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Total Quality Management and Environmental Performance: The Mediating Role of Green Manufacturing in Ceramic Industries

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Abstract: This study explores the effect of Total Quality Management (TQM) on corporate environmental performance (EP), with Green Manufacturing (GM) as a mediating variable, in the context of the ceramic industry in Indonesia. This study uses a quantitative approach with data collection through questionnaires distributed to ceramic companies that meet certain criteria. Data were analyzed using Structural Equation Modeling (SEM) to test the relationship between variables. The results show that TQM has a significant positive effect on EP, both directly and through GM mediation. GM is proven to strengthen the impact of TQM on environmental performance, with a focus on energy efficiency, waste management, and the use of sustainable raw materials. These findings emphasize the importance of integrating quality management practices and green manufacturing strategies to improve operational sustainability in the ceramic industry. This study provides theoretical contributions by filling the research gap regarding the mediating role of GM in the relationship between TQM and EP, and offers practical recommendations for companies and policy makers to drive the industry's transformation towards sustainability. With increasing market demands and environmental regulations, the results of this study are relevant in supporting the transition towards more environmentally friendly industrial practices.

Keyword: TQM, Green manufacture, Environmental Performance, Ceramic industry

INTRODUCTION

The In recent decades, environmental sustainability has become one of the main issues of concern in various industrial sectors, including the ceramic industry. This industry has a strategic role in supporting the national economy, especially through its contribution to infrastructure development and the property sector. However, the ceramic industry is also known as one of the sectors with a significant carbon footprint due to its high energy consumption intensity and large waste production (Andreola et al., 2016). The ceramic production process, which involves firing at high temperatures, consumes large amounts of fossil fuels and produces greenhouse gas emissions such as carbon dioxide (CO_2) on a significant scale.

In Indonesia, the ceramic industry has experienced rapid growth, with a significant increase in production capacity in recent years. According to data from the Association of Various Ceramic Industries of Indonesia (ASAKI), national ceramic production is projected to reach 625 million square meters in 2024, making Indonesia one of the main producers in Southeast Asia (Garinas, 2020). However, this growth is accompanied by major challenges in complying with environmental regulations and meeting the demands of an increasingly sustainability-oriented international market. The global market is increasingly demanding products that are not only of high quality but also produced through environmentally friendly processes. Additional pressure comes from the government through policies such as reducing carbon emissions and implementing green industry standards.

However, many ceramic companies in Indonesia are still struggling with balancing operational efficiency and environmental sustainability. These challenges include investing in new technologies, such as the use of renewable energy and effective waste management systems, which often come at a high cost. On the other hand, the imbalance between large-scale production and compliance with environmental regulations means that many companies have yet to fully adopt environmentally friendly practices. This highlights the need for managerial and technical solutions that can integrate operational efficiency with sustainability.

These dynamics make it clear that the Indonesian ceramics industry is at a critical crossroads to transform towards more sustainable practices. With the challenges of high energy consumption and pressure to reduce environmental impact, a strategic approach that integrates efficiency and sustainability, such as Total Quality Management (TQM) linked to Green Manufacturing (GM) practices, is key to addressing these issues (Wiyatno et al., 2023). This approach is not only relevant to meet environmental standards but can also be a competitive advantage in a global market that is increasingly focused on sustainability (Li et al., 2020).

As a transformational approach, GM has great potential to optimize environmental performance through energy efficiency, waste management, and the use of sustainable raw materials (Dornfeld & Wright, 2007). Unfortunately, GM has not been fully implemented widely in the ceramics sector. This study aims to fill this gap by analyzing the influence of TQM on the environmental performance of ceramic companies in Indonesia, as well as exploring the role of GM as a mediating variable. The results of this study are expected to provide practical contributions for managers to integrate TQM and GM in daily operations, while providing guidance for policy makers in supporting the ceramic industry's transition towards sustainability. Thus, this study not only offers new theoretical insights but also concrete solutions to the sustainability challenges faced by the ceramics industry.

METHOD

This study uses a quantitative approach with a survey method to examine the relationship between Total Quality Management (TQM), Green Manufacturing (GM), and Environmental Performance (EP). This approach was chosen because it allows the collection of empirical data that can be analyzed statistically to explain direct and indirect relationships between variables.

The research population consists of ceramic companies in Indonesia, especially those that have environmental certification or implement quality management practices. Purposive sampling technique is used to determine the sample with certain criteria (Campbell et al., 2020), namely companies that have implemented TQM, have GM-related initiatives, and are willing to provide data related to environmental performance. A total of 20 companies were selected as research samples, which are expected to be sufficient to represent the characteristics of the ceramic industry in Indonesia in the context of environmental sustainability.

