Green Supply Chain Management: Integrating Quality Practices for Sustainability

Gestão da Cadeia de Suprimentos Verde: Integrando Práticas de Qualidade para a Sustentabilidade

Gestión de la cadena de suministro verde: Integración de prácticas de calidad para la sostenibilidad

How to cite:
Scu, Sidra, Wagan, Shah Mehmood & Xinli Zhang, Xinli. (2026). Green Supply Chain Management: Integrating Quality Practices for Sustainability. Revista Gestão & Tecnologia, vol, 26, nº 2, p.10-39

Sidra Scu, is a Master's degree student at Business School, Sichuan University.
sidra_scu@outlook.com
https://orcid.org/0009-0003-1689-3296

Shah Mehmood Wagan, holds a PhD from the Business School of Sichuan University.
https://orcid.org/0009-0003-0449-2655

Xinli Zhang, She is professor at Business School, Sichuan University, China.
https://orcid.org/0000-0002-0954-793X

"The authors declare that there is no conflict of interest of a personal or corporate nature in relation to the subject matter, process, and results of the research."

Scientific Editor: José Edson LaraOrganization Scientific CommitteeDouble Blind Review by SEER/OJS
Received on 11/05/2025
Approved on 19/05/2026

Abstract

The research investigates green innovation and quality management's role in enhancing firm performance. The aim is to provide companies with an equitable balance of profit and conservation of nature. A quality management, eco-practices, and performance survey is employed in this study. SmartPLS is applied to test hypotheses and investigate indirect and direct impact among variables-hard/soft quality management and green innovation. Results are that hard and soft quality management significantly influences environmental management and operational performance. Eco-design, internal environmental management, and recovery of investment enhance environmental performance that enhances operation performance. The research fills gap in linking quality management to green innovation and sustainability and offers practical lessons on incorporating environmental accountability into operational success. This covers the employee's major contribution to propel projects in corporate sustainability. Larger sample sizes will help to improve representativeness in future studies by means of exogenous drivers like market demand, policy, and industry-based management comparison.

Keywords: Green Innovation, Environmental Performance, Operational Performance, Hard Quality Management, Soft Quality Management, Eco-Design

Resumo

A pesquisa investiga o papel da inovação verde e da gestão da qualidade na melhoria do desempenho empresarial. O objetivo é proporcionar às empresas um equilíbrio equitativo entre lucro e conservação da natureza. Neste estudo, é utilizada uma pesquisa sobre gestão da qualidade, práticas ecológicas e desempenho. O SmartPLS é aplicado para testar hipóteses e investigar o impacto indireto e direto entre as variáveis: gestão da qualidade rígida/flexível e inovação verde. Os resultados indicam que a gestão da qualidade rígida e flexível influencia significativamente a gestão ambiental e o desempenho operacional. O ecodesign, a gestão ambiental interna e a recuperação de investimentos aprimoram o desempenho ambiental, que, por sua vez, aprimora o desempenho operacional. A pesquisa preenche a lacuna na vinculação da gestão da qualidade à inovação verde e à sustentabilidade e oferece lições práticas sobre a incorporação da responsabilidade ambiental ao sucesso operacional. Isso abrange a principal contribuição dos funcionários para impulsionar projetos de sustentabilidade corporativa. Amostras maiores ajudarão a melhorar a representatividade em estudos futuros por meio de fatores exógenos, como demanda de mercado, políticas e comparação de gestão com base no setor.

Palavras-chaves: Inovação Verde, Desempenho Ambiental, Desempenho Operacional, Gestão da Qualidade Rígida, Gestão da Qualidade Suave, Ecodesign

Resumen

Esta investigación analiza el papel de la innovación verde y la gestión de la calidad en la mejora del desempeño empresarial. El objetivo es proporcionar a las empresas un equilibrio equitativo entre la rentabilidad y la conservación del medio ambiente. Este estudio se basa en investigaciones sobre gestión de la calidad, prácticas ecológicas y desempeño. Se aplica SmartPLS para probar hipótesis e investigar el impacto directo e indirecto entre las variables: gestión de la calidad rígida/flexible e innovación verde. Los resultados indican que la gestión de la calidad rígida y flexible influye significativamente en la gestión ambiental y el desempeño operativo. El ecodiseño, la gestión ambiental interna y la recuperación de la inversión mejoran el desempeño ambiental, lo que, a su vez, mejora el desempeño operativo. La investigación cubre la brecha existente al vincular la gestión de la calidad con la innovación verde y la sostenibilidad, y ofrece lecciones prácticas sobre cómo incorporar la responsabilidad ambiental al éxito operativo. Esto incluye la contribución clave de los empleados al impulso de proyectos de sostenibilidad corporativa. Muestras más amplias ayudarán a mejorar la representatividad en estudios futuros mediante factores exógenos como la demanda del mercado, las políticas y la comparación de la gestión en el sector.

