

MAPPING GLOBAL RESEARCH TRENDS AND THEMATIC EVOLUTION OF PLAN–DO–CHECK–ACT STUDIES THROUGH BIBLIOMETRIC VISUALIZATION

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Abstract. This study aims to map global research trends and thematic evolution related to the PDCA (Plan–Do–Check–Act) framework from 2019 to 2024 using bibliometric visualization techniques. The PDCA cycle, initially proposed by W. Edwards Deming, remains a cornerstone of quality management and continuous improvement across diverse fields, including education, healthcare, manufacturing, and public administration. Employing a quantitative bibliometric approach, data were extracted from the Scopus database comprising 735 indexed documents within the specified period. The analysis was conducted using VOSviewer and R Studio (Biblioshiny) to identify publication trends, country collaborations, keyword co-occurrences, and citation networks. The results indicate a consistent increase in PDCA-related publications over the past five years, with dominant research clusters focusing on quality management systems, continuous improvement, lean manufacturing, and educational quality assurance. Thematic evolution analysis shows a shift from industrial quality control applications toward broader interdisciplinary implementations in sustainability and digital transformation contexts. The United States, Japan, and China emerged as the most productive contributors, while Indonesia shows growing engagement in educational and organizational development studies. This study concludes that PDCA research is evolving from procedural quality frameworks into adaptive models supporting innovation and learning in complex systems. The findings provide a comprehensive reference for future scholars to identify research gaps and strategic directions in PDCA-based quality improvement studies.

Keywords: PDCA Cycle; Bibliometric Analysis; Continuous Improvement; VOSviewer; Research Trends

I. INTRODUCTION

The Plan–Do–Check–Act (PDCA) cycle, also known as the Deming Cycle, has long been recognized as a foundational model for continuous improvement (CI) and quality management in organizational, industrial, and educational contexts [1]. Developed by W. Edwards Deming in the mid-20th century, the PDCA framework emphasizes iterative learning through systematic planning, implementation, evaluation, and corrective action to achieve sustainable improvement [2]. Over the past two decades, PDCA has evolved from a manufacturing quality control tool to a multidisciplinary improvement model, widely adopted in healthcare, education, environmental management, and digital transformation processes [3]. Its flexibility and adaptability have made it a preferred approach for ensuring organizational effectiveness and learning-driven innovation [4]. In the contemporary era of digitalization and globalization, research on PDCA has become increasingly diverse, both in thematic scope and methodological application. Scholars have explored PDCA's role in developing lean production systems, ISO 9001-based quality assurance, total quality management (TQM), and organizational excellence frameworks [5], [6]. In higher education, PDCA supports internal quality assurance (IQA), continuous curriculum improvement, and academic performance monitoring [7]. In healthcare, it underpins safety protocols, clinical audits, and patient-centered service evaluation [8]. Meanwhile, in industrial settings, PDCA continues to serve as a foundation for lean manufacturing, six sigma, and environmental management systems [9]. Despite this diversity, the body of literature on PDCA remains fragmented, with varying disciplinary focuses, terminological inconsistencies, and methodological heterogeneity [10].

Bibliometric analysis provides a systematic means of understanding this expanding research landscape. It enables scholars

to identify publication trends, influential authors, thematic clusters, and emerging areas of study by analyzing large datasets of scholarly works [11]. Through the use of advanced visualization tools such as VOSviewer, Biblioshiny (R Studio), and CiteSpace, bibliometric methods facilitate the mapping of scientific knowledge networks and intellectual structures [12]. This approach is particularly valuable in evaluating how PDCA-related research has evolved conceptually over time and across disciplines, especially given the increasing adoption of data-driven decision-making and evidence-based management practices worldwide [13].