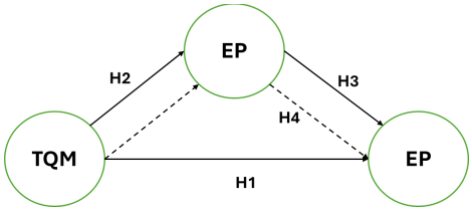
Data collection was conducted through two main sources, namely primary and secondary data. Primary data was obtained through questionnaires distributed to production managers, environmental managers, or executives related to quality management. Meanwhile, secondary data was collected from company sustainability reports, industry publications, and other official documents relevant to the study.

The research variables consist of independent, mediating, and dependent variables. TQM as an independent variable is measured using indicators such as continuous improvement, employee engagement, and data-based decision making. GM as a mediating variable includes indicators such as energy efficiency, waste management, sustainable raw materials, and pollution prevention. Meanwhile, EP as a dependent variable is measured through indicators of carbon emission reduction, compliance with environmental regulations, and development of environmentally friendly products.

Data analysis was conducted in several stages. Descriptive statistics were used to describe the characteristics of the data, while validity and reliability tests were conducted to ensure the reliability of the research instrument (Kimberlin & Winterstein, 2008). Path analysis was applied to test the direct and indirect relationships between variables and measure the mediation effect of GM. All analyses were conducted using statistical Structural Equation Modeling (SEM).

The research procedure begins with the preparation of a questionnaire based on the established variable indicators. After conducting a trial of the instrument to ensure its validity and reliability, data were collected from 20 companies that met the sample criteria. The collected data were then processed and analyzed statistically to obtain relevant findings. The results of the analysis were used to compile interpretations and draw conclusions that could answer the research objectives.

Based on the background, objectives, and research methodology that have been explained, the relationship between Total Quality Management (TQM), Green Manufacturing (GM), and Environmental Performance (EP) is formulated in a conceptual framework. This framework is designed to visually illustrate how TQM as an independent variable affects EP as a dependent variable, both directly and through GM as a mediating variable. This approach not only provides a strong theoretical foundation but also explains the mediating mechanism of GM in strengthening the relationship between TQM and corporate environmental performance. The following is the conceptual framework that is used as a reference in this study:



The conceptual framework presented in this study explains the relationship between three main variables, namely Total Quality Management (TQM), Green Manufacturing (GM), and Environmental Performance (EP). TQM as an independent variable plays an important role in improving company performance through the application of quality management principles, such as continuous improvement, employee involvement, and data-based decision making. This relationship is assumed to not only affect EP directly but also through the mediating role of GM.

Green Manufacturing (GM) in this framework is positioned as a mediating variable that strengthens the influence of TQM on EP. GM includes various environmentally friendly practices, such as energy efficiency, waste management, use of sustainable raw materials, and pollution prevention. By utilizing GM principles, companies are expected to integrate quality management strategies into environmental sustainability efforts, which ultimately improve EP.

This conceptual framework is based on the literature showing that TQM can drive GM implementation, and GM, in turn, contributes directly to EP improvement. Thus, this study not only tests the direct relationship between TQM and EP but also examines the extent to which GM is able to mediate the relationship. The following research hypotheses are formulated based on this conceptual framework to be tested through designed statistical methods. Based on the theoretical framework and research objectives, the hypotheses proposed are as follows:

Direct Hypothesis

H1: Total Quality Management (TQM) has a positive and significant effect on Environmental Performance (EP).

H2: Total Quality Management (TQM) has a positive and significant effect on Green Manufacturing (GM).

H3: Green Manufacturing (GM) has a positive and significant effect on Environmental Performance (EP).

Mediation Hypothesis

H4: Green Manufacturing (GM) mediates the relationship between Total Quality Management (TQM) and Environmental Performance (EP).

RESULTS AND DISCUSSION

Some This study was conducted to analyze the relationship between Total Quality Management (TQM), Green Manufacturing (GM), and Environmental Performance (EP) based on the data that has been collected and processed. The analysis was conducted using descriptive statistics to describe the characteristics of the data, as well as path analysis to test direct and indirect relationships between variables. The results of the study are presented in the form of a table that summarizes the average value (mean), standard deviation (SD), and the results of statistical tests including correlation coefficients and significance levels. This table provides an empirical description of the contribution of each variable in supporting operational sustainability in the ceramics industry, while also answering the hypothesis proposed in this study.

