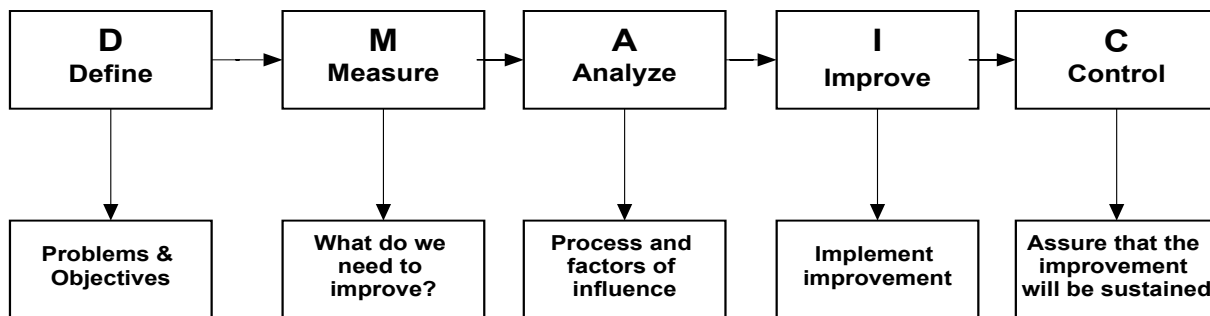


Figure 2. Lean six sigma green belt certification, 2017 (Adapted from http://www.optiontrain.com/Lean_Six_Sigma_Green_Belt_Certification_Training.php).

Chakrabarty and Tan (2007) described DMADV as the incorporation of more innovative tools such as the theory of creative problem solving and axiomatic design which DMAIC does not, Figure 3 shows steps taken for DMADV projects. According to Eckes (2001), DMADV is suitable when any of these situations arise; when a new process is required to assist an organization to achieve a strategic objective, and when a current process is irreparably broken.

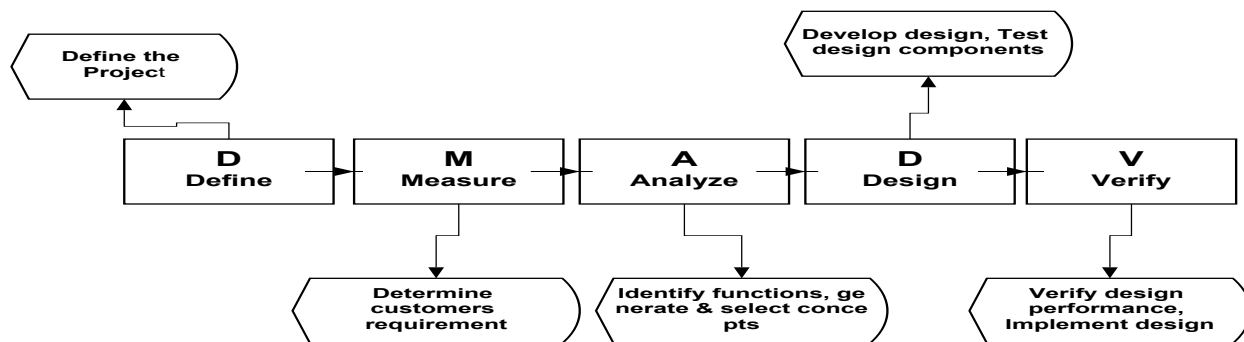


Figure 3. Six Sigma DMADV methodology (Adapted from <https://theblogspotblog.wordpress.com/2014/02/18/six-sigma-methodology/>).

2.2 Six Sigma Structure and Metric and Capability

A well-organized Six Sigma infrastructure is necessary for an organization to carry out related improvement projects (Hung & Sung, 2011). Six Sigma's responsibilities are well defined and in an organizational context cuts across numerous ranks in a well-coordinated formation (Sinha & Van de Ven, 2005). A black belt is a full-time Six Sigma practitioner who had rigorous training in the statistical methods used to gather and analyze data in a Six Sigma project. A green belt is a Six Sigma practitioner usually part-time who has been trained in the SS-DMAIC problem-solving methodology and basic statistical tools, whereas champions are heads of business divisions or process owners who run the processes.