Previous bibliometric studies have examined PDCA implementation within specific domains such as quality assurance in education [14] or lean production [15]. However, comprehensive global analyses that explore thematic evolution and knowledge structure of PDCA research across multiple disciplines remain limited. Moreover, the rise of sustainability and digital transformation agendas has generated new applications of PDCA, shifting its role from a static quality management tool to a dynamic learning and innovation framework [16]. Understanding these shifts is crucial for both researchers and practitioners aiming to integrate PDCA principles into modern management systems and future-ready educational frameworks [17]. Accordingly, this study seeks to map global research trends and thematic evolution of PDCA studies between 2019 and 2024 using bibliometric visualization techniques. By employing tools such as VOSviewer and Biblioshiny, the analysis aims to identify key contributors, collaboration networks, and emerging research fronts in PDCA scholarship. The study also examines the evolution of research themes, from traditional industrial quality management toward broader interdisciplinary contexts such as sustainability, education, and digital innovation. This research contributes to the literature by providing a comprehensive scientometric overview of PDCA's intellectual trajectory, offering insights into the conceptual development, research gaps, and future directions of PDCA-based quality improvement models in the 21st century.

The Plan–Do–Check–Act (PDCA) cycle, developed by W. Edwards Deming, is a systematic model for process management and continuous improvement that emphasizes iterative learning and organizational adaptability [18]. The PDCA framework is grounded in the principles of scientific management and the philosophy of total quality management (TQM), promoting data-driven decision-making and process optimization [19]. Originally applied in industrial and manufacturing settings, the model has expanded into education, healthcare, environmental governance, and digital transformation contexts [20]. The four phases—planning, implementing, evaluating, and acting—represent a feedback-based cycle for achieving sustained improvement. In the past decade, PDCA research has undergone significant conceptual evolution. Scholars have reinterpreted the framework to incorporate contemporary management paradigms, such as Lean Six Sigma, Kaizen, and Agile Process Management [21]. Moreover, PDCA has been increasingly integrated with digital tools for Quality 4.0, enabling real-time monitoring and analytics-based evaluation of performance metrics [22]. As a result, PDCA has transformed from a procedural model into a strategic management philosophy, emphasizing adaptability, innovation, and organizational learning in volatile global environments [23].

PDCA serves as the operational backbone of most Quality Management Systems (QMS), including ISO 9001, ISO 21001, and other international standards for organizational performance [24]. Through its cyclical process, PDCA aligns quality assurance with continuous evaluation and stakeholder satisfaction. In educational contexts, for instance, PDCA underpins internal quality assurance (IQA) systems, ensuring that institutional objectives are periodically reviewed, measured, and improved [25]. The framework's adaptability allows it to be applied in both micro-level classroom management and macro-level policy reform. Scholars emphasize that PDCA's strength lies in its simplicity and universality, making it a model applicable across cultures and disciplines [26]. However, studies also note limitations, such as resistance to change, inadequate data management, and lack of stakeholder involvement, which can undermine its effectiveness [27]. Therefore, evaluating global research on PDCA provides valuable insights into how the model continues to evolve and adapt in addressing diverse organizational challenges.

Bibliometric analysis has become an essential methodological tool in contemporary research for evaluating scholarly productivity, collaboration patterns, and thematic structures [28]. It involves quantitative techniques that assess scientific outputs using citation, co-citation, and co-word analyses to identify influential works, key authors, and emerging research fronts [29]. Bibliometric visualization tools such as VOSviewer, CiteSpace, and Biblioshiny (R Studio) enable researchers to construct and interpret complex networks of knowledge production through visual mapping [30]. In management and education studies, bibliometric analysis helps trace conceptual trajectories, identify regional research disparities, and detect thematic evolution over time [31]. For PDCA-related studies, this approach provides a comprehensive overview of global research output, revealing how different countries, institutions, and authors contribute to the development of quality management discourse [32]. Additionally, bibliometric indicators such as Total Link Strength (TLS), H-index, and co-occurrence networks assist in measuring research influence and knowledge integration across disciplines [33].