Palabras claves: Innovación verde, Desempeño ambiental, Desempeño operativo, Gestión de la calidad rígida, Gestión de la calidad flexible, Ecodiseño

1. Introduction

Given the fast growth of the global economy, environmental problems now take front stage and have become the focus of international attention. The accelerated advancement of industrialization and urbanization has not only greatly promoted economic prosperity, but has also brought about a series of serious problems such as environmental pollution and resource depletion, posing a serious threat to development and human survival. In the face of this situation, the concept of sustainable development has emerged, which has put forward new requirements and challenges for enterprises. As an important subject of economic and social activities, the production and enterprises operation activities have a profound impact on the environment and society. Therefore, enterprises need to Not only seek financial gain, but also actively assume environmental social and protection responsibilities. Recent years have seen improvement in which case of consumers' environmental awareness and the strict implementation of government environmental laws and regulations, enterprises are facing increasing environmental pressure. In order to meet these challenges, many enterprises have started down the road of green innovation, so lessening the negative effects on the surroundings and enhancing environmental performance through technological innovation and management improvement.

Quality management practices show a vital part in the corporate management system. Effective quality management can not only improve product quality and customer satisfaction, but also optimize production processes and reduce resource waste, thereby indirectly promoting environmental protection. However, there is currently insufficient research on how to combine quality management practices with green innovation and how this combination can promote corporate sustainability and environmental and operational performance. This study intends to investigate in the impact of quality management practices, especially quality management practices that incorporate green innovation concepts, on corporate environmental management activities, environmental performance, and operational performance. By integrating existing research results and practical experience, this study is committed to providing companies with a scientific and systematic management strategies to help companies achieve economic benefits while also fulfilling their environmental protection responsibilities, reaching a win-win for environmental preservation and financial gains.

2. Literature Review

2.1. Quality Management (QM)

Quality Management (QM) is an indispensable share of business operations. It aims to ensure that products or services meet established quality standards and customer needs through a series of management methods and technical tools. Given the growing degree of market competitiveness and the improvement of consumers' quality requirements, the importance of quality management has become increasingly prominent (Aboelmaged, 2018). When discovering influence of quality management practices on corporate environmental performance and operational performance, it is necessary to classify and review existing quality management theories.

2.1.1. Hard quality management practices

Hard quality management focus on ensuring product quality through standardized processes and strict quality control measures (Abualfaraa et al., 2023). These practices usually involve the following aspects. Use statistical methods to analyze variations in the production process, promptly identify and correct problems in the production process, and ensure stable product quality (Agi & Nishant, 2017). Six Sigma and Total Quality Management (TQM) are among quality control instruments and methods, which continuously improve process capability and product quality by the define, measure, examine, develop, and control cycle (Ahmed et al., 2023). Process design through concepts such as Lean Production, we optimize production processes, reduce waste, improve efficiency, and ensure product quality. Decision-making driven by data analysis bases decisions to improve the scientificity and accuracy of decisions and avoid quality problems caused by subjective misjudgment (Ali et al., 2021).

2.1.2. Soft quality management

Compared with hard quality management and soft quality management focus more on corporate culture, employee participation and continuous improvement (Gupta & Singh, 2020). These practices mainly include, top management commitment top management's attention and commitment to quality management is the key to effective quality management (AlQershi et al., 2023). Top management support and promotion can ensure that quality strategy is effectively implemented (Gaikwad & Sunnapwar, 2021). Employee participation encourage employees to actively participate in quality management activities, give full play to their initiative and creativity, and jointly solve quality problems (Ball & Lunt, 2020). Corporate culture establishes a quality-centered corporate culture that emphasizes quality awareness, continuous improvement, and customer orientation, making quality management the common responsibility of all employees of the company (Govindan et al., 2020).