A metric is a specification or attribute against which the outputs of a process are compared and declared acceptable or unacceptable. Six Sigma metrics can be in the form of several complaints, percentage scrap, cost of poor quality

(COPQ), defect rate, process capability, first-time yield, throughput yield. In general, Six Sigma methodology and process capability analysis (PCA) occupy important places in quality and process improvement initiatives (Senvar and Tozan, 2010). Six Sigma typically monitors the process using control charts, which compares control limits with specification limits to determine process capability (Murugappan and Keeni, 2003). Seven basic quality tools that are very helpful in SS-DMAIC projects are the cause and effect diagram (fishbone diagram), flow chart, Pareto chart, histogram, check sheet, scatter plot, and control charts (Rastogi 2018).

2.3 Six Sigma Capability

The Sigma capability is the number of standard deviations from the mean and is also called "**Z-score**" or "**Standard score**". This metric is also used to standardize a distribution (that is, used to convert a normal distribution to a standard normal distribution). For a Six Sigma process, the error probability is 0.0000034 (meaning there are only 3.4 defects per million delivered units). For a three-sigma process, the probability of error is 0.0668 (66,800 defects per million units). The sigma or Z capability is the simple metric for measuring a process's capability to produce defect-free products. The presence of process variations especially the special causes make prediction impossible and thereby making the meaning of a capability index unclear. As a result of this complex nature of most manufacturing processes, it requires vibrant monitoring and successive improvement strategies. The capability indices relate the voice of the customer to the voice of the process (Steiner et al. 2014). Process capability indices (PCIs) relate the engineering specification to the behavior of the process (Bangphan et al. 2014) and can be viewed as an effective and excellent means of measuring product quality and performance (Chen et al. 2006). Capability measures are developed based on various criteria such as process consistency, process departure from a target, process yield, and process loss. Benefits of applying this capability concept are described by (Kane 1986), as Prevention of non-conforming product, continuous improvement, enhancing communication between the manufacturer and the suppliers by creating a common language; prioritization of process for improvement; locating / identification of process variability and assessment of quality systems.

The concept of capability has been applied in most of the manufacturing industries; the concept has been applied in the silicon-filler manufacturing process (Chen et al. 2006); in the electronic industry (Motton et al. 2008); in the aluminum capacitor manufacturing process (Pearn and Road 1997); in drug manufacturing companies (Akeem et al. 2013); in the automotive industry (Kane, 1986). It is pertinent to note some assumptions are mandatory procedural conditions in any Process Capability studies (PCs) so that one does not misrepresent the true capability of a process. These procedural assumptions and conditions are as follows:

- The process is in statistical control.
- The distribution of the process considered is normal.
- As a rule of thumb, a minimum of 50 randomly selected samples must be chosen for process capability studies, a minimum of 20 subgroups, and a subgroup size, of at least four.
- The data chosen for process capability studies should attempt to encompass all-natural variations.
- The process to be studied should be devoid of any special causes of variation.

2.4 Six Sigma Implementation/ Applications

Six Sigma implementation requires resource commitments in terms of money, time, and effort from the entire workforce. A uniform way to implement Six Sigma usually remains a myth as Six Sigma implementation processes and styles differ from company to company, country to country due to the uniqueness of experiences and nature of problems (Moosa and Sajid 2010). Identification of factors critical to the success of Six Sigma implementation plays a vital role in the development of an adaptive Six Sigma framework (Amar & Davis, 2008). Moosa and Sajid (2010) explored and analyzed the critical success and failure factors of implementing Six Sigma in organizations based on lessons drawn from real-life practices, case studies, and available literature. The researcher attributed most failures to the implementation approach to the lack of a standard model available for Six Sigma implementation and to several social factors that prevail in the organization. Antony and Coronado (2002) identified 12 typical critical success factors as Management involvement and commitment; cultural change; communication; organization infrastructure; training; linkage to business; linkage to the customer; linkage to human resource; linkage to suppliers; understanding tools and techniques within six sigma; project management skills; project prioritization and selection.