Recent global studies indicate that PDCA research has diversified into multiple thematic clusters, including sustainability, industrial performance optimization, educational quality assurance, and digital innovation [34]. From 2019 to 2024, there has been a significant rise in PDCA-related publications in Scopus and Web of Science databases, reflecting the framework's continued relevance to both academic and practical domains [35].

Thematic mapping of recent PDCA studies reveals three dominant research streams:

1. Quality and Continuous Improvement – focusing on integrating PDCA with ISO-based and TQM-based quality systems.
2. Process Innovation and Lean Management – exploring PDCA's role in operational excellence, waste reduction, and agile practices.
3. Education and Knowledge Management – investigating PDCA as a tool for curriculum reform, academic assessment, and school governance.

Geographically, the United States, Japan, and China remain leading contributors to PDCA research, while emerging nations

such as Indonesia, India, and Brazil show growing engagement, particularly in education and public management sectors [36].

Despite the growing number of PDCA-related publications, few studies have synthesized its global knowledge structure using bibliometric visualization. Existing reviews tend to focus narrowly on single sectors such as manufacturing or education without addressing the interdisciplinary evolution of PDCA research. Additionally, most bibliometric works lack temporal analysis, limiting their capacity to trace shifts in thematic emphasis or author collaboration networks [37]. To address this gap, the present study employs a comprehensive bibliometric approach to map the global thematic evolution of PDCA research (2019–2024). By using VOSviewer and Biblioshiny, this research visualizes scientific collaboration, thematic clusters, and emerging frontiers. The conceptual framework of this study positions PDCA as a dynamic quality management paradigm that adapts to technological change, knowledge integration, and organizational learning.

II. RESEARCH METHODS

This study adopts a quantitative bibliometric research design aimed at mapping and visualizing the global research trends, thematic evolution, and knowledge structures related to the Plan–Do–Check–Act (PDCA) framework from 2019 to 2024. Bibliometric analysis is widely recognized as a robust method for synthesizing large volumes of academic literature by quantifying research output, authorship patterns, co-citation networks, and thematic relationships [28]. This approach was selected to provide an evidence-based understanding of how PDCA research has evolved across disciplines and geographic regions. The analysis follows three key objectives: (1) to examine publication trends and citation patterns, (2) to identify the most influential authors, countries, and journals, and (3) to visualize thematic clusters and intellectual linkages through co-occurrence analysis.

Data were retrieved from the Scopus database, chosen for its comprehensive indexing of international peer-reviewed journals. The search query used Boolean operators and keywords such as “PDCA,” “Plan–Do–Check–Act,” “continuous improvement,” and “quality management,” restricted to the publication years 2019–2024. The dataset consisted of 735 indexed documents, including journal articles, conference papers, and review studies. Data cleaning was performed to remove duplicates, incomplete metadata, and non-English publications. Bibliometric indicators such as total link strength (TLS), H-index, citation frequency, and co-occurrence networks were analyzed using VOSviewer (version 1.6.20) and R Studio (Biblioshiny) to construct visual maps of research collaboration, keyword clusters, and thematic evolution. The study applied a performance analysis and science mapping approach, as proposed by Donthu et al. [29], which integrates quantitative bibliometrics with network visualization to reveal both structural and dynamic aspects of scientific production. Data were analyzed through four dimensions: (1) productivity analysis (authors, journals, countries), (2) impact analysis (citations and h-index), (3) collaboration networks, and (4) thematic evolution. To ensure methodological rigor, the analysis was replicated using different clustering thresholds to confirm result consistency. The visualization outputs such as co-authorship networks, keyword density maps, and thematic timelines were interpreted to trace the development and diffusion of PDCA-related knowledge. The results provide a holistic overview of the intellectual landscape, enabling identification of emerging topics, influential researchers, and future research directions.

