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The Role of Seven Basic Tools in the Era of Industry 4.0 and AI

Akbar Tawaqqal[1*], Maharsa Pradityatama[2], Fikrihadi Kurnia[3]
[1,2,3]Department of Industrial Engineering, University of Mataram, Mataram City, Indonesia.
*Corresponding Email: akbartawaqqal@gmail.com

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ABSTRACT

This study examines the evolving role and relevance of the Seven Basic Tools of Quality in the context of Industry 4.0 and Artificial Intelligence through a systematic literature review. The research explores how these traditional quality management tools have adapted and integrated with emerging technologies while assessing their continued relevance in modern manufacturing environments. Through a comprehensive analysis of academic literature, this study reveals significant transformations in the implementation of the Seven Basic Tools. The findings demonstrate that these tools remain fundamentally relevant but require substantial adaptation to address contemporary challenges. Integration with Industry 4.0 technologies has enhanced their capabilities. For example, studies indicate that the implementation of IoT in real-time control charts improves accuracy rates up to 100% and reduces calculation time to 4.731 seconds compared to manual systems. Similarly, the use of machine learning to enhance production quality control has shown accuracy improvements ranging from 75% to 100% under various lighting conditions in textile manufacturing. The research also identifies key challenges in implementation, particularly concerning data complexity and workforce competency requirements. This study contributes to the understanding of how traditional quality management tools can be effectively modernized and proposes frameworks for their integration with advanced digital technologies.

INTRODUCTION

The advent of Industry 4.0 and the rapid development of Artificial Intelligence (AI) have presented intelligent solutions for humanity (Malik et al., 2024). This digital transformation not only presents significant challenges but also opens up opportunities to exponentially increase the efficiency and effectiveness of production processes (Gaglio et al., 2022). In this context, the urgency to re-evaluate the role and relevance of basic quality control tools, particularly the Seven Basic Tools of Quality, becomes increasingly crucial to ensure their optimal use in the increasingly complex and interconnected industrial environment of today (Antony et al., 2023).

The Seven Basic Tools of Quality, comprising the Pareto Diagram, Cause-and-Effect Diagram, Stratification, Check Sheet, Histogram, Scatter Diagram, and Control Chart, have long been the foundation of quality management practices (Tague, 2023). These tools have demonstrated their effectiveness in identifying, analyzing, and resolving quality issues across various industrial sectors for decades (Montgomery, 2020). However, with the emergence of Industry 4.0 technologies such as the Internet of Things (IoT), Big Data Analytics, and AI,

critical questions arise regarding how the Seven Basic Tools can adapt and maintain their relevance in the ever-evolving industrial landscape (Shahin et al., 2024).

The era of Industry 4.0, characterized by the integration of cyber-physical systems, IoT, and cloud computing, has fundamentally altered the paradigm of data collection, analysis, and utilization in industrial decision-making processes (Lehmhus et al., 2015). The development of AI with its machine learning and deep learning capabilities has opened new horizons in quality prediction, anomaly detection, and process optimization that transcend the limitations of conventional methods (Rane et al.., 2024).

In this context, this research aims to:

1. Conduct a comprehensive analysis of the role and relevance of the Seven Basic Tools of Quality in the context of Industry 4.0 and the AI era.
2. Identify and explore potential synergies between the Seven Basic Tools and cutting-edge Industry 4.0 and AI technologies to enhance the effectiveness of quality management.
3. Formulate strategic recommendations for the adaptation and development of the Seven Basic Tools to maintain their significance as vital instruments in the modern industrial ecosystem.

The urgency of this research lies in the pressing need to bridge the gap between traditional quality management practices and the demands of the digital era. Without proper and planned adaptation, there is a substantial risk that tools that have proven effective for decades will experience a degradation of relevance amid the inevitable tide of digitalization. Conversely, carefully planned integration between the Seven Basic Tools and Industry 4.0 and AI technologies has the potential to create synergies that can significantly enhance industry capabilities in holistic quality management.

Furthermore, this research has crucial implications in the context of education and professional development in the field of quality management. A deep understanding of the evolution and adaptation of the Seven Basic Tools will enable educational and training institutions to make necessary curriculum updates, preparing a generation of quality practitioners competent in facing the complexities of the digital era.

Through a comprehensive and systematic literature review, this research will explore the latest body of knowledge on the implementation of the Seven Basic Tools in the context of Industry 4.0 and AI. The analysis will include identification of emerging trends, intrinsic challenges, and potential opportunities arising from this intersection. The results of this research are projected to provide valuable and applicable insights for industry practitioners, academics, researchers, and policymakers in efforts to optimize quality management practices in the era of the fourth industrial revolution.

Thus, this research not only contributes to the development of theoretical knowledge but also offers significant practical implications for the adaptation and evolution of quality management practices in facing the challenges and leveraging the opportunities presented by the era of Industry 4.0 and AI.

