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Achieving Excellence in SMEs: A Deep Dive into Six Sigma Methodologies for Process Improvement

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Abstract

The present study examines the relationship between Small and Medium Sized Enterprises (SMEs) and Six Sigma methodology, recognizing the importance of SMEs in global economies. It is difficult for SMEs to seamlessly implement new processes due to a lack of resources. Developed in the manufacturing sector, Six Sigma emerges as a systematic approach to defect minimization. It is, however, critical to navigate the challenges SMEs face strategically in order to integrate successfully. Using an extensive literature review from 2012 to 2023, this paper examines the challenges and opportunities of implementing Six Sigma in SMEs. Using existing research, the paper synthesizes frameworks, models, and best practices for implementing Six Sigma in SMEs. A comprehensive resource will be established for Six Sigma implementation in SMEs, addressing the literature gap specific to SME contexts. Using systematic literature reviews, the paper answers key research questions and identifies Six Sigma implementation models and frameworks. A discussion of the strengths and weaknesses of recent models is presented in the results and discussion section. To conclude, the paper emphasizes the importance of inclusive models for SME growth and encourages future research to expand its scope.

Keywords
Small and Medium-Sized Enterprises, SMEs, Six Sigma

1. Introduction

Today, SMEs and the Six Sigma methodology are increasingly intertwined in business landscapes. A small and medium-sized enterprise (SMEs) is an integral part of the global economy, contributing significantly to job creation and economic growth (Lande, Seth, & Shrivastava, 2022; Soltani Nejad Roodabadi & Bhandari , 2023-1-a) based on factors such as manpower strength, capital investment, and turnover. Soltani Nejad Roodabadi & Bhandari, 2023-1-b, argue that SMEs face unique challenges, including limited financial and human resources, making it difficult for them to introduce new processes and technologies. In order to remain competitive in the global market, SMEs must continually seek innovative approaches to enhance their operational efficiency and enhance their competitiveness (Soltani Nejad Roodabadi & Bhandari, 2023-2).

The Six Sigma methodology emerges as a beacon for organizations in modern business, providing a systematic approach for minimizing defects and variances in products and processes (Sodhi, Singh, & Singh, 2020-a). This method, which originated in the 1980s in the manufacturing industry, now emphasizes statistical methods, data analysis techniques, and a structured improvement procedure (Ibikunle, Rajemi, & Zahari, 2023-5). Applied by industry giants like Motorola and General Electric, this methodology has contributed significantly to operational excellence, resulting in a significant reduction in variability and errors (Sodhi, Singh, & Singh, 2020-b). The five general steps of Six Sigma are illustrated in Figure 1.

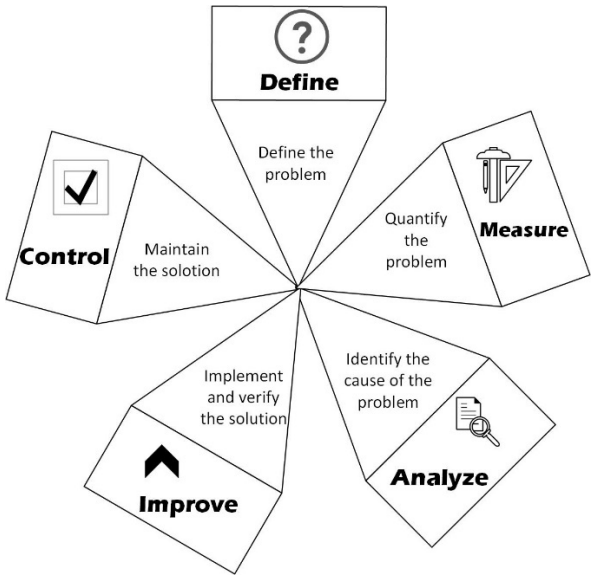

Figure 2. DMAIC process

In order to have Six Sigma successfully integrated into an organization, particularly within SME processes, thorough consideration and systematic thinking are required (Ibikunle, Rajemi, & Zahari, 2023-b).