Kwak and Anbari (2006), in their classification, identified four factors as being more critical for a successful Six Sigma projects implementation: Management involvement and organizational commitment - organizational infrastructure needs to be established with well-trained individuals ready for actions; project selection, management,

and control skills - the project has to be feasible, organizationally and financially beneficial, and customer-oriented; encouraging and accepting cultural change: there should be a clear communication plan, and scheme for motivating individuals facing cultural change in order to overcome resistance; continuous education and training: - organizations need to continuously learn and adopt the latest trends and techniques that are outside the Six Sigma domain that might be useful to complement the Six Sigma approach. However, Llorenz-Montes and Molina (2006) suggested that the implementation of the Six Sigma program needs successful change management of behavioral and work processes to achieve the desired result as inadequate knowledge sharing capability is one of the factors that inhibit successful change. Successful Six Sigma projects are recorded with some organizations like the food processing industry, (Hakimi et al. 2018), Cigarette production processes (Usman and Hutasoit 2019), plumbing industries (Takao et al. 2017), in the clinical laboratory (Yang et al. 2020; Westgard et al. 2018; Kumar and Mohan 2018), Magazine production process (Hernadewita et al. 2019), Aluminium die casting operation (Marques and Matthe 2017), Health centre (Arafah et al. 2018), Vehicle fleet logistics (Stanivuk et al. 2020).

3. Six Sigma and Quality Management Approaches

Quality management can be described as a new way of thinking about organizational management in the direction of improvement (Andersson et al. 2006). Six Sigma improvement strategies are the latest and most effective technique in the quality engineering and management spectrum (Desai & Shrivastava 2008). It incorporates a systematic, scientific, statistical, and smarter approach for management innovation, that builds on previous ones like TQC, TQM, and well-suited in the knowledge-based information society (Park, 2003). Six Sigma is not entirely new with respect to prior quality tools or principles, but the deployment approach and emergent structure of Six Sigma are new (Schroeder et al. 2008; Parast, 2011). Many proponents of the Six Sigma approach claimed that the approach has developed beyond a quality approach into a broader process improvement concept (Nonthaleerak and Hendry 2008). Six Sigma is known for employing specific challenging process improvement goals (Pande et al. 2000). Most of the quality management concepts that have been widely promoted in literature and practice are TQM, Six Sigma, lean manufacturing, business process re-engineering, just-in-time (JIT), Kaizen and Business excellence, Baldrige model, Statistical Quality Control (SQC), and Six Sigma is one of the more recent quality improvement initiatives to gain popularity and acceptance in many industries across the globe (Wang et al., 2009). However, Six Sigma differs from other quality improvement programs due to their measurable and quantifiable goals (Andersen et al. 2006).

Contrary to TQM, Six Sigma allows organizations to measure process capability and improvement efforts internally and externally (Aboelmaged 2010). In Six Sigma, there are two major improvement methodologies DMAIC & DMADV, while the improvement cycle in TQM is comprised of four stages. The core advantages of Six Sigma over TQM according to Schroeder et al. (2008) is on focused attention on financial and business result, the use of specific metrics such as Critical-to-quality (CTQ), DPMO, use of a structured method for process improvement, and the use of a significant number of full-time improvement specialists. TQM generally focused on organizational results rather than on business results (Quinn 2003). In the Six Sigma program, all improvements are economically justified (Andersson et al. 2006). However, the use of TQM as an overall quality program is still prevalent in the modern industry but many companies are extending this kind of initiative to incorporate strategic and financial issues (Harry 2000). There are four aspects of Six Sigma strategy that are not emphasized in other business improvement methodologies and TQM (Antony et al. 2005). These aspects are as follows:

- Six Sigma distinctively emphasis on quantifiable project outcome.
- Six Sigma has been successful in integrating both process and organic aspects of continuous improvement.
- Six Sigma methodologies DMAIC sequentially link the tools and techniques.
- Six Sigma creates a powerful infrastructure for the training of champions, master black belts, black belts, green belts, and yellow belts.