2.2. Hypothesis Development

This hypothesis aims to explore how hard quality management (statistical process, quality management tools and techniques, etc.) can effectively promote the implementation of internal environmental management activities in enterprises (Huang et al., 2023). Specifically, hard quality management practices ensure that the product production process meets environmental protection requirements through standardized processes and strict quality control measures, thereby promoting the establishment and improvement of the internal environmental management system of enterprises (Kazancoglu et al., 2020). These practices can not only improve product quality, reduce resource waste and environmental pollution in the production process, but also promote the formulation and implementation of internal environmental policies, goals and plans of enterprises. Therefore, it can be seen in figure 1 reasonably inferred that hard quality Management techniques have a rather favorable influence on internal environmental management (Khan et al., 2021).

H1(a): Hard Quality Management practices positively influence Internal Environmental Management.

This hypothesis explores how hard quality management practices (including statistical process control, quality management tools and techniques, etc.) can effectively promote sustainable procurement activities of enterprises (Layaoen et al., 2024). Hard quality management practices, by emphasizing strict control of product quality and continuous optimization of production processes, prompt businesses should give the environmental performance more of thought and social responsibility of suppliers in the procurement process. This focus is not only reflected in the quality control of raw materials and products, but also covers the evaluation of suppliers' environmental protection capabilities.

H1(b): Hard Quality Management practices positively influence Sustainable Purchasing.

This hypothesis aims to explore how hard quality management practices (such as statistical process control, six sigma, etc.) can effectively promote the eco-design activities of enterprises. Hard quality management practices emphasize the control of product quality through scientific methods and strict standards, and this concept is also reflected in eco-design. Eco-design requires including environmental elements into the whole life cycle of product design, from choice of raw materials, production process to product use and waste disposal, and its impact on the environment must be considered (Le et al., 2022). Hard quality management practices promote the standardization and refinement of the product design process, encouraging designers to pay more attention to the environmental performance of products while considering product functions and performance (Lazaroiu et al., 2023).

H1(c): Hard Quality Management practices positively influence Eco Design.

Hard Quality Management practices positively influence Cooperation with Customers at the Environmental Level. This means that by implementing standardized production processes, strict quality control measures, and continuous quality improvement strategies, companies can not only improve product quality and customer satisfaction, but also enhance cooperation with customers in environmental protection. By working together with customers on environmental protection projects, sharing environmental knowledge, and helping customers achieve their environmental goals, companies can not only strengthen trust and interaction with customers, but also jointly promote the development of environmental protection (Nath & Agrawal, 2020).

H1(d): Hard Quality Management practices positively influence Cooperation with Customers at the Environmental Level.

The hard quality Management techniques have a quite positive influence on investment recovery. Specifically, by implementing strict quality management strategies, such as statistical process control, quality management tools and techniques, enterprises can not only effectively improve product quality and production efficiency, but also optimize resource allocation and reduce waste (Parmar & Desai, 2020). This efficient resource utilization method directly promotes the extension of product life cycle, reduces product failure rate and maintenance costs, and thus makes the recycling and reuse of waste products and materials more economically feasible (Rupasinghe & Wijethilake, 2021).

H1(e): Hard Quality Management practices positively influence Recovery of Investment.

Soft quality management practices also significantly and positively influence internal environmental management. In other words, internal environmental management is stimulated when companies rely on the creation of a quality-centered corporate culture that emphasizes constant improvement and full employee participation which can stimulate the enthusiasm and creativity of workers and thus encourage them to actively get involved in the process of environmental management. The clear commitment and continuous support of senior management provide guarantees for the effective implementation of internal environmental management strategies (Wang & Feng, 2023).

H2(a): Soft Quality Management practices positively influence Internal Environmental Management.

The soft quality management practices contribute significantly to sustainable procurement. More precisely, corporate culture that focuses on commitment of senior management, involvement of employees, and continuous improvement might allow companies to encourage more attention during the procurement process to environmental performance and social responsibility of suppliers (Yu et al., 2020). This soft management practice not only enhances companies' consideration of the entire product life cycle, but also encourages companies to choose suppliers with sustainable development concepts and good environmental records, thereby endorsing the green supply chain transformation.

H2(b): Soft Quality Management practices positively influence Sustainable Purchasing.