RESEARCH METHOD

This research adopts a systematic literature review approach to explore and analyze the role of the Seven Basic Tools of Quality in the context of Industry 4.0 and the era of Artificial Intelligence (AI). This method is chosen for its ability to integrate and synthesize findings from various literature sources comprehensively and systematically. The literature search is conducted using several leading academic databases, including but not limited to Scopus, Web of Science, IEEE Xplore, Science Direct, and Google Scholar. The search utilizes combinations

of keywords such as "Seven Basic Tools of Quality," "Quality Control Tools," "Industry 4.0," "Artificial Intelligence," "Smart Manufacturing," "Digital Transformation," and "Quality Management."

The article selection process is conducted in multiple stages, beginning with initial screening based on title and abstract, followed by full-text evaluation for articles that pass the initial screening, quality assessment of articles using established criteria, and data extraction from articles that meet all criteria. The analytical framework utilized in this research encompasses the evaluation of the traditional role of Seven Basic Tools, identification of challenges and opportunities in the context of Industry 4.0 and AI, analysis of adaptation and integration of Seven Basic Tools with new technologies, and assessment of impact on quality management practices.

The research acknowledges several limitations, including a primary focus on academic literature, which may not fully reflect current industry practices, and a limited publication time range, which may neglect previous historical developments. Through this methodological approach, the research aims to provide a comprehensive and in-depth analysis of the role of the Seven Basic Tools of Quality in the era of Industry 4.0 and AI, as well as identify directions for future research and development.

RESULTS AND DISCUSSION

1. Recent Research on Seven Basic Tools in the Context of Industry 4.0 and AI
   1.1. AI-Enhanced Cause-and-Effect Analysis

   Maeda et al. (2022) developed an AI model that enhances the capabilities of the Fishbone Diagram. The results show that external ideas obtained from generative AI inspire the fishbone diagram process. The concepts and designs created seem imaginative and appropriate for competition.

   1.2. Real-time Control Charts

   A study by Firdaus (2020) explores the use of IoT to implement in real-time control charts. This research shows that this quality control system has the accuracy and speed in calculating the quality control process with an accuracy rate of 100% and a calculation speed of 4.731 seconds, significantly compared to manual system, so that it can overcome existing quality control problems.

   1.3. Machine Learning for Quality Control

   Yosephine et al. (2024) implement machine learning and computer vision technologies to enhance production quality control. The result showed good accuracy, ranging from 75% to 100% under various lighting conditions in real-world textile manufacturing environments, confirming their suitability for practical quality control applications.

2. Analysis of the Influence of Industry 4.0 and AI on the Use of Seven Basic Tools
   2.1. Transformation of Data Collection

   Industry 4.0, with its IoT technology, has transformed how data is collected for the Seven Basic Tools. For example, in research by Okpala et al. (2024), Studies have shown that the adoption of IoT technologies in manufacturing can lead to improvements in supply chain management and logistics, impacting cost considerations.

2.2. Enhanced Analytical Capacity

AI, especially machine learning, has significantly increased the analytical capacity of the Seven Basic Tools. For instance, a study by Tuan et al. (2022) shows how deep learning algorithms can enhance the predictive capabilities of control charts, allowing for the identification of trends and patterns that are difficult to detect with traditional statistical methods.

2.3. Automation and Efficiency

AI-driven automation has increased the efficiency of using the Seven Basic Tools. Research by Emad et al. (2023) demonstrates an artificial intelligence-based SPC framework outperforms the traditional SPC techniques in terms of timeliness, accuracy, and efficiency.

3. Relevance of Seven Basic Tools in the Modern Era

The literature review indicates that the Seven Basic Tools remain an important foundation in quality management and relevant in the era of Industry 4.0 and AI, but with significant adaptations. Although relevant, the implementation of Seven Basic Tools in the context of Industry 4.0 and AI faces challenges. A research by Qazy et al. (2022) indicate that 64% of organizations use AI to optimize business processes within quality strategies.

CONCLUSION

Based on the analysis of recent literature, it can be concluded that the Seven Basic Tools of Quality remain highly relevant in the era of Industry 4.0 and AI. However, this relevance depends on the ability to adapt and evolve. Integration with Industry 4.0 and AI technologies not only enhances the capabilities of the Seven Basic Tools but also opens new dimensions in quality analysis and control.

Research shows that the best approach is to combine the fundamental strengths of the Seven Basic Tools with the advanced capabilities offered by Industry 4.0 and AI. This hybridization allows organizations to maintain focus on the basic principles of quality management while leveraging the analytical and predictive power of modern technology.

Nevertheless, implementation challenges remain, particularly in terms of technology integration and competency development. Further research is needed to develop more integrated frameworks and effective training methodologies to ensure successful adoption of augmented Seven Basic Tools in the context of Industry 4.0 and AI.

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