Due to the distinctive characteristics of SMEs, implementing Six Sigma presents a unique set of challenges. Small and medium-sized enterprises are limited in terms of financial and human resources (Soltani Nejad Roodabadi & Bhandari, 2023-2-c). They often lack capital, technology, and skilled personnel, compared to their larger counterparts. As a result of financial limitations, SMEs cannot allocate enough funds for extensive training and infrastructure required for successful Six Sigma implementations (Moya et al., 2019-a). In addition, SMEs' leaders may be hesitant to invest in new processes and technologies for fear of disrupting existing operations (Soltani Nejad Roodabadi & Bhandari, 2023-2-d). Within SMEs, where adaptability is key for survival but can be hindered by the fear of change, the cultural shift needed to embrace Six Sigma practices may encounter resistance. It is also possible for SMEs to have difficulty mobilizing the resources necessary for implementing Six Sigma strategies, because these methodologies have traditionally been implemented by larger organizations with more substantial resources(Moya et al., 2019-b). As a result, while Six Sigma holds great promise for process improvement and enhancing efficiency, SMEs must navigate multifaceted challenges strategically to implement it successfully.

Due to the increasing complexity of the global market, the intersection of SMEs and Six Sigma is becoming a focal point for sustainable performance and competitive advantage. A key objective of this study is to explore the challenges and opportunities associated with implementing Six Sigma methodologies in small and medium-sized companies. By using Six Sigma to enhance their processes and contribute meaningfully to sustainable development goals, it sheds light on the transformational journey these enterprises undertake. A comprehensive analysis of Six Sigma integration in SMEs and its economic, environmental, and social implications is presented in this paper.

1.1 Objectives

SMEs can use this research paper as a valuable resource for implementing Six Sigma methodologies effectively. SMEs face unique challenges, strategies, and outcomes in integrating Six Sigma, and this endeavor explores them

comprehensively. In the past two decades, considerable attention has been paid to the presentation of Six Sigma implementation frameworks for large organizations. However, there is still a notable gap in addressing Six Sigma implementation in SMEs and evaluating its success or failure in this unique operating environment. To close this gap, this paper examines the challenges and opportunities associated with Six Sigma adoption in SMEs. Consequently, the research contributes to the existing body of knowledge and provides SMEs with a practical and comprehensive guide to Six Sigma application.

2. Literature Review

A comprehensive literature review is undertaken in this paper in order to explore the frameworks guiding Six Sigma implementation in SMEs. Initially, the study focused on articles published from 2017 onwards in order to capture the most recent and relevant research in this area. Nonetheless, due to a limited supply of research papers during this period, articles dating back to 2012 were included. The inclusion criteria further refined the search by considering only peer-reviewed papers to ensure scientific credibility.

To establish a robust knowledge foundation for Six Sigma implementation in SMEs, scholarly articles were rigorously examined, filtering out non-peer-reviewed papers. SMEs' dynamic landscape was introduced with a concise elaboration of the Six Sigma concept and its application within the dynamic landscape. Afterwards, a nuanced analysis of literature was conducted which addressed models for implementing Six Sigma practices in small and medium-sized businesses.

Researchers utilized Google Scholar and MavScholar, the library repository of Minnesota State University, Mankato, to gather a variety of insights. To formulate pertinent research questions and draw meaningful conclusions, a structured literature search involved rigorous scrutiny of papers. The purpose of this literature review is to synthesize and critically examine existing knowledge to identify key themes, as well as to provide a comprehensive understanding of the frameworks, models, and best practices that have evolved to guide effective integration of Six Sigma methodologies within the distinctive context of SMEs.

