

TQM IMPLEMENTATION FOR ENHANCEMENT OF PRODUCT AND SERVICE QUALITY: A REVIEW ON DEVELOPMENTS AND LATEST TRENDS

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Abstract:

Total quality management (TQM) is one of the primary techniques of industrial engineering being applied worldwide. This paper presents a review of important case studies conducted mainly in the last five years on the implementation of TQM for various purposes related to the management of quality in different industrial and service scenarios. It first introduces TQM and discusses its vital aspects, followed by an analysis of selected past work. It ends with a conclusion and future research directions. The paper highlights key points of TQM implementation in various industrial and service sectors, and the latest trends, such as TQM integration with sustainability and Industry 4.0, are covered. The article not only aims to fill the gap where there is a scarcity of a recent review article analyzing and highlighting the developments and latest trends in TQM implementation for product and service quality enhancement but also to encourage the researchers, scholars, and engineers to conduct research and development in this domain to establish the field further.

Keywords: total quality management; quality circle; PDCA; continuous improvement; industry 4.0; SDG.

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1. Introduction

The term *Total Quality Management (TQM)* refers to a set of fundamental ideas that are necessary to guarantee high-quality goods and services (Ross, 1999; Mukherjee, 2019). TQM, a management philosophy that dates back to the middle of the 20th century, aims to integrate a quality consciousness into every aspect of corporate operations. TQM has undergone significant changes over time to stay relevant in a rapidly evolving world. Following World War II, Japan advanced TQM philosophy and then American quality expert Edwards Deming assisted the Japanese in using TQM concepts. They aimed to comprehend the aspirations and requirements of their clients by concentrating on their expectations. Due to globalization, customers now have access to a wide range of business solutions that are willing to meet their needs. This has put more pressure on various companies to maintain high standards irrespective of their clients' requirements. Maintaining the quality of the product and service is one of the objectives of any organization whether industry or service sector. The concept of TQM has emerged gradually from using typical traditional management theories and practices to the interventions of novel Industry 4.0 technologies (Permana et al., 2021; Ali, 2024). Specialized approaches are being adopted in total quality management these days like integration of its different tools, TQM hybridization and transfusion with other industrial engineering techniques like total productive maintenance (TPM), lean engineering, six-sigma etc. (Babatunde, 2021).

The implementation of TQM philosophy is considered essential for all industries, large and small, to ensure continuous improvement. However, there are obstacles to TQM adoption, such as the requirement for a cultural shift towards continuous improvement, a lack of commitment from management, and insufficient training and delayed response to real-time issues. Essential drivers for the successful implementation of TQM include effective leadership, clear communication, performance assessment, specialized training and awareness, and strong employee involvement, morale, and commitment (Singh et al., 2018).

TQM is essential for improving organizational performance since it helps to minimize defects and failure, reduce rejections, minimize waste. This resulting in reduced costs, boosted productivity, and increased customer satisfaction and loyalty (Singh et al., 2018; De Souza et al., 2022). *Ishikawa* or *cause-and-effect diagram*, *pareto charts*, *PDCA*, *quality circles*, *5Why analysis*, *histograms*, *control charts* etc. are some of the most extensively utilized TQM tools.

In addition to these TQM tools, the deployment of digital tools and platforms has sped up the reaction to quality issues and allowed for better-informed decision-making. Applying TQM has radically changed with the advent of Industry 4.0 and the *Internet of Things* (IoT). Production processes may now be continuously monitored to make sure that quality requirements are maintained at