3.1 Six Sigma Integration

Some of the identified challenges that plague lone Six Sigma initiatives can be made better, through a synergetic support of other existing innovative management practices (U-Dominic & Godwin, 2018). Through a proper integration between Six Sigma methodology and other improvements/management initiatives, any process can be improved into an infinite position. Sustainable results can also be achieved when an integrated and cohesive approach is adopted with respect to training and learning (Alsagheer and Mohammed 2011). However, as has been reported in the existing literature, most of these integrations fail to take full advantage of each methodology due to organizational constraints/philosophy. The integration challenge is to create the best process and organizational infrastructure to support each of these methods and to align these infrastructures so that the integrated initiatives are complementary. In recent time, a lot of studies that focused on the shared relationship between Six Sigma and other

innovative management and practices were as follows; integrating with Lean and industry 4.0 (Chiarini and Kumar 2020), integrating with Grey FMEA (Ishak et al. 2019), integrating and comparing principles and characteristic of Six Sigma with TQM (Revere & Black, 2006), integrating and comparing principles and characteristics of Six Sigma with human resource functions (Wyper and Harrison 2000), integrating with the theory of constraints (Ehie and Sheu 2005), integrating with lean production (Bhaskar 2020; Shokri and Li 2020); Sandner et al. 2020; Farrukh et al. 2020; Henny et al. 2019; Kowang et al. 2019), integrating with Balanced score card SCOR model (Knowles et al. 2005), integrating Six Sigma with ISO 9000 (Catherwood 2002), integrating with ISO 9001 (Dalglish 2005) are all part of the effort to maximize the positive effect of the Six Sigma method.

3.2 Six Sigma and Innovation

One commonly overlooked utilization of Six Sigma methods is sourcing innovation (Six Sigma 2017). Six Sigma has always sought-after innovation as its overall goal is to achieve product efficiency, decrease waste, and seek constant improvement. Six Sigma initiatives according to some researchers are not very effective in environments where the rate of technological change is intense. Process management deals with minimizing sources of variability in internal and external activities (Camgoz-Aldag 2004). Because of the focus of process management programs in variance reduction for improving the operations and continuous improvement of activities in a firm, over-emphasis on these programs affects the balance between exploitation and exploration (Benner & Tushman 2003). In other words, Garvin (1991) believes that focusing much on process management will have negative effects on innovation and may negate long-term performance. In the same vein, Chennupati et al. (2012) encourage that Six Sigma practitioners should embrace creativity and innovation as a basis, along with quantitative ideas. In the pursuit of higher operational effectiveness and organizational performance, scholars and practitioners are looking for new approaches to improve operational performance, boost profitability and enhance competitiveness (Parast 2011).

The premise of Six Sigma is that improving an organization's processes can lead to a consistent output that is welcomed by customers (Zhang et al. 2009), but what happens when customers taste changes or competition heighten has not been given wide recognition. Few researchers have proposed theoretical models explaining why process management will impede innovation and empirically tested the relationship in the paint industry. Six Sigma's mechanistic approaches to improvement are highly prescriptive in mandating how improvement efforts should be implemented. The contemporary business environment is most appropriately characterized by versatile customer requirements, complex global supply chains, and fierce global competition. Such a mechanistic approach may likely not be appropriate for organizations operating in a dynamic environment; thus, organizations need to be adaptive. However, Six Sigma is about overall management strategy, culture, and change, and the organization needs to build all of this into a sound corporate strategy plan (Antony et al. 2005), thus, to incorporate all these in an organization is to integrate other innovative approaches like knowledge management (KM). Schroeder et al. (2008) also suggested a specified number of additional research projects using contingency theory, organizational learning, and organization change theories to ensure organizations' innovation processes are not hindered.