3. Methods

The purpose of this study is to review the existing literature on Six Sigma implementation in SMEs as well as its impact on their strategic and operational goals. Following are the research questions that guide the study:
RQ1: In SMEs, what models and frameworks have been used to implement Six Sigma?
RQ2: In terms of Six Sigma implementation in SMEs, what are the most studied industries?
A systematic review approach was adopted to address these questions, which included a search, selection, and synthesis of relevant studies on Six Sigma implementation in SMEs. Searches for relevant studies are conducted within academic databases such as MavScholar and Google Scholar.
Inclusion criteria for this review are studies that provide theoretical frameworks and models for Six Sigma implementation in SMEs, as well as studies that focus on Six Sigma implementation in real SMEs. Through the articulation of these criteria, the review ensures a nuanced and focused examination of the literature related to Six Sigma implementation within SMEs.
A thorough examination of the literature review data was conducted, with the aim of identifying key themes, models, and frameworks pertaining to the implementation of Six Sigma within SMEs.

4. Results and Discussion

Results and Discussion describe recent models for implementing Six Sigma in SMEs. Literature reviews are based on both empirical and theoretical studies. There have been selected a variety of models that are representative of the different approaches to implementing Six Sigma in SMEs and have been extensively cited in the literature. SMEs looking to implement Six Sigma and measure its success should consider the strengths and weaknesses of each approach. Through the combination of these models and approaches, this section will provide SMEs with a comprehensive understanding of how to implement Six Sigma successfully.

4.1. Model 1: DMAIC-Based Service-Level Improvement in a Gaming Peripherals SME

A case study conducted in a gaming peripherals Small and Medium-Sized Enterprise (SME) located in Lima, Peru, constitutes the first model presented by Daza-Moran et al. (2022). In this model, traditional engineering tools are integrated into the widely used DMAIC framework to enhance service-level performance. The study utilized Ishikawa diagrams, Pareto charts, and statistical process controls to validate the results over a two-month pilot program. By

using statistical control planning, the investigation reveals that SMEs can manage delays in order processing, despite financial limitations. A lean warehousing model based on the DMAIC methodology, statistical process controls, Failure Modes and Effects Analysis (FMEA), and 5S, line balancing, and Poka Yoke is proposed.
Each phase of the DMAIC methodology contributes to achieving a specific objective. The Define phase identifies critical elements of the process and selects metrics for improving it, such as service-level performance.

In the Measure phase, vital process data are collected, such as takt time, order cycle time, and compliance with 5S. By using tools such as C&E diagrams and non-normal data analysis, the Analyze phase identifies waste and waste. Poka Yoke and the 5S methodology are used in the Improvement phase to minimize waste. Finally, the Control phase involves designing and documenting control plans to monitor critical metric performance.

A Six Sigma implementation in a gaming peripherals SMEs demonstrated satisfactory results and provided a cost-effective solution, especially for SMEs with limited financial resources. In addition to demonstrating the application of statistical and engineering tools in small organizations, the proposed DMAIC framework demonstrates the competitive advantages derived from the use of continuous improvement techniques. Despite this, the study acknowledges limitations, especially in assessing space utilization due to the lack of warehouse racking systems. As a result of this limitation, a just-in-time model for more accurate demand projections and inventory management may be possible through the implementation of Kanban cards. Figure 2 illustrates how this model works.