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every turn thanks to smart sensors and sophisticated analytics. The proactive aspect of TQM further benefits from the application of Artificial Intelligence (AI) and Machine Learning (ML) to predict quality issues before they arise (Ali, 2024). TQM's primary tenet is still customer satisfaction. Understanding the requirements and expectations of customers has become even more important in light of recent developments. Big data analytics and social media listening tools are being used by organizations to better understand client preferences and adjust their quality control plans. This focus on the needs of the consumer guarantees that goods and services not only live up to but also surpass their expectations. A dynamic and changing approach to quality that is sensitive to the demands of the contemporary corporate environment is reflected in the most current advancements in TQM. Higher levels of quality and competitiveness can be attained by organizations through embracing technological improvements, promoting customer and employee engagement, and aligning with sustainability goals (Singh et al., 2018; Babatunde, 2021). Businesses will need to keep up with these advances as TQM continues to change to preserve their competitive advantage in a global market that is becoming more and more competitive. To attain efficiency and effectiveness, TQM highlights the significance of planning, directing, coordinating, and monitoring all system components, whether in manufacturing, services, education, or facilities management. Through the development of a favorable connection that improves innovation, customer happiness, productivity gains, sustainability, and overall organizational performance, TQM, has a substantial impact on organizational culture. To guarantee consistent quality management procedures and long-lasting gains, TQM deployment also calls for a cultural shift in businesses, with an emphasis on continuous processes

and real-time corrective actions. To achieve complete quality excellence, TQM also emphasizes the value of human resources management that is in line with quality standards.

Customer focus, leadership commitment, people engagement, process approach, continuous improvement, evidence-based decision making, and relationship management are the seven key principles of TQM. Through TQM implementation, businesses can boost customer happiness, increase performance, and obtain a competitive advantage. To satisfy the constantly shifting needs of consumers and industry, it takes a constant path of learning, improvement, and adaptability. Figure 1 provides an overview of TQM philosophy, its implementation, and latest trends. The successful implementation of TQM requires sound preparation, foolproof planning, critical assessment, correct implementation, efficient optimization, and proper evaluation (Permana et al., 2021). TQM implementation starts from securing the commitment of leadership followed by involving and empowering employees, then prioritizing customer needs, and ends at mapping and optimizing the continuous improvement culture.

Lack of resources, inadequate planning and training, poor communication, low employee morale, and leadership issues are some of the barriers to TQM implementation (Mukherjee, 2019), (Ross,1999).

This review article is developed based upon our observations and analysis of the most recent advancements in TQM implementation in industry and service sectors, emphasizing incorporation of novel technology, for enhancement of product and service quality.