Table 1. Variables Indicators

Variables	Indicator	Average Value (Mean)	Standard Deviation (SD)
TQM	Continuous Improvement	4.35	0.68
	Employee Engagement	4.20	0.75
	Data-Driven Decision Making	4.40	0.70
Green Manufacturing (GM)	Energy Efficiency	4.50	0.65
	Waste Management	4.30	0.72
	Use of Sustainable Raw Materials	4.45	0.68
Environmental Performance (EP)	Carbon Emission Reduction	4.55	0.62
	Compliance with Environmental Regulations	4.40	0.70
	Environmentally Friendly Product Development	4.50	0.65

Table 2. Relationships Between Variables

Connection	Correlation Coefficient (r)	p-value	Information
TQM➔CGP	0.78	0.000	significant positive relationship
TQM➔GM	0.82	0.000	very positive relationship
GM➔CGP	0.76	0.000	significant positive relationship
TQM➔GM➔CGP	0.86	0.000	Mediating

Analysis The results of the analysis presented in the table show a significant positive relationship between Total Quality Management (TQM), Green Manufacturing (GM), and Environmental Performance (EP) in ceramic companies. Based on the data, each indicator measured provides a clear picture of the implementation of TQM and GM principles in improving the company's environmental performance.

TQM (Total Quality Management):

Total Quality Management (TQM) is a comprehensive management approach that focuses on continuous improvement, employee involvement, and data-driven decision-making to enhance organizational performance. In this study, TQM indicators show strong implementation levels, as reflected in high average scores for Continuous Improvement (4.35) and Data-Driven Decision Making (4.40). These scores suggest that the ceramic companies studied have effectively embraced TQM principles, fostering a culture of quality and operational efficiency. TQM emphasizes systematic efforts to reduce inefficiencies, optimize processes, and align organizational goals with customer expectations. This robust implementation provides a foundation for integrating sustainability-focused practices into daily operations, setting the stage for improvements in both operational and environmental performance.

The strong correlation coefficient of 0.82 (p-value = 0.000) between TQM and Green Manufacturing (GM) further underscores the importance of TQM in encouraging environmentally friendly practices. By embedding continuous improvement and data-driven strategies into their operations, companies are better positioned to adopt GM initiatives, such as energy efficiency and sustainable material use. This positive relationship highlights that TQM not only drives operational excellence but also supports the transition toward sustainability, aligning with findings (Agyabeng Mensah et al., 2020). These results emphasize the strategic value of integrating TQM with sustainability practices, offering companies a dual benefit of enhancing their competitive edge and contributing to environmental goals.

Green Manufacturing (GM)

Green Manufacturing (GM) is a strategic approach aimed at minimizing the environmental impact of production processes by implementing eco-friendly practices. In this study, GM indicators show high levels of implementation, with Energy Efficiency scoring an average of 4.50 and Sustainable Raw Material Use scoring 4.45. These results indicate that ceramic companies have significantly integrated environmentally friendly practices into their operations, reflecting a strong commitment to sustainability. GM practices, such as optimizing energy consumption, using renewable raw materials, and improving waste management, not only reduce the ecological footprint but also align with market expectations for sustainable production methods. This commitment is consistent with previous studies, which found that GM practices significantly help reduce industrial waste and improve energy efficiency (Zhu & He, 2017) .

The positive relationship between GM and Environmental Performance (EP) is further demonstrated by the correlation coefficient of 0.76 (p-value = 0.000), indicating that GM directly contributes to improving the environmental outcomes of companies. Previous research by

Chiarini (2014) and Yang et al. (2021) similarly concluded that GM adoption significantly impacts carbon emission reductions, compliance with environmental regulations, and the development of environmentally friendly products. These findings underscore the critical role of GM as a key driver for achieving superior environmental outcomes. By investing in GM, companies not only demonstrate environmental responsibility but also position themselves as leaders in sustainability-oriented markets. This strategy allows businesses to achieve ecological benefits and long-term competitive advantages simultaneously..

Environmental Performance (EP)

EP Environmental Performance (EP) reflects the company's ability to reduce its negative environmental impact while maintaining compliance with sustainability standards and regulations. In this study, EP indicators demonstrate strong results, with Carbon Emission Reduction scoring an average of 4.55 and Environmentally Friendly Product Development scoring 4.50. These findings indicate that the companies studied have successfully implemented strategies to minimize their environmental footprint. Such achievements align with global demands for sustainable practices, showcasing the ceramic industry's capacity to align production processes with eco-friendly goals. This aligns with previous research, which highlights the importance of reducing emissions and promoting green innovation as core aspects of environmental performance performance (Abbas, 2020).