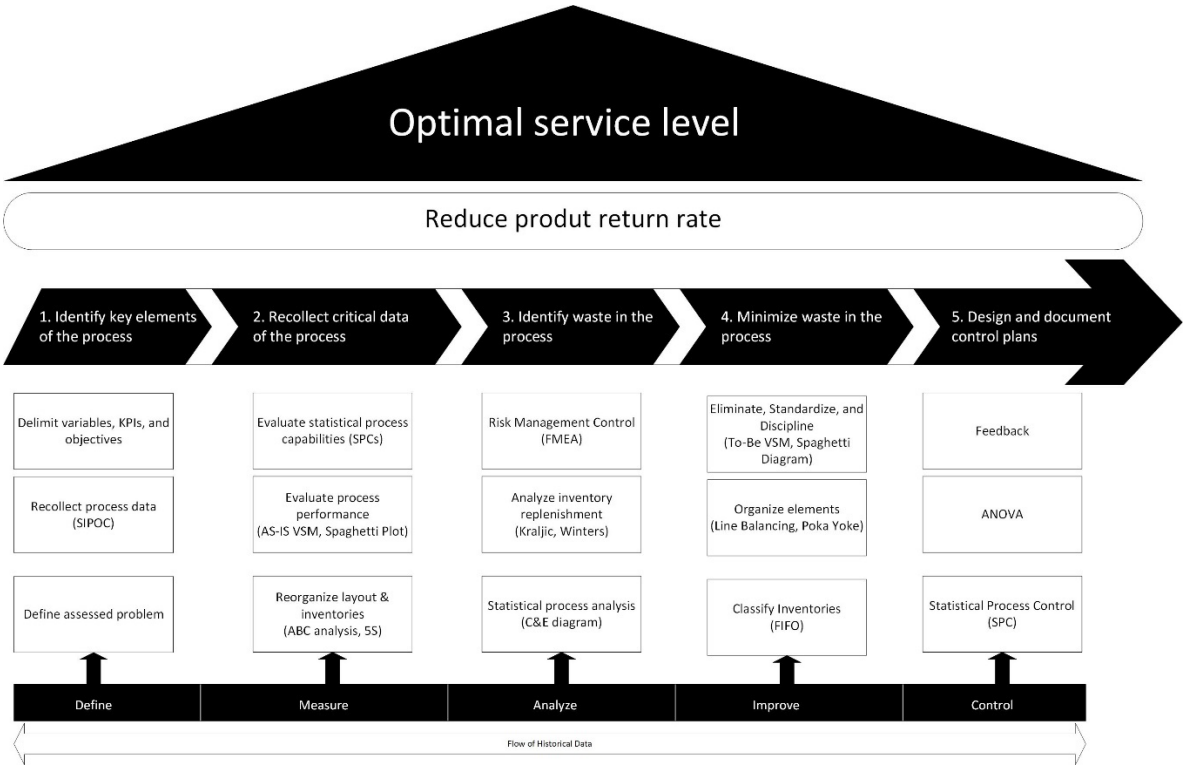

Figure 3. DMAIC-Based Service-Level Improvement model in a Gaming Peripherals SME

Figure 2 offers valuable insights into integrating traditional engineering tools and statistical methodologies within the DMAIC framework, offering SMEs a comprehensive approach to enhancing their service-level performance. This study offers a roadmap for organizations looking to improve operational efficiency and service-level outcomes by applying DMAIC phases, statistical controls, and lean warehousing techniques to effective Six Sigma implementation in SMEs.

4.2. Model 2: Integrating DMAIC and PDCA for Six Sigma Implementation in Clothing SMEs

Abbes et al. (2018) propose a comprehensive approach to implementing Six Sigma in clothing SMEs. With its simple yet effective structure, the model facilitates the application of Six Sigma methodologies. This process improvement

framework integrates Six Sigma initiatives into the DMAIC (Define, Measure, Analyze, Improve, and Control) approach.

Due to its well-established framework for continuous learning and knowledge creation within the realm of quality management, the PDCA cycle is used as the basis of this model. The PDCA cycle is aligned with the stages in Six Sigma projects in this PDCA-applied-to-DMAIC model, enhancing the rigor of the project lifecycle (PLC) in the implementation and closure of Six Sigma initiatives. Figure 3 illustrates how the PDCA framework is applied to each DMAIC step, emphasizing continuous learning and knowledge creation throughout (Figure 3).