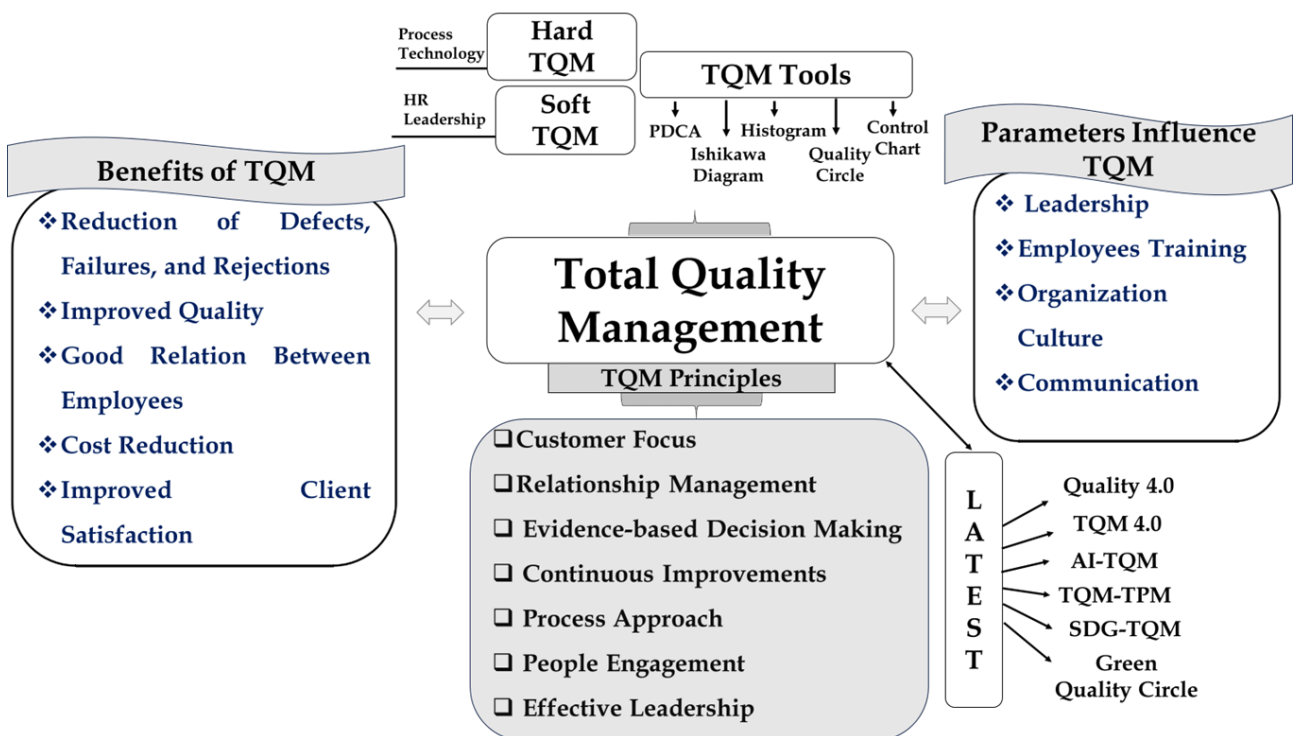


Figure 1: An overview of the modern philosophy of TQM for industrial and service sectors.

2. Related Review Studies and Scope of the Current Review

The integration of TQM with *Industry 4.0* is an expanding field that presents numerous opportunities for enhancing both service and product quality. The literature search reveals that several significant review studies have addressed the implementation of TQM, either focusing exclusively on this topic or highlighting specific perspectives, such as Industry 4.0. An earlier review study explored TQM 4.0; adapting quality management to Industry 4.0 technologies; integrating technology, quality, and people (De Souza et al., (2022)). It presents a model for future research but lacks sector-specific and cultural context analysis. Another review study examined TQM and its link to Industry 4.0, identifying key TQM practices, and proposing “Quality 4.0” dimensions for future research (Ali and Johl, 2022). They reviewed significant studies, identifying key soft dimensions include management commitment and customer focus; hard dimensions include process management and continuous improvement relevant to industry 4.0. Baran and Polat (2022) examined TQM’s role in ensuring quality across all enterprise processes, technologies, and workforce. This study reviews literature on Industry 4.0 and quality, highlighting a gap in research on using these technologies for comprehensive quality monitoring and control. In their review study, Sader et al. (2022) defined Quality 4.0 as an evolution of quality management influenced by Industry 4.0 advancements. It identifies key features—automation, advanced data analysis, and integration—and supporting technologies like Big Data, AI, and connectivity. The study highlights Quality 4.0’s impact on various sectors and discusses challenges, including skill requirements and technology adoption. Liu et al. (2023) categorized the reviewed studies into four themes: Quality 4.0 concept, implementation, management, and models. They outlined key definitions, features, and trends, introducing the quality curve theory and highlighting research gaps and future directions.

While these studies are significant, they generally do not address sustainability aspects and tend to focus either on service quality or product quality. Although previous studies have laid the groundwork by exploring TQM in the context of Industry 4.0, there remains a crucial need to incorporate sustainability into this framework.

This review article aims to bridge this gap by presenting the latest advancements and practices in TQM from the past five years that not only focus on traditional quality dimensions but also align with sustainability principles and Industry 4.0 integration. This holistic approach ensures that TQM implementation in the era of Industry 4.0 is both technologically advanced and environmentally responsible, contributing to the long-term success and resilience of organizations. The paper begins with an introduction to TQM, explores its critical aspects, and then analyzes selected past studies. The review highlights key points of TQM implementation in diverse industrial and service sectors, and addresses emerging trends such as the integration of TQM with Industry 4.0 and alignment with sustainability. The article aims to address the gap in recent literature by analyzing the latest developments and trends in TQM for enhancing product and service quality. It concludes with

a summary and recommendations for future research. Additionally, it seeks to inspire researchers, scholars, and practitioners to further investigate and advance the field of TQM.

