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The Impact of Green Manufacturing on TQM and Environmental Performance in Ceramic Industries

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Abstract

Purpose: This study aims to explore the effect of Total Quality Management (TQM) on corporate environmental performance (EP), with Green Manufacturing (GM) acting as a mediating variable, specifically within the ceramic industry in Indonesia.
Research Methodology: A quantitative approach was adopted using a survey method, where data were collected through questionnaires distributed to ceramic companies that implement TQM and GM practices. A total of 20 companies were selected based on purposive sampling. Structural Equation Modeling (SEM) was used for data analysis to examine the direct and indirect relationships between the variables.
Results: The study found that TQM has a significant positive effect on EP, both directly and indirectly through the mediation of GM. GM, specifically in areas such as energy efficiency, waste management, and sustainable raw materials, strengthened the impact of TQM on environmental performance.
Conclusions: TQM and GM together play a crucial role in enhancing the environmental performance of ceramic companies. The integration of quality management practices and green manufacturing strategies significantly contributes to operational sustainability and environmental improvements in the industry.
Limitations: The study is limited to ceramic companies in Indonesia, and the sample size is small. Further research with a larger sample across different industries and regions could provide a more comprehensive understanding of the relationships between TQM, GM, and EP.
Contributions: This study provides theoretical contributions by addressing the research gap regarding the mediating role of GM in the relationship between TQM and EP. It also offers practical recommendations for ceramic companies and policymakers to foster sustainability in the industry.

Keywords: *Ceramic Industry, Environmental Performance, Green Manufacture, TQM*

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1. Introduction

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 (Kurniawan & Hariadi, 2022). However, the ceramic industry is also known as one of the sectors with a significant carbon footprint owing to its high energy consumption intensity and large waste

production (Abbas, 2020). 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 (Aichouni et al., 2024).

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 (Afum et al., 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 (Wiyatno et al., 2023). The global market increasingly demands products that are not only of high quality but also produced through environmentally friendly processes. Additional pressure is exerted by the government through policies such as reducing carbon emissions and implementing green industry standards (Alshammari et al., 2025).

However, many ceramic companies in Indonesia still struggle to balance operational efficiency and environmental sustainability (Zairi, 2002). These challenges include investing in new technologies, such as renewable energy and effective waste management systems, which often come at a high cost (Alwan Abidin et al., 2022). 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 integrate operational efficiency and sustainability (Andreola et al., 2016).

These dynamics indicate that the Indonesian ceramics industry is at a critical crossroads in its transformation towards more sustainable practices (Setyawati et al., 2021). With the challenges of high energy consumption and pressure To address these issues, a strategic approach that integrates efficiency and sustainability, such as Total Quality Management (TQM) linked to Green Manufacturing (GM) practices, is essential (Agyabeng Mensah et al., 2020). This approach is not only relevant for meeting 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 widely implemented 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 and exploring the role of GM as a mediating variable (Zhu & He, 2017). 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 policymakers in supporting the ceramic industry's transition towards sustainability (Campbell et al., 2020). Thus, this study offers not only new theoretical insights but also concrete solutions to the sustainability challenges faced by the ceramics industry.

2. Literature Review & Hypothesis Development

2.1 Total Quality Management (TQM)

Total Quality Management (TQM) is a comprehensive management philosophy that focuses on continuous improvement, customer satisfaction, and overall organizational efficiency. TQM emphasizes the active involvement of all employees in enhancing processes, products, and services, with a view to achieving long-term success and improving competitiveness (Diharjo et al., 2026). The approach is characterized by key principles such as customer focus, continuous improvement, process management, and employee involvement (Nawrocka & Parker, 2009).

TQM is widely recognized as a strategy to improve product quality and operational efficiency, and its

application extends beyond product quality to encompass environmental and social performance. Garinas (2020) defined TQM as a "management approach to long-term success through customer satisfaction." Deming (1986), a pioneer in TQM, emphasized the importance of statistical quality control and process management in achieving organizational excellence. According to Gul et al. (2024), companies that implement TQM are more likely to enhance operational performance by focusing on efficiency, reducing waste, and fostering a culture of continuous improvement.

In terms of environmental outcomes, TQM can help organizations integrate environmental considerations into their quality management processes. Hamdan and Alheet (2021) demonstrated that TQM principles lead to a better understanding of how operational improvements can reduce waste, conserve resources, and minimize environmental impacts. As such, TQM plays a pivotal role in helping organizations adopt sustainable practices while enhancing overall operational efficiency.

2.2 Green Manufacturing (GM)

Green Manufacturing (GM) refers to the adoption of environmentally sustainable practices in manufacturing processes. These practices focus on minimizing environmental impact by reducing waste, conserving energy, and ensuring the responsible use of resources (Hassan & Jaaron, 2021). Green manufacturing aims to produce high-quality products while promoting environmental sustainability, with an emphasis on reducing harmful emissions and minimizing material waste.