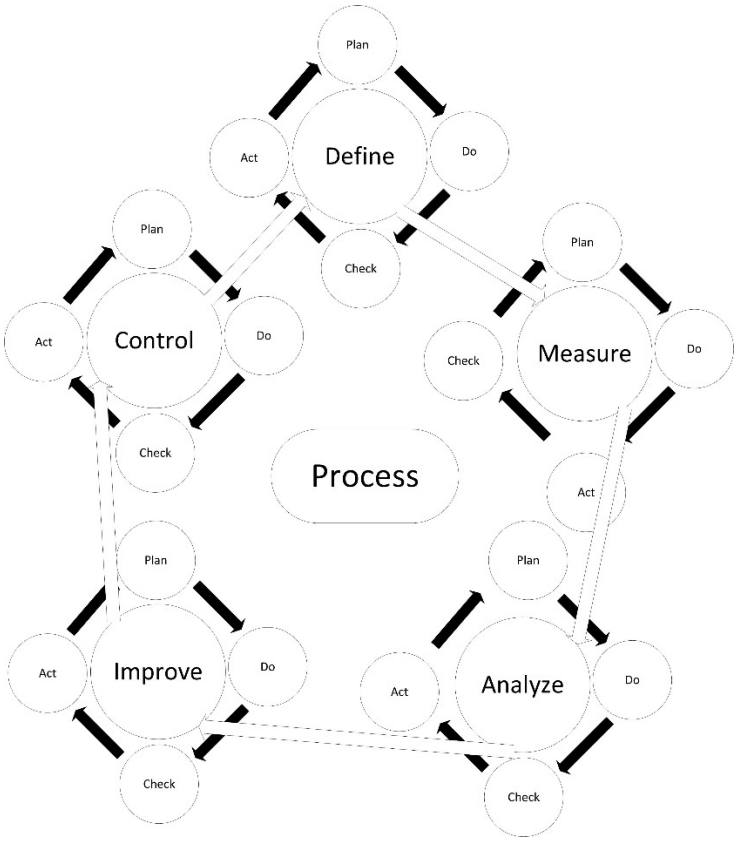

Figure 4. PDCA – DMAIC Framework

This model is like Model 1 but focuses on clothing SMEs. PDCA and DMAIC are integrated to identify measurement defects in a specific unit and enhance its indexing capability. In a systematic analysis of results, the parameters responsible for defects are identified, and optimal combinations are determined. In order to demonstrate the model's efficacy in improving process capability, the optimal combination set is then applied to improve sigma from 0.7 to 2. By combining the Six Sigma approach with continuous improvement and learning, this integrated model provides a robust framework for clothing SMEs to implement Six Sigma. With DMAIC and PDCA, Six Sigma initiatives are aligned with a well-established quality management cycle, providing a comprehensive approach to process improvement. Improvements in sigma levels demonstrate the practical utility of this integrated model in addressing measurement defects and improving the performance of clothing SMEs.

4.3. Model 3: Six Sigma and MR&Z Integrated Implementation for Industry 4.0 Ventures in Textile SMEs

Caballero-Morales et al.'s work addresses the limited use of Six Sigma in the textile industry and contributes to this field through a critical analysis of Six Sigma ideas and principles. Within the manufacturing sector, this model focuses on the textile industry, which contributes significantly to global pollution. For continuous improvement and innovation projects in manufacturing and business enterprises, the model introduces an implementation guideline that combines Six Sigma with the Mixed Model of Rothwell and Zegveld (MR&Z).

This integration is based on the MR&Z model, which supports non-sequential steps with continuous feedback. Innovation, according to MR&Z, involves understanding the market's current state and technological needs through research, aligned with the company's resources and vision. Figure 4 shows the process of MR&Z model as an innovation driven model for Industry 4.0 ventures (Figure 4).