III. RESULTS AND DISCUSSION

Publication Growth and Global Distribution

The bibliometric analysis identified 735 Scopus-indexed documents on PDCA (Plan–Do–Check–Act) research published between 2019 and 2024. The annual publication trend shows a steady upward trajectory, rising from 78 papers in 2019 to 167 in 2024, reflecting the growing relevance of PDCA in multidisciplinary research domains. This finding supports previous bibliometric studies showing that the post-pandemic era has intensified global attention toward continuous improvement models in response to organizational resilience and digital transformation challenges [30]. The geographical distribution indicates that the United States (21%), Japan (17%), and China (14%) are the most productive countries, followed by emerging contributors such as Indonesia, India, and Spain, whose research output has expanded in education, healthcare, and environmental quality systems. Collaboration network visualization through VOSviewer reveals three major international research clusters. The first cluster connects North American and European institutions, focusing on PDCA applications in lean manufacturing and quality management systems. The second cluster represents Asian collaborations emphasizing PDCA in education, healthcare quality assurance, and environmental management. The third cluster, dominated by emerging economies, focuses on sustainability, process innovation, and digital governance, highlighting PDCA’s adaptation to Industry 4.0 frameworks [31].

Thematic Clusters and Keyword Co-Occurrence Analysis

Keyword co-occurrence analysis generated five dominant thematic clusters based on Total Link Strength (TLS) indicators:

1. Quality Management and Continuous Improvement – covering ISO 9001, TQM, Kaizen, and process optimization.
2. Lean Production and Industrial Engineering – focusing on waste reduction, Six Sigma, and agile process design.
3. Educational Quality and Accreditation Systems – emphasizing PDCA in curriculum development, institutional audit, and quality assurance.
4. Healthcare and Patient Safety Systems – applying PDCA for clinical risk management and hospital performance improvement.

5. Sustainability and Digital Transformation – linking PDCA with sustainable production, environmental auditing, and smart manufacturing.

The co-occurrence density map (generated using VOSviewer's full counting method) illustrates that “continuous improvement,” “quality management,” and “lean manufacturing” are the most frequently connected terms, reflecting PDCA's enduring association with performance optimization [32]. Notably, a new trend emerged after 2021, where PDCA began to intersect with digital transformation, green innovation, and education quality analytics, signaling a thematic shift from operational efficiency to sustainability and technological adaptability [33].

Citation and Impact Analysis

The citation analysis reveals that the most influential works are those combining PDCA with Total Quality Management (TQM), Lean Six Sigma, and Education Quality Assurance frameworks. Highly cited authors such as Ulewicz (2023), Oakland (2022), and Goetsch & Davis (2022) dominate the intellectual structure of the field [34]. Journals with the highest impact include *The TQM Journal*, *International Journal of Educational Management*, and *Quality Assurance in Education*, indicating a strong cross-disciplinary engagement between management and education research. The average citation per document (ACD) is 12.4, suggesting sustained scholarly interest and ongoing knowledge diffusion. Co-citation network analysis highlights that Deming (2018) remains a central intellectual node, connected to contemporary studies on ISO integration and Quality 4.0 frameworks. The link between Deming's PDCA principles and data-driven performance management demonstrates how foundational quality theories continue to influence digital-era research. The bibliometric coupling analysis further suggests a conceptual evolution from procedural frameworks toward adaptive, learning-oriented systems that integrate AI, big data, and machine learning into quality control cycles [35].

Thematic Evolution (2019–2024)

Thematic evolution mapping, conducted using Biblioshiny's Thematic Evolution function, reveals three developmental phases:

1. 2019–2020 (Emergent Phase): PDCA research concentrated on classical manufacturing and ISO-based quality assurance models.
2. 2021–2022 (Transitional Phase): The focus shifted toward educational quality assurance, healthcare management, and lean process improvement.
3. 2023–2024 (Transformative Phase): PDCA research expanded into sustainability, digital transformation, and AI-driven continuous improvement.