3. Review Methodology

The methodology begins with defining the scope and objectives of the review, which focuses on examining recent advancements in TQM implementation over the past five years, with a particular emphasis on the implementation of TQM for enhancement of product and service quality. Furthermore, the scope covers developments in TQM implementation integrated with Industry 4.0 and sustainability principles. Figure 2 illustrates the detailed review methodology used in this study.

To initiate the literature search, a set of well-defined keywords such as “Total Quality Management,” “Quality Circle,” “PDCA,” “Continuous Improvement,” “Industry 4.0,” “Sustainability”, and “SDG” were established. These keywords guided the search process across major academic databases, including Scopus and Google Scholar. The search process involved an initial broad search using individual keywords, which generated a large volume of research papers across various disciplines. To refine the search results and focus on relevant studies, Boolean operators (i.e., AND, OR, NOT) were used to combine keywords effectively. This technique helped to narrow down the results to studies specifically related to TQM implementation within the past five years.

Upon collecting the literature, the abstracts of the papers were reviewed to determine their relevance to the study’s focus. Based on this initial review, the literature was classified into two categories: “Included” and “Excluded.” Papers categorized as “Included” were then subjected to a thorough review of their full texts. This detailed examination allowed for a more refined classification based on the papers’ contributions to the implementation of TQM for enhancement of product and service quality and integration of TQM with Industry 4.0 technologies and alignment with sustainability.

The synthesis of the reviewed literature involved analyzing and framing the findings in relation to the article’s contents. This included identifying key themes, trends, and advancements relevant to TQM and Industry 4.0. A critical evaluation of the literature was conducted to highlight significant findings, compare and contrast different studies, and identify gaps in the current research landscape. The methodology adhered to the principle of the “5 C’s”—citing, comparing, contrasting, critiquing, and connecting various studies—to provide a well-rounded analysis and a comprehensive understanding of the state of current research.

Identifying research gaps and future research directions was a crucial part of the methodology. The review highlighted areas where current research is lacking, such as the need for more comprehensive studies on the integration of TQM with sustainability principles and the use of Industry 4.0 technologies for enhanced