The concept of GM is closely linked to sustainable development, where organizations are encouraged to integrate environmental considerations into their production processes. According to Hosta and Zabkar (2021), GM encompasses strategies such as energy efficiency, waste reduction, and the use of renewable resources, all of which contribute to environmental sustainability. Kimberlin and Winterstein (2008) emphasized that GM not only improves operational efficiency but also helps companies meet regulatory standards and respond to market demands for eco-friendly products.

Furthermore, Kouser et al. (2025) highlighted that green manufacturing is a key element in achieving both operational and environmental goals. Companies that implement green manufacturing practices tend to experience long-term benefits, including cost savings through resource optimization, improved brand reputation, and a competitive edge in markets that value sustainability. The integration of GM into organizational strategies is essential for enhancing environmental performance and achieving regulatory compliance (Machingura et al., 2025).

2.3 Environmental Performance (EP)

Environmental Performance (EP) refers to an organization's ability to manage and mitigate its environmental impact. It includes various dimensions, such as resource efficiency, waste management, energy consumption, pollution control, and overall sustainability. EP is often used as a measure of how well an organization adheres to environmental regulations and the effectiveness of its environmental management practices (Masoudi & Shahin, 2025).

The relationship between EP and organizational practices is widely studied in the literature. Masudin et al. (2025) defined environmental performance as a company's efforts to minimize its environmental footprint through improved resource utilization and waste reduction. Muchlish and Retnowati (2025) argued that firms with better environmental performance are more likely to enhance their competitiveness by building a positive public image, reducing costs, and meeting customer expectations for sustainable products.

Muliyati et al. (2023) demonstrated that EP can be influenced by both voluntary practices (such as green initiatives) and mandatory regulations (such as government-imposed environmental standards). Companies that adopt green manufacturing practices tend to have better environmental performance

by reducing their waste generation, improving energy efficiency, and lowering emissions. As such, EP serves as a critical indicator of the effectiveness of environmental management systems and sustainability efforts within an organization (Parmenas, 2022).

2.4 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 conceptual framework was used as a reference in this study:

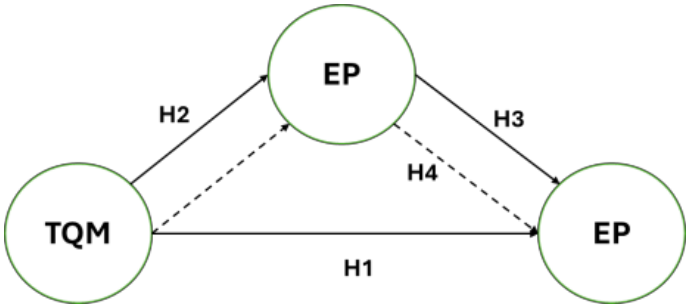

Figure 1. Conceptual framework

Figure 1 explains the relationship between three main variables: 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 affect EP directly and indirectly 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, the use of sustainable raw materials, and pollution prevention. By utilizing GM principles, companies are expected to integrate quality management strategies into their environmental sustainability efforts, ultimately improving their EP.

This conceptual framework is based on the literature showing that TQM can drive GM implementation, and GM, in turn, can contribute 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 mediates this relationship. The following research hypotheses were formulated based on the conceptual framework using designed statistical methods. Based on the theoretical framework and research objectives, the following hypotheses are proposed:

- H_1**:** Total Quality Management has a positive and significant effect on Environmental Performance.
- H_2**:** Total Quality Management has a positive and significant effect on Green Manufacturing.
- H_3**:** Green Manufacturing has a positive and significant effect on Environmental Performance.
- H_4**:** Green Manufacturing mediates the relationship between Total Quality Management and Environmental Performance.

3. Methodology

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 the direct and indirect relationships between variables. The research population consists of ceramic companies in Indonesia, especially those with environmental certification or quality management practices. The purposive sampling technique was 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. Twenty companies were selected as research samples, which is expected to be sufficient to represent the characteristics of the ceramic industry in Indonesia in the context of environmental sustainability (Hudaya, 2022a).

Data were collected from two main sources: primary and secondary data. Primary data were obtained through questionnaires distributed to production managers, environmental managers, and executives related to quality management. Secondary data were collected from company sustainability reports, industry publications, and other official documents relevant to the study. The research variables consisted 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 the development of environmentally friendly products.

Data analysis was conducted in several stages as follows. 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; Nugraha & Purnomo, 2022). Path analysis was applied to test the direct and indirect relationships between variables and to measure the mediation effect of GM. All analyses were conducted using Structural Equation Modeling (SEM). The research procedure began 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 was assessed by collecting data from 20 companies that met the sample criteria. The collected data were 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 of this study.