4. Six Sigma and Organizational Sustenance

Some researchers, like Demast and Lobberkol (2012), recommend DMAIC methodology suitable for empirical problems varying from well-structured to semi-structured, but not to ill-structured problems or pluralistic messes of subjective problems (people problem solving). Recently, operations management scholars have recognized that "incorporating" human behavior into operation management models will yield more realistic insights" (Boudreau et al. 2003). Operations management should not be understood as a purely technical problem but must be considered simultaneously with behavioral underpinnings (Linderman et al. 2003). Recent studies have now re-focused research attention to incorporate the psychological, and contextual human side of Six Sigma (Buch and Tolentini 2006), goal setting (Linderman et al. 2006), organizational context, and psychological safety (Choo et al. 2007). Six Sigma benefits can only be sustained by having a mechanism that will address product innovation, the pattern of change in customer base, and environmental uncertainty, while improving organizational processes.

4.1 Six Sigma Benefits

Traditionally, between 1989 and the early 90s, the aspiration of many quality improvement practitioners/proponents was to improve and maintain a process three (3) sigma (Fursule et al. 2012), and which is half-way to what Six Sigma stands to offer in terms of improvement levels. Six Sigma benefits are numerous as counted in both manufacturing and service industries. Organizations benefits from Six Sigma the most when a significant number of its employees are trained in the methodology (Villanova University 2020). The most cited benefit of Six Sigma in the literature is customer satisfaction (Planettogether 2020; Aboelmagd 2010). In the area of manufacturing, Six

Sigma benefits are highlighted in various areas such as the reduction in in-process defect levels, reduction of customer's complaint, reduction of the production lead time, improving process capabilities, reduction in the cost of poor quality (COPQ), reduction in unplanned maintenance hours, etc. The other benefits derived by service organizations for successful Six Sigma include reduction in documentary defects, timely and accurate claim reimbursement, improved report accuracy, reduced defect rate in service processes (Kwak & Anbari 2004; Bhanushali 2019). Tahiri (2017) opined that Six Sigma methodology was designed to help organizations reduce waste, improve time management, increase customer loyalty, boost employees' motivation, and minimize the cost of production. In academics, the three main contributions of Six Sigma to academic according to Brady and Allen (2006) are aligned to increased emphasis on complete case studies, the development of a large market of industrial non-experts that are interested in practically oriented research, and lastly, its approaches are core-specific with a well-formalized structure.

4.2 Confrontational Concerns on Six Sigma Improvement Strategies

There is a need to better understand organizational and contextual variables that facilitate or impede the effective implementation of Six Sigma. There is little theoretical support on the effectiveness of Six Sigma projects on organizational achievements, and the existing literature seems to suggest that Six Sigma may hinder an organization's effort to be innovative. Alsagheer and Mohammed (2011) stated that Six Sigma challenges are multidimensional due to many reasons, ranging from a commitment from management, the bottom-up and top-down communication mechanisms, unrealistic expectations, inappropriate resources, inappropriate projects, and problem definitions and failure to sustain the results of Six Sigma projects. Six Sigma adoption requires statistical analytics, but most organizations lack the technical fluency to propagate the strategic idea (Mantec 2018). In aerospace companies as documented by Zimmerman and Weiss (2005), less than 50% of the respondents were satisfied with their Six Sigma programs. Similar survey was made on healthcare companies and the revelation showed that 54% of the surveyed subjects do not intend to embrace Six Sigma programs (Feng & Manuel, 2007).

