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Analyzing Factors Influencing Quality 4.0 Development in the Smart Supply Chain Using a Hybrid DEMATEL and Interpretive Structural Modeling (ISM) Approach

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Abstract

In the era of digital transformation and increasing pressures on supply chains, the adoption of emerging technologies to enhance quality and ensure sustainable performance has become a strategic imperative. In this context, "Quality 4.0" emerges as a novel paradigm in quality management, leveraging tools such as the Internet of Things (IoT), Artificial Intelligence (AI), and Big Data to move beyond traditional quality control approaches. This study aims to identify and analyze the key factors influencing the implementation of Quality 4.0 in smart supply chains. To achieve this objective, relevant factors were first extracted through a comprehensive literature review and expert consultation. Subsequently, the causal relationships among the factors were examined using the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method, followed by their hierarchical structuring via Interpretive Structural Modeling (ISM). The results offer a practical framework for decision-makers to identify foundational factors and prioritize them in facilitating the effective deployment of Quality 4.0. The findings provide valuable insights for developing innovative strategies that enhance flexibility, transparency, and competitive advantage in complex and dynamic supply chain environments.

Keywords: Quality 4.0, Smart Supply Chain, ISM, DEMATEL

JEL Classification: M10, A22

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INTRODUCTION

In the era of digital transformation, supply chains are facing unprecedented pressures due to increased complexity, uncertainty, and the necessity for rapid responsiveness. In this environment, the emergence of "Quality 4.0"- a paradigm integrating modern technologies like the Internet of Things (IoT), Artificial Intelligence (AI), and Big Data with traditional quality management has become a strategic necessity for organizations striving for sustainable excellence. Simultaneously, smart supply chains, leveraging digital technologies, have become critical for achieving competitive advantage. This study aims to identify and analyze the key factors influencing the implementation and development of Quality 4.0 within smart supply chains, offering a strategic framework for organizational decision-makers.

METHODOLOGY

This research is applied in nature and utilizes a descriptive survey methodology for data collection. Initially, an extensive literature review and expert consultations were conducted to identify the critical factors impacting the deployment of Quality 4.0. In the next phase, causal relationships among these factors were analyzed using the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method. Subsequently, Interpretive Structural Modeling (ISM) was employed to structure these factors hierarchically. By combining DEMATEL and ISM, this research provides a comprehensive view of the cause-and-effect relationships and prioritization among the identified factors.

RESULTS

The study identified 33 critical factors categorized under six primary dimensions: management, organizational, human resources, technological, financial, and infrastructure factors. DEMATEL analysis revealed that management, technology, and financial resources are causal factors, whereas organizational structure, human resources, and infrastructure are primarily effect factors.

Key findings from the DEMATEL analysis include:

- Management (C1) and Technology (C4) showed the highest impact among causal factors.
- Financial resources (C5) were critical for enabling infrastructure and technological readiness.
- Organizational and human resource factors demonstrated significant dependence, emphasizing the need for supportive leadership and culture.

Through ISM, the factors were structured into four hierarchical levels, with management and technology at the highest level, indicating their pivotal role in driving successful Quality 4.0 implementation. Infrastructure and human resources occupied intermediate levels, highlighting their supportive but dependent roles.

The MICMAC analysis further classified the factors based on their driving power and dependence:

- Management, technology, and financial resources were classified as "independent key factors."
- Organizational, human resource, and infrastructure factors were found to be highly dependent.

CONCLUSION

This study concludes that the successful implementation and development of Quality 4.0 in smart supply chains are critically dependent on strong leadership commitment, strategic technological investments, and adequate financial support. Management and technological readiness act as the primary drivers, creating a ripple effect across organizational structures and processes.

Managers are advised to:
• Foster a supportive organizational culture aligned with digital transformation objectives.
• Invest in staff training to overcome resistance to technological changes.
• Prioritize technological infrastructure development alongside financial planning to facilitate Quality 4.0 adoption.
By following the strategic framework presented, organizations can achieve enhanced flexibility, transparency, operational efficiency, and competitive advantage in dynamic market environments.

Contribution of Authors
All authors contributed equally to the writing, editing, and publication process of this article.

Ethical Approval
Written informed consent was obtained from all participants for the publication of their anonymous information in this study.

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Conflict of Interest
The authors declare that there is no conflict of interest.

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