4. 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 collected and processed data. The analysis was conducted using descriptive statistics to describe the characteristics of the data and path analysis to test the 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 results of statistical tests, including correlation coefficients and significance levels. This table provides an empirical description of the contribution of each variable to support 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
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 1 presents the indicators of Total Quality Management (TQM), Green Manufacturing (GM), and Environmental Performance (EP), along with their respective average values and standard deviations. The data shows that TQM indicators, such as continuous improvement, employee engagement, and data-driven decision-making, have strong mean values ranging from 4.20 to 4.50, with employee engagement showing some variability (standard deviation of 0.75). Green Manufacturing indicators, including energy efficiency, waste management, and use of sustainable raw materials, also exhibit high mean values (4.30 to 4.50) and low standard deviations, suggesting consistent agreement among respondents. Environmental Performance indicators, such as carbon emission reduction and environmentally friendly product development, show high mean values (4.40 and above), with relatively low variability, highlighting the importance of environmental regulations and sustainability practices across the sample.

Table 2. Relationships Between Variables

Connection	Correlation Coefficient	p-value	Information
TQMCGP	0.78	0.000	significant positive relationship
TQMGM	0.82	0.000	very positive relationship
GMCGP	0.76	0.000	significant positive relationship
TQMGMCGP	0.86	0.000	Mediating

Table 2 illustrates the relationships between TQM, Green Manufacturing (GM), and Environmental Performance (EP), with strong positive correlations across all connections. TQM shows a positive correlation with both GM (0.78) and EP (0.82), indicating that improved TQM practices are associated with better environmental and green manufacturing outcomes. The correlation between GM and EP (0.76) further emphasizes the significant role of green practices in achieving environmental goals. Additionally, TQM is shown to act as a mediator between GM and EP, with a high correlation of 0.86, suggesting that TQM practices facilitate the effective implementation of green and sustainable practices, ultimately enhancing overall environmental performance. All correlations are statistically significant, with p-values of 0.000, underscoring the importance of integrating TQM with green manufacturing and environmental strategies.

4.1 Total Quality Management (TQM)

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 showed strong implementation levels, as reflected in the 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 in their organizations. 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 of the industry.

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 practice. 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 drives operational excellence and supports the transition toward sustainability, aligning with the findings of (Agyabeng Mensah et al., 2020). These results emphasize the strategic value of integrating TQM with sustainability practices, offering companies the dual benefit of enhancing their competitive edge and contributing to environmental goals.

4.2 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 showed 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 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. This commitment is consistent with previous studies that 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 a correlation coefficient of 0.76 (p = 0.000), indicating that GM directly contributes to improving the environmental outcomes of companies. Previous research by (Hudaya, 2022b) similarly concluded that GM adoption significantly impacts carbon emission reduction, compliance with environmental regulations, and the development of environmentally friendly products. These findings underscore the critical role of GM as a key driver in 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 simultaneously achieve ecological benefits and long-term competitive advantages.

4.3 Environmental Performance (EP)

Environmental Performance (EP) reflects a company's ability to reduce its negative environmental impact while maintaining compliance with sustainability standards and regulations. In this study, EP indicators demonstrated 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 successfully implemented strategies to minimize their environmental footprints. These 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 (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 a company's environmental outcomes. Prior studies by (Abbas, 2020) similarly emphasize the role of TQM in enhancing environmental performance through structured and efficient management practices. These results highlight the importance of integrating quality management systems with sustainability initiatives. By adopting TQM, companies can optimize their operational efficiency while simultaneously achieving environmental goals, thereby creating a competitive advantage in increasingly eco-conscious markets.

4.4 Analysis of Relationships Between Variables

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

It is important to note that the relationship between TQM, GM, and EP also shows a significant mediating 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 a company's environmental performance. 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)

5. Conclusions

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) of 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 has a direct positive impact on a company's environmental performance, which is reflected in the reduction of carbon emissions, 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 significantly improved environmental performance. Thus, the The implementation of TQM, followed by GM implementation, can improve operational sustainability and reduce negative environmental impacts.

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

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, fostering the adoption of effective GM practices. These practices, in turn, enhance the company's environmental performance, as evidenced by This has resulted in reduced carbon emissions, the development of environmentally friendly products, and improved compliance with environmental regulations. Furthermore, GM is a crucial mediator that strengthens the relationship between TQM and EP. This indicates that integrating TQM and GM can significantly improve operational sustainability and mitigate the negative environmental impacts.

The 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 and sustainability goals. Companies are encouraged to invest in energy-efficient technologies, implement comprehensive waste management systems, and utilize sustainable raw material. Policymakers should support this transformation by providing incentives for green technology adoption and enforcing environmental regulations that encourage sustainable practices.

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

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Author Contributions

ADV conceptualized the research, designed the study, and coordinated the overall research process. SS contributed to the data collection process and the statistical analysis, specifically handling the Structural Equation Modeling (SEM) analysis. ARF assisted with the interpretation of data and the literature review, providing insights on Green Manufacturing and its relation to Total Quality Management. All authors were involved in drafting the manuscript, reviewing the content, and approving the final version for submission.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this study. This research was conducted independently, and no financial or personal relationships influenced the results or interpretation of the findings.

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