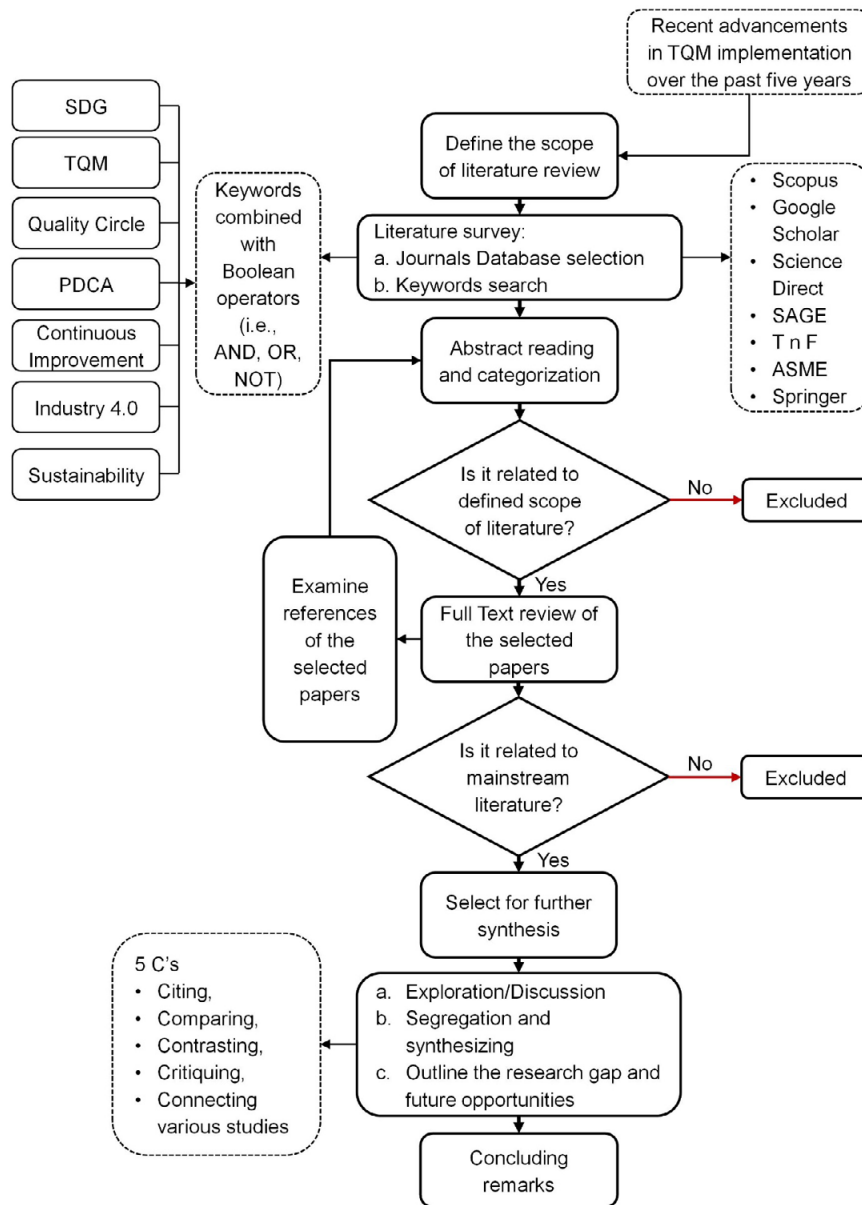


Figure 2: Review methodology adopted in this study.

quality monitoring and control. Based on these identified gaps, the review provided recommendations for future research, aiming to guide scholars and practitioners in advancing the field of TQM.

To ensure a comprehensive and inclusive search, the methodology emphasized the importance of carefully defining search criteria and avoiding the omission of significant literature. The search strategy was designed to be specific enough to yield relevant results while also being broad enough to encompass a wide range of pertinent studies. This approach was critical for covering the selected subject thoroughly and providing a detailed and accurate review of recent advancements in TQM.

In conclusion, the methodology for this review article involves a mixed systematic approach to literature search, evaluation, and synthesis. By focusing on recent advancements and the integration of TQM with Industry

4.0 technologies and sustainability, the methodology aims to provide valuable insights and contribute to the advancement of knowledge in the field. The review not only offers a comprehensive analysis of current developments but also identifies research gaps and proposes directions for future studies, thereby aiming to support ongoing research and practical applications in TQM.

The objectives of the present review can be summarized as follows:

- To collect and review literature focusing on recent advancements in TQM implementation over the past five years, with an emphasis on enhancing product and service quality and exploring emerging trends such as Industry 4.0 and sustainability principles.
- To analyse results to understand how recent ad-

vancements in TQM contribute to improved product and service quality.

- To explore emerging trends and the integration of TQM with Industry 4.0 and sustainability principles.
- To Identify and address research gaps in the current literature, particularly related to TQM implementation and its integration with other techniques.
- To provide a comprehensive synthesis of findings to offer detailed insights into key themes, trends, and advancements in TQM.

4. Review and Analysis

4.1. Analysis and Discussion of Previous Studies on TQM Implementation in Service and Industrial Sectors

4.1.1. Service Sector

Banks, hospitals and health services, educational institutions, hospitality industry etc. are important in the service sector, where TQM implementation has been conducted and studied. TQM is required in such organizations for ease of functioning, higher operation efficiency, quick decision making, and good work culture (Sukdeo et al., 2017; Magd et al., 2021).