The study further reveals a strong positive relationship between Total Quality Management (TQM) and EP, supported by a correlation coefficient of 0.78 (p-value = 0.000). This relationship indicates that the implementation of TQM principles—such as continuous improvement and data-driven decision-making—contributes significantly to the company's environmental outcomes. Prior studies by (Abbas, 2020; Hosta & Zabkar, 2021)similarly emphasize the role of TQM in enhancing environmental performance through structured and efficient management practices. These results underline the importance of integrating quality management systems with sustainability initiatives. By adopting TQM, companies can optimize operational efficiency while simultaneously achieving environmental goals, thereby creating a competitive advantage in increasingly eco-conscious markets.

Analysis of Relationships Between Variables

Overall, the analysis of the relationship between variables shows that TQM has a significant positive effect on GM and EP. TQM has a correlation coefficient of 0.82 (p-value = 0.000) with GM, indicating that the implementation of TQM can improve GM practices. Meanwhile, the relationship between TQM and EP is also significant with a correlation coefficient of 0.78 (p-value = 0.000), indicating that the implementation of TQM can directly improve the company's environmental performance.

It is important to note that the relationship between TQM, GM, and EP also shows a significant mediation effect. The correlation coefficient of 0.86 (p-value = 0.000) indicates that GM mediates the relationship between TQM and EP, meaning that TQM implementation strengthens GM implementation, which in turn improves environmental performance. In addition, the positive relationship between GM and EP (correlation coefficient of 0.76, p-value = 0.000) indicates that GM practices directly improve the environmental performance of the company. Thus, the results of this analysis confirm that good TQM implementation, supported by Green Manufacturing practices, can significantly improve a company's environmental performance (Hassan & Jaaron, 2021).

CONCLUSION

Based on the results of the analysis that has been done, it can be concluded that Total Quality Management (TQM) has a significant positive influence on Green Manufacturing (GM) and Environmental Performance (EP) in ceramic companies. The application of TQM principles, such as continuous improvement and data-based decision making, has been shown to encourage companies to adopt more effective Green Manufacturing practices. In addition, TQM also has a direct positive impact on the company's environmental performance, which is reflected in the reduction of carbon emissions, the development of environmentally friendly products, and compliance with environmental regulations.

Furthermore, Green Manufacturing acts as a mediator that strengthens the relationship between TQM and corporate environmental performance. Environmentally friendly practices implemented in GM, such as energy efficiency and the use of sustainable raw materials, have shown significant contributions to improving environmental performance. Thus, the implementation of TQM followed by the implementation of GM can improve operational sustainability and reduce negative impacts on the environment.

Overall, the results of this study confirm the importance of integration between TQM and GM in promoting environmental sustainability, especially in the ceramics industry. The implementation of these two approaches not only improves operational efficiency but also supports the transformation towards a more environmentally friendly industry.

Based on the findings of this study, it can be concluded that Total Quality Management (TQM) significantly influences Green Manufacturing (GM) and Environmental Performance (EP) in ceramic companies in Indonesia. The application of TQM principles, such as continuous improvement and data-driven decision-making, fosters the adoption of effective GM practices. These practices, in turn, enhance the company’s environmental performance, as evidenced by reduced carbon emissions, the development of environmentally friendly products, and improved compliance with environmental regulations. Furthermore, GM acts as a crucial mediator, strengthening the relationship between TQM and EP. This indicates that integrating TQM and GM can significantly improve operational sustainability and mitigate negative environmental impacts.

Theoretical contributions of this study lie in addressing the research gap on the mediating role of GM, demonstrating its importance in linking TQM to enhanced EP. On a practical level, the findings offer actionable insights for ceramic companies aiming to balance operational efficiency with sustainability goals. Companies are encouraged to invest in energy-efficient technologies, implement comprehensive waste management systems, and utilize sustainable raw materials. Policymakers are also advised to support this transformation by providing incentives for green technology adoption and enforcing environmental regulations that encourage sustainable practices.

Lastly, this study highlights the need for future research to expand the sample size, include other industries, or explore additional mediating variables. Longitudinal studies to assess the sustained impact of TQM and GM on EP could further enrich the understanding of these dynamics. These efforts can contribute to broader advancements in achieving environmental sustainability across various industrial sectors.

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