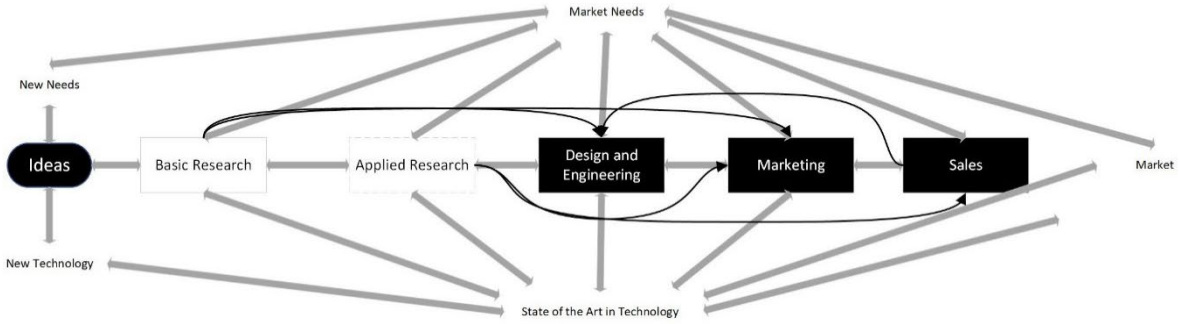

Figure 5. Mixed Model of Rothwell & Zegveld

As a reference for Six Sigma projects in manufacturing systems, the guideline model integrates the MR&Z innovation model with the Six Sigma continuous improvement model, specifically using the DMAIC methodology (Define, Measure, Analyze, Improve, and Control).

Due to its established reputation in SME lean manufacturing projects for continuous improvement, Six Sigma DMAIC methodology is considered as it supports SMEs for Industry 4.0 (I4.0) ventures. A key component of I4.0 initiatives is the integration of the MR&Z model to identify appropriate relationships between SME departments and activities. By implementing the DMAIC methodology along with the MR&Z model, Six Sigma is reinforced as a key component of the I4.0 initiative. Despite the focus on textile SMEs, the methodology can be applied to other SMEs as well because it is based on DMAIC, a well-established methodology for continuous improvement. SMEs venturing into I4.0 will benefit from the comprehensive approach provided by each step in the model, which offers key recommendations and tools for analysis and prototyping. A case study illustrates the model's applicability in the textile manufacturing sector and beyond, emphasizing its potential for innovation and continuous improvement.

4.4. Model 4: Application of Six Sigma DMAIC Methodology in Automotive Manufacturing SMEs

In Kaushik and Kumar (2017), a comprehensive review of the application of Six Sigma in SMEs is conducted, focusing specifically on the automotive industry. DMAIC methodology is used to address and reduce defects in a small seat slider lock nut manufacturing unit in order to alleviate play issues in K2 seat slider locks within automobile units.

This model is tailored for automotive manufacturing SMEs using the traditional Six Sigma DMAIC methodology. As part of the initial stage, the project must be registered, indicating formal approval from management to begin the project and ensuring key stakeholders' support and involvement. To investigate the cause of a high rejection rate in the play issue of seat slider lock nuts, the DMAIC methodology is systematically applied.

Define: An outline of the project title, problem statement, mission statement, team composition, and milestones is outlined in the this Phase. It is necessary to completely rework the seat slider locks before assembly in order to eliminate the play issue.

Measure Phase: the Measurement System Analysis (MSA), including Gauge Repeatability and Reproducibility (Gauge R&R), is conducted to ensure statistical soundness when measuring lock nut dimensions. R&R studies on gauges demonstrate that the measurement system is functioning correctly.

Analysis Phase: An analysis of the process capacity is conducted in this phase to determine the current state of the process. Fishbone diagrams are used in the study to identify the root causes of rejection, and a Two Sample-T Test is used to examine the impact of factors such as operator skill on rejection.
Improve Phase: Countermeasures are developed based on the analysis, addressing key rejection factors. To reduce play in seat sliders and improve productivity, modifications are made to the lock blank.

Control Phase: In order to monitor the process and ensure sustainable improvements, an X bar/R Control Chart is drawn after implementing the changes. After implementing Six Sigma, the play issue in seat sliders was significantly reduced, validating the effectiveness of the intervention.

As a result of the study, Six Sigma is applied in manufacturing units, specifically to control play in seat slider lock nut mechanisms. There has been a reduction in wastage and an increase in product quality, as evidenced by an increase in sigma from 1.59σ to 5.53σ. The success of this project demonstrates the potential for profitability in automotive manufacturing SMEs through the implementation of Six Sigma methodologies.

4.5. Model 5: Hybrid Flexible Approach for Six Sigma Implementation in Constructional SMEs

A study by Paslawski (2013) explores the possibility of implementing Six Sigma in small and medium enterprises (SMEs). The paper proposes a hybrid flexible approach that combines robustness, adaptability, simplification, and modification of organizational culture to address the unique challenges faced by the construction sector, which is characterized by a high level of risk, limited automation, and hierarchical culture. Figure 5 illustrates the process and typical activities for elimination of special causes when dealing with chance variations in construction projects (Figure 5).