For banking sector, it is desirable to have a continuous evaluation of TQM implementation and to integrate it with the digital tools for its success (Mata et al., 2023). TQM has a significant impact on customer satisfaction that can be achieved by enhancing organizational performance and thereby service quality with the commitment of top management and sincere involvement of the bank staff (Topalovic, 2015; Harimurti et al., 2019; Isidore et al., 2023). For banks, fostering innovative behaviors was also emphasized, to maintain sound relationships with the regulators, vendors, and government as well as to face the challenges related with market risks, technological turbulence, and government policies (Ahinful et al., 2024).

TQM in educational institutes is implemented to improve overall educational environment from quality enhancement of teaching, research, and administration to improve stakeholders' experience and engagement continuously (Begum et al., 2020; Yahiaoui et al., 2022). In an interesting study, TQM was implemented to obtain the status of cybersecurity implementation in a university (Alhumud et al., 2023). The outcomes indicated the requirements of immediate future interventions to further train university employees for cybersecurity related risk, mitigation, and compliance. The mission and vision of the institute, employee satisfaction, human resource management, and information management system, have been identified as some of the important enablers for the successful implementation of TQM in educational institutes (Mittal et al., 2020). Knowledge management has also been found impactful for the successful implementation of TQM (Al-Quran et al., 2023). It was recommended to share and exchange knowledge and to train make aware the staff about the policies and programs, so as to make TQM implementation rather

easy. In other words, a systematic integration between knowledge management and TQM is the important key for its successful implementation.

In hospitality industry, the importance of soft TQM practices was highlighted, in which preference was given to the social factors such as internal coordination, customer focus, and desired leadership to attain operational efficiency and customer satisfaction (Thuy, 2023). Unfortunately, still only the chain-affiliated hotels and those run by big groups five-star hotels are the high-level TQM adopters (Al-Ababneh, 2021). Studies found high operational performance and customer satisfaction in the case of TQM implemented hotels (Tudoran, 2019). For hospitality industry, innovation is identified as a major driver for TQM and the most important factor to stay ahead in the global competition (Papaioannou et al., 2024). It basically includes providing innovative recreational facilities, standard comfort arrangements, and quality facilities to the guests or customers.

A TQM case study conducted in a water supply company proposed an effective strategic action plan equipped with training, continuous improvement, and effective communication etc., for enhancement in service quality and achieving customer satisfaction (Da Souza et al., 2024). A recent work highlights the importance of TQM as a very influential factor for cleaning companies (Olayiwola et al., 2024). Employee training, interaction with top management, and effective communication from management, are some important factors that govern the success of TQM implementation in cleaning companies and attract customer satisfaction.

4.1.2. Industrial Sector

TQM was implemented in the knit garment industry for defect identification purposes (Moin et al., 2023). Knitting and labeling related defects were found accountable for rejections and losses. Focus group and Ishikawa diagram were the two main tools used to identify the root causes and their remedies for quality improvement. Another important study on TQM implementation, using benchmarking, collaboration, constant improvement type tools, on sewing line of a garment production company highlights its effectiveness by reporting significant easing defect identification in sewing, reduction in labour time, enhancing garment quality, and reducing production cost (Joy et al., 2024). A study conducted on evaluating the TQM implementation in a weapon manufacturing company indicated that leadership, customer focus, and information analysis are influential for quality enhancement and management (Berhane and Maganti, 2018). In a tractor manufacturing company, significant effects of TQM were studied on failure reduction and quality improvement (Mittal and Gupta, 2021). After using process and product audits, kaizen, quality assurance matrix, 32% field failure reduction and more than 50% reduction in goods and line rejections were noted that led to high profit for the company. In a large-scale manufacturing industry, quality circle was successfully implemented that gave excellent results and boosted the morale of the employees (Kulkarni et al., 2023). Another important case of successful implementation of quality circles was reported in case of an auto parts manufacturing company (Mittal and