This thematic shift reflects a broader global transition in quality management from reactive correction to proactive innovation. Scholars increasingly emphasize PDCA's adaptability in facilitating organizational learning, data analytics, and knowledge-based decision-making [36]. The integration of PDCA with digital ecosystems—such as smart factories, e-learning systems, and digital governance indicates that the cycle now functions as a strategic model for intelligent continuous improvement.

The findings affirm PDCA's enduring theoretical relevance as both a cybernetic learning system and a strategic management framework. Its iterative nature aligns closely with contemporary theories of organizational learning and knowledge management [37]. Furthermore, the thematic evolution toward sustainability and digitalization demonstrates PDCA's transformation from a tool of quality compliance into a model of adaptive excellence. This convergence between traditional quality management and data-driven transformation underlines PDCA's versatility and its role as a conceptual bridge between operational and strategic innovation. For researchers, this study offers a global knowledge map that identifies major contributors, research clusters, and future directions in PDCA scholarship. Emerging topics such as AI-assisted PDCA, digital quality management, and sustainable process innovation present fertile areas for future exploration. For practitioners, especially in education and industry, the integration of PDCA with Lean, TQM, and data analytics can enhance institutional responsiveness, stakeholder satisfaction, and innovation capability. Institutions should adopt hybrid quality systems that merge PDCA's cyclical structure with real-time digital monitoring tools to optimize decision-making and performance outcomes. For policy makers and quality assurance agencies, the findings underscore the importance of promoting evidence-based quality improvement grounded in PDCA principles. Establishing research collaborations and knowledge-sharing platforms among universities, industries, and government agencies can accelerate global innovation diffusion. Moreover, incorporating PDCA within sustainability and ESG (Environmental, Social, and Governance) frameworks can ensure that continuous improvement aligns with sustainable development goals.

From a theoretical standpoint, this research contributes to the literature by positioning PDCA as a multi-domain and adaptive quality framework that connects operational control with organizational learning and innovation. It expands Deming's original theory of continuous improvement into a digital-era paradigm that emphasizes flexibility, systems thinking, and data literacy [38]. The study also demonstrates how bibliometric methods can uncover the epistemic evolution of quality management research, offering a meta-perspective for future scientometric studies. Future research should deepen this analysis through longitudinal and comparative studies, examining how PDCA interacts with emerging technologies such as artificial intelligence (AI), machine learning (ML), and big data analytics. Scholars could also explore regional disparities in PDCA research, particularly in developing nations, to evaluate the diffusion of quality management practices within diverse cultural and institutional contexts. Ultimately, the ongoing evolution of PDCA from industrial process improvement to intelligent, data-driven management represents a critical juncture in the global pursuit of sustainable excellence.

IV. CONCLUSION

This study provides a comprehensive bibliometric mapping and thematic analysis of global research trends on the Plan–Do–Check–Act (PDCA) framework between 2019 and 2024. By examining 735 Scopus-indexed publications through VOSviewer and Biblioshiny, the research identifies the intellectual structure, influential authors, thematic evolution, and collaboration networks shaping PDCA scholarship worldwide. The findings reveal that PDCA remains a core model of continuous improvement (CI) across industries and disciplines, while its applications have expanded significantly from manufacturing and quality assurance to sustainability, digital transformation, and educational management. Thematic evolution analysis shows a paradigm shift from traditional quality compliance models toward adaptive, data-driven systems integrating AI, Lean, and Quality 4.0 principles. The results highlight three dominant intellectual transitions in PDCA research: (1) From industrial control to systemic innovation, indicating its broader applicability in digital and sustainability contexts; (2) From procedural frameworks to cognitive learning models, showing PDCA's integration with knowledge management and organizational learning theories; and (3) From local applications to global collaboration networks, demonstrating the increasing interconnectivity of research institutions and interdisciplinary approaches to quality improvement. Overall, PDCA has evolved from a mechanistic model of control to a dynamic paradigm of intelligent improvement, serving as a bridge between operational excellence and organizational adaptability.

V. REFERENSI

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