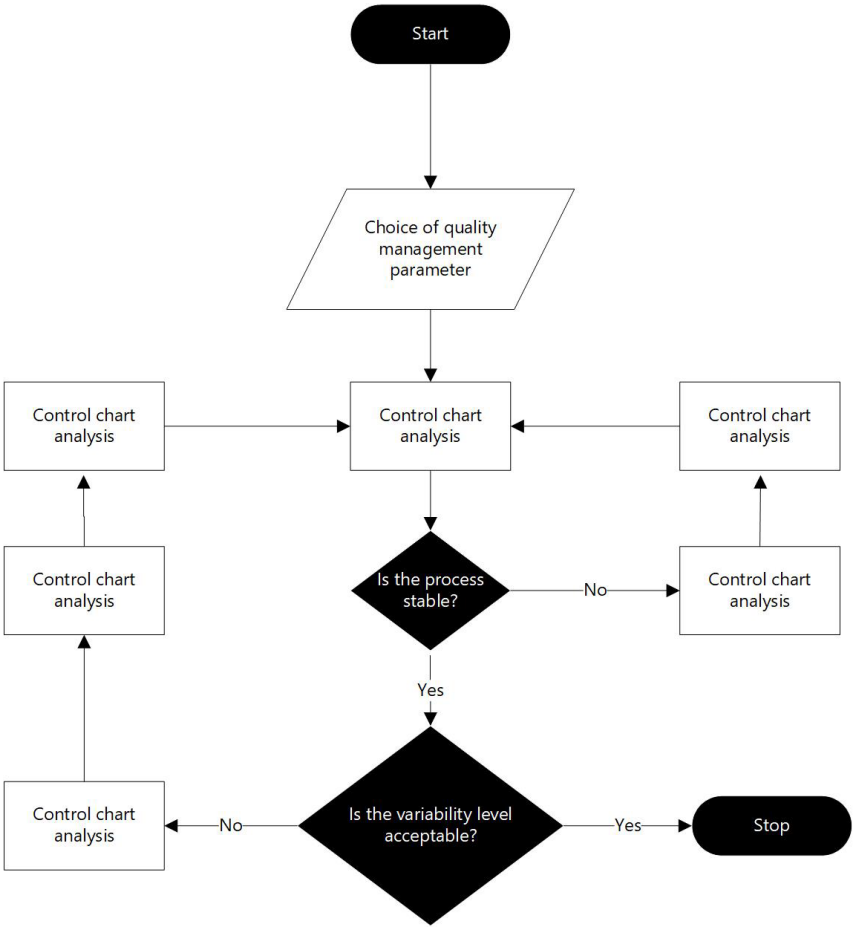

Figure 6. Typical activities for elimination of special causes of variations

Hybrid flexible approaches consist of four elements:
Robustness: In spite of changes in the environment, robustness ensures that desired results are achieved. A resilient Six Sigma framework is intended for SMEs in the construction industry, where factors like limited automation and a dynamic environment influence operations.

Adaption: The Six Sigma methodology can be adapted to meet the specific needs of SME's. The flexibility of Six Sigma is ensured by this element, which recognizes the unique challenges and requirements of the construction industry.

Simplification: Enhances the accessibility and ease of implementation of Six Sigma in SMEs by simplifying the methodology. Construction SMEs typically have fragmented activities and low-cost preferences, which makes simplification essential for successful implementation.

Modification of Organizational Culture: Establishes a culture conducive to Six Sigma implementation. Often, construction industries have hierarchical cultures, which underscores the need for cultural adaptations to foster a Six Sigma environment.

A construction SME implements a hybrid flexible approach, demonstrating its effectiveness in improving quality and performance. Based on the findings, the approach is viable, adaptable to SME needs, can be implemented with limited resources, and has the potential to significantly improve performance and quality.