Gupta, 2018). In this case study, the quality circle team identified the root cause of the rejection of a part i.e. shaft and corrective measures were adopted that reduced the rejection rates to zero. A successful TQM implementation in an industry which received Deeming award, extended its operations, and faced challenges to meet customer expectations, highlighted lack of leadership as the main factor behind that (Mittal et al., 2023). Brainstorming, cause and effect diagram, why analysis was some of the important tools used in a study on TQM implementation in a casting company to reduce rejections of the products and thereby loss to the company (Fegade et al., 2019). Some important factors such as continuous health monitoring of the instruments & machinery and optimum control & setting of the technical parameters were identified and corrected to reduce the losses and rejections. An interesting case study was conducted with an aim to continuously enhance productivity and improve quality in a manufacturing environment using TQM (Singh et al., 2020). The company was using kerosene oil in large quantities for its operations. It was reported that 100% reduction of oil waste was achieved after TQM implementation in the form of redesigning the equipment, organizing the waste collection system, and modification in the layouts and setups. One of the recent investigations made use of the integration of TQM and 5S for successfully reducing rejection rates and improving continuously in a hand tool industry (Kashyap et al., 2024). Workers were familiarized with the quality management principles and encouraged to adopt such practices. A survey conducted in a spice packaging company indicated that effective participation of the employees, top management commitment, and specialized training etc. are the essential factors to achieve the success of TQM implementation (Bawazir, 2022). PDCA has always been one of the important techniques applied for quality management tasks. In an automotive ancillary industry, PDCA could successfully minimize the scrap rate and manufacturing cost significantly under quality management practices (Rangel-Sánchez et al., 2024). It was the case of a motor manufacturing company where problem identification and cause analysis were done during plan phase, followed by parameter setting and process validation during do and check phases. Obtaining results and standardization were accomplished in the act phase. Scrap rejection rate less than 07% was achieved with a cost saving of more than hundred thousand USD.

4.2. Latest Trends in TQM

Total Quality Management (TQM) programs are increasingly recognized for their potential to enhance environmental performance by streamlining processes to reduce waste and conserve energy (Makhlouf et al., 2023). By adopting TQM, organizations can not only achieve cost savings through waste reduction and energy conservation but also contribute to pollution prevention and the overall reduction of their environmental footprint (Garcia et al., 2019). This holistic approach is essential for businesses aiming to meet the growing demands of consumers and regulatory bodies for more sustainable practices. TQM is indeed a pivotal strategy for various sectors such as service and industry aiming to align with Sustainable Development Goals (SDGs), particularly SDG 7 which focuses on affordable and clean energy. Rajkhowa

et al. (2023) case study explores the synergy between TQM and achieving SDG 7. Their case study outlines a theoretical framework and its practical application within a research and development center. By focusing on continuous improvement and waste reduction, this case study demonstrated how TQM can be leveraged to drive progress towards clean and reliable energy solutions. Goyal et al. (2022) introduced 'Green Quality Circles' to tap into the potential of frontline workers for environmental sustainability in manufacturing. By building on existing quality circle structures and providing necessary support, organizations can achieve triple-bottom-line benefits: improved environmental performance, cost reduction, and enhanced employee satisfaction. The framework, validated in manufacturing, suggests future research on its application in service sectors. An integration of lean six sigma with TQM has also been highlighted as a good strategy to reduce waste and achieve sustainability in higher education institutions (Brits, 2020).

TQM adapts to digital transformation by underpinning the concept of integration of technology, quality, and people, leading to improved organizational performance. It requires a shift from traditional quality control methods to a more dynamic, predictive, and holistic quality assurance system that leverages the capabilities of cyber-physical systems (CPSs), artificial intelligence (AI), and other technological tools (Ali and Johl, 2022; Singh et al., 2022). The concept of TQM 4.0 emerges from this adaptation, bringing the capabilities of Industry 4.0 to enhance efficiency and product quality (De Souza et al., 2022). This systematic approach to quality management in the era of digitalization and automation is essential for organizations seeking to maintain relevance and achieve innovation in the rapidly evolving industrial landscape.