However, the ability of Six Sigma to achieve both efficiency and innovation has been challenged from different perspectives, and many researchers have argued that the utilization of process management methodologies favors exploitative innovation at the expense of eliminating explorative innovation. With much emphasis on process improvement and variance reduction, Six Sigma would impede product innovation and radical change (Parast, 2011). Many quality management proponents argued that Six Sigma projects focus primarily on understanding and identification of critical characteristics to the existing customers (Dasgupta 2003; Evans and Lindsay 2005), at the expense of threatening the ability of the firm to identify new customers and introduce new products and/ or services. Thirdly, as a spin-off of quality management, Six Sigma maintains a strong emphasis on setting specific goals (Linderman et al. 2003), and according to Pande et al. (2000) setting a clear goal is central to Six Sigma and as such, cannot address the core principles of quality management such as a culture of learning, continuous improvement of processes, and a system view of the organization. There are cases of six sigma project failures in literature, amidst their wide promotion in the practitioner's literature (Fursule et al. 2012). Chandra (2008) attributed poor program implementation and poor utilization of expert knowledge, as the reasons why Six Sigma projects fail. Further study by Gopal (2008) has linked Six Sigma implementation failures because of the poor commitment from organizational management. Zimmerman and Weiss, (2005) linked many Six Sigma improvement program failures to wrongfully identified projects. There is also a growing concern that Six Sigma or other process improvement programs fail because they do not consider the human side of implementation (Fursule, et al. 2012). To achieve the maximum advantages in the form of removed defects, continuous improvement, and sustainability, Six Sigma needs to be integrated with other strategic frameworks like knowledge management (KM) that are targeted at achieving corporate sustainability (U-Dominic et al. 2018).

4.3 Future of Six Sigma

Quality Improvement in manufacturing processes can be achieved using several methods such as statistical process control, inspection, zero defects, total quality control, lean Six Sigma, kaizen, and others. This study focused on the review of Six Sigma and the way forward. To make effective and precise decisions based on quality and process improvement in a company or organization, sufficient data is required. These datasets are analyzed and results obtained can be used to forecast and predict the next step require to take accurate decisions. In literature, most research conducted focused on classical data analysis techniques; conversely, with the emergence of industry 4.0 technologies, it is possible to generate and analyze massive data obtained from organizations. It is equally recommended to look in the direction of the advanced technologies or fourth industrial revolution technologies since they are very appropriate for big data. A good example is big data analytics. It is equally important to think of

possible ways of hybridizing or merging different techniques. In literature, hybrid techniques offer much more robust solution in terms of making effective decisions during optimization and quality check (Machesa et al. 2020; Okwu and Tartibu 2020). In terms of hybridization of philosophical techniques, Dogan and Gurcan (2018), believe that the consolidation of lean and Six Sigma in manufacturing produces the lean Six Sigma approach which is capable of reducing waste and variations in systems as well as making powerful decisions. Roughly 95% of lean Six Sigma task and developments has led to quality improvement, this is a good example of hybrid philosophy.

5. Conclusion

This study focused on the review of the Six Sigma philosophy. This quality management philosophy is very important in terms of quality and process performance in systems. Existing literature focused on Six Sigma has been observed and the future of the Six Sigma approach in manufacturing was detailed. This research is focused on the appraisal of Six-Sigma and recommendation of the fourth industrial revolution for process improvement, assertiveness and offer foreseeable decisions in every phase of the Six sigma technique. Other aspects covered in this review include Six Sigma developments, metrics and capabilities, Six Sigma and quality management approaches; Six Sigma integration and innovation; Six Sigma and organizational sustenance and benefits of Six Sigma philosophies; confrontational concerns on Six Sigma Improvement Strategies and the future of Six Sigma. Future research directions focused on the Six Sigma philosophy and innovative technologies to support the technique have been highlighted with effective recommendations.

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