This paper concludes by asserting that SMEs seeking to enhance the quality and performance of their construction projects will benefit greatly from a hybrid flexible approach. It recognizes and addresses the unique challenges posed by the construction industry by nuanced and tailored applications of Six Sigma principles.

5. Conclusion

SME's pivotal role in the economy underscores the importance of effective Six Sigma implementation for their sustained growth. SMEs can benefit from Six Sigma implementation models presented in this research and its potential advantages have been highlighted. As a concise synthesis of different Six Sigma models for SMEs discussed in this paper, Table 1 provides a structured overview. Readers will find it useful as a quick reference, demonstrating how Six Sigma can be adapted and applied in diverse industries and operational contexts to foster continuous improvement (Table 1).

Table 1. Overview of Six Sigma Models for SMEs.

Model	Description
Model1: DMAIC-Based Service-Level Improvement in a Gaming Peripherals SME	An analysis of a gaming peripherals SME in Lima, Peru, using traditional engineering tools to enhance service-level performance through the application of the DMAIC framework. The DMAIC methodology emphasizes critical elements, vital process data, waste identification, and improvement through the phases of Define, Measure, Analyze, Improve, and Control. In this study, lean warehousing techniques and statistical controls are highlighted as potential cost-effective solutions for SMEs.
Model2: Integrating DMAIC and PDCA for Six Sigma Implementation in Clothing SMEs	Using DMAIC and PDCA, Abbes et al. (2018) propose a model to implement Six Sigma in clothing SMEs. DMAIC steps follow the PDCA cycle, which is known for its continuous learning in quality management. The model identifies measurement defects in clothing SMEs and improves indexing capabilities. It improves sigma levels by strengthening the rigor of the project lifecycle.
Model3: Six Sigma and MR&Z Integrated Implementation for Industry 4.0 Ventures in Textile SMEs	Caballero-Morales et al.'s model for Industry 4.0 ventures in textile SMEs combines Six Sigma and the MR&Z model. This model emphasizes understanding market needs, integrating DMAIC methodology, and providing recommendations for Industry 4.0 pilot projects. As a roadmap for SMEs, the integrated approach supports innovation and continuous improvement in manufacturing systems.
Model 4: Application of Six Sigma DMAIC Methodology in Automotive Manufacturing SMEs	Kumar and Kaushik (2017) apply the traditional Six Sigma DMAIC methodology to a small automotive seat slider lock nut manufacturing unit. Using DMAIC phases such as Define, Measure, Analyze, Improve, and Control, the model addresses defects. In this study, sigma levels were significantly improved, wastage was reduced, and product quality was enhanced.
Model 5: Hybrid Flexible Approach for Six Sigma Implementation in Constructional SMEs	In Paslawski (2013), a hybrid flexible approach to Six Sigma implementation is proposed for constructional SMEs. This approach combines robustness, adaptability, simplification, and culture modification. In demonstrating improvements in quality and performance, it addresses the unique challenges of the construction sector.

However, the majority of studies have focused on manufacturing SMEs rather than non-manufacturing SMEs in order to develop standardized Six Sigma models. Future research endeavors should prioritize developing inclusive models that account for the diverse industries within SMEs to assess Six Sigma's impact on SMEs comprehensively.

There have been several case studies conducted globally, but the focus has been disproportionately on developing countries. Future research should therefore broaden its scope by gathering data and conducting case studies on

companies in developed countries. A noteworthy concern is the lack of research devoted to Six Sigma in SMEs in the United States, despite SMEs accounting for 99 percent of the country's manufacturing sector. There is a dearth of studies that address the specific challenges faced by SMEs in the United States. Therefore, more research is needed in this area to provide practical insights that facilitate Six Sigma implementation in SMEs.

This study underscores the untapped potential of Six Sigma methodologies for SMEs, emphasizing the need for tailored approaches and extensive research to facilitate their successful integration and address the unique challenges faced by these enterprises. Unlocking the full benefits of Six Sigma can be a transformative step towards enhancing SME operational efficiency and overall competitiveness, as they continue to drive economic growth.

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