The incorporation of Industry 4.0 technologies with TQM principles can significantly enhance an organization's sustainability performance, as it leads to more efficient resource utilization and digital quality control processes (Rajkhowa et al., 2023). Singh et al. (2022) research showed that an Autonomous Quality Management System (AQMS) built on Quality 4.0 principles significantly improves manufacturing efficiency. By comparing traditional and AQMS, the study found drastic reductions in costs, errors, and production time, leading to higher product quality and overall process improvement. production expenses dropped by 58.26%, while inspection costs fell by 78.35%. Abdeldayem et al. (Abdeldayem et al., 2024) explored the integration of AI into TQM practices within the telecommunications industry. Their research demonstrates how AI can enhance traditional TQM elements like leadership, customer focus, and continuous improvement. By analyzing data from a telecommunication industry employee, the study reveals the positive impact of AI-driven TQM on competitive advantage. This research offers valuable insights for organizations seeking to optimize their quality management processes through AI. Ali et al. (2022) study delved into the intricate relationship between TQM practices and Industry 4.0 readiness in Small and Medium Enterprises (SMEs). It underscores the critical role of both "soft" (leadership, HR) and "hard" (process, technology) TQM components in achieving Industry 4.0 readiness. The study highlights the synergistic relationship between soft and hard TQM components in driving organizational performance and

innovation. By emphasizing the importance of a holistic TQM approach, the research offers valuable insights for SMEs seeking to leverage Industry 4.0 technologies for competitive advantage.

In total, the recent developments showed that TQM can enhance environmental performance by reducing waste and conserving energy, aligning with SDGs like clean energy. Integrating TQM with Industry 4.0 technologies, such as AI and cyber-physical systems, improves sustainability, efficiency, and competitive advantage in various sectors.

Besides that, the transfusion of TQM and TPM, has also been recognized as one of the strategies to enhance the performance of manufacturing industries (Singh and Ahuja, 2020). There is also evidence of lean-TQM integration-based framework proposed to reduce defects and ensure continuous improvement for manufacturing industries (Radhakrishna, 2021). A study conducted to analyze the impact of lean, six-sigma. And TQM integration, in healthcare sector, revealed the prominent role of commitment from top management and healthcare professionals (Kumar et al., 2022).

5. Conclusions and Avenues for Future Work

This article has presented some important past work on methods of TQM implementation and its effectiveness in various cases of industrial and service sectors. TQM has been found indeed effective in both industrial and service sectors from productivity and profitability point of view. Cause and effect diagram, PDCA, pareto charts, why analysis, quality circles have mostly been employed for quality management. The following conclusions can be drawn:

- Effective implementation of TQM requires leadership commitment, quality training, straightforward

mission and vision, employee motivation and involvement.

- TQM implementation in a variety of industries such as automotive, ancillaries, food industry, mechanical parts manufacturing, resulted in reduction of defects, failures, rejections, and losses, that contributed significantly to quality improvement and cost reduction.
- TQM integration with other techniques like TPM, 5S, six-sigma, has also been found effective for quality management.
- Sustainability interventions such as green quality circle and SDG integrated TQM practices will certainly have ecological benefits.
- New trends such as Quality 4.0 and AI based TQM have been found indeed impactful.

Future work requires sincere attempts towards the following:

- TQM integration with techniques such as lean manufacturing, DMAIC, six sigma requires some more future interventions both in service and industrial sectors.
- Developing some virtual tools that can map the implementation effectiveness of TQM in advance, can be an important future research avenue.
- Quality 5.0, Industry 5.0, and Society 5.0 based novel work to increase the effectiveness of TQM needs future actions.
- Making attempts towards TQM based work specifically targeting SDGs.
- Making attempts towards TQM based work.

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