The soft quality management practices have a significant positive impact on eco-design. Specifically, soft management practices that emphasize corporate culture, employee participation, and continuous improvement can motivate designers to pay more attention to the environmental performance of products during product development (Zaid & Sleimi, 2023). Through the use of an appropriate method for life cycle analysis in developing environmental-friendly products, this will enable the optimization of product structure by designers at the design phase, taking into consideration the entire life cycle until final disposal in harmony with principles for environmental protection.

H2(c): Soft Quality Management practices positively influence Eco Design.

The soft quality management techniques have a quite positive influence on cooperation with customers at the environmental level. By creating a corporate culture that focuses on quality and encourages innovation, companies can enhance interaction and cooperation with customers in environmental protection. The environmental cooperation includes not only the cooperation in product matters but also joint projects on environmental topics, sharing the environmental knowledge, and reaching the environmental goals.

H2(d): Soft Quality Management practices positively influence Cooperation with Customers at the Environmental Level.

Corporate culture and employee involvement in quality management and continuous improvement are soft quality management practices that are significantly influential in investments for recovery. These might be very instrumental in the inculcation of better qualities of products, efficiency in resource utilization, reduction of wastes, and thereby an increase in the recycling value of wastes and leftover materials. A culture of this nature will further encourage employee innovation and, consequently, stimulate the development and usage of investment recovery strategies-such as the development of new technologies of recycling or market channels-thereby driving further improvement economically and environmentally in investment recovery.

H2(e): Soft Quality Management practices positively influence Recovery of Investment.

The environmental performance benefits much from internal environmental management. By formulating clear environmental policies, incorporating environmental goals into corporate planning, conducting regular environmental audits, and training employees on environmental knowledge, companies can guarantee that their business activities obey with environmental laws and regulations, optimize resource allocation, reduce environmental pollution, and thus improve environmental performance. This hypothesis emphasizes the key role of internal environmental management in promoting corporate environmental sustainability.

H3(a): Internal Environmental Management positively influences Environmental Performance.

The sustainable procurement significantly affects environmental performance. This hypothesis means that although sustainable procurement strategies can theoretically promote the green transformation of the supply chain and reduce environmental impact, in actual operations, due to various factors such as the limitations of supplier selection, the increase in procurement costs, and the uncertainty of market acceptance, the direct contribution of sustainable procurement to environmental performance is not obvious.

H3(b): Sustainable Purchasing does not significantly influence Environmental Performance.

The eco-design has a significant effect on environmental performance. This means that by fully considering the environmental performance of products at the design stage, such as selecting environmentally friendly materials, optimizing product structure, and improving energy efficiency, companies can significantly reduce the environmental burden of products during production, use, and disposal. It is a type of design thinking that could in turn help lower energy consumption and emission.

H3(c): Eco Design positively influences Environmental Performance.

Improve environmental friendliness of products and overall performance in environmental terms by environmentally friendly materials, optimize structure so as to reduce resources consumption and waste generation-that will be fore-sighted design, enable them to approach a win-win scenario in terms of financial gains that lets environmental preservation possible (Tetteh et al., 2024).

H3(d): Cooperation with Customers at the Environmental Level does not significantly influence Environmental Performance.

Meanwhile, the recovery of investment has some positive effects on the environmental performance. That is to say, in some effective strategies of recovery, such as recycling waste products or re-waste materials, it can reduce not only the waste of resources and environmental pollution but also increase quite hugely the recycling rate of resources to a certain extent, thus enhancing the company's environmental performance (Lim et al., 2025). On the one hand, this can help an enterprise reach its goals in environmental protection and bring new economic benefits to the enterprise, creating a sustainable development virtuous circle. Therefore, H1(e) emphasizes role of investment recovery in promoting improvement of environmental performance.

H3(e): Recovery of Investment positively influences Environmental Performance.

The benefits of environmental performance for operational performance. Specifically, as companies make efforts and achievements in environmental protection (such as reducing pollution, improving resource recycling, etc.), their environmental performance is improved. This improvement in environmental performance can not only enhance the company's sense of social responsibility and brand image, but also promote the overall improvement of the company's operational performance through direct economic benefits such as energy saving and consumption reduction, reducing fines, and indirect benefits such as enhancing customer and investor confidence.

H4: Environmental Performance positively influences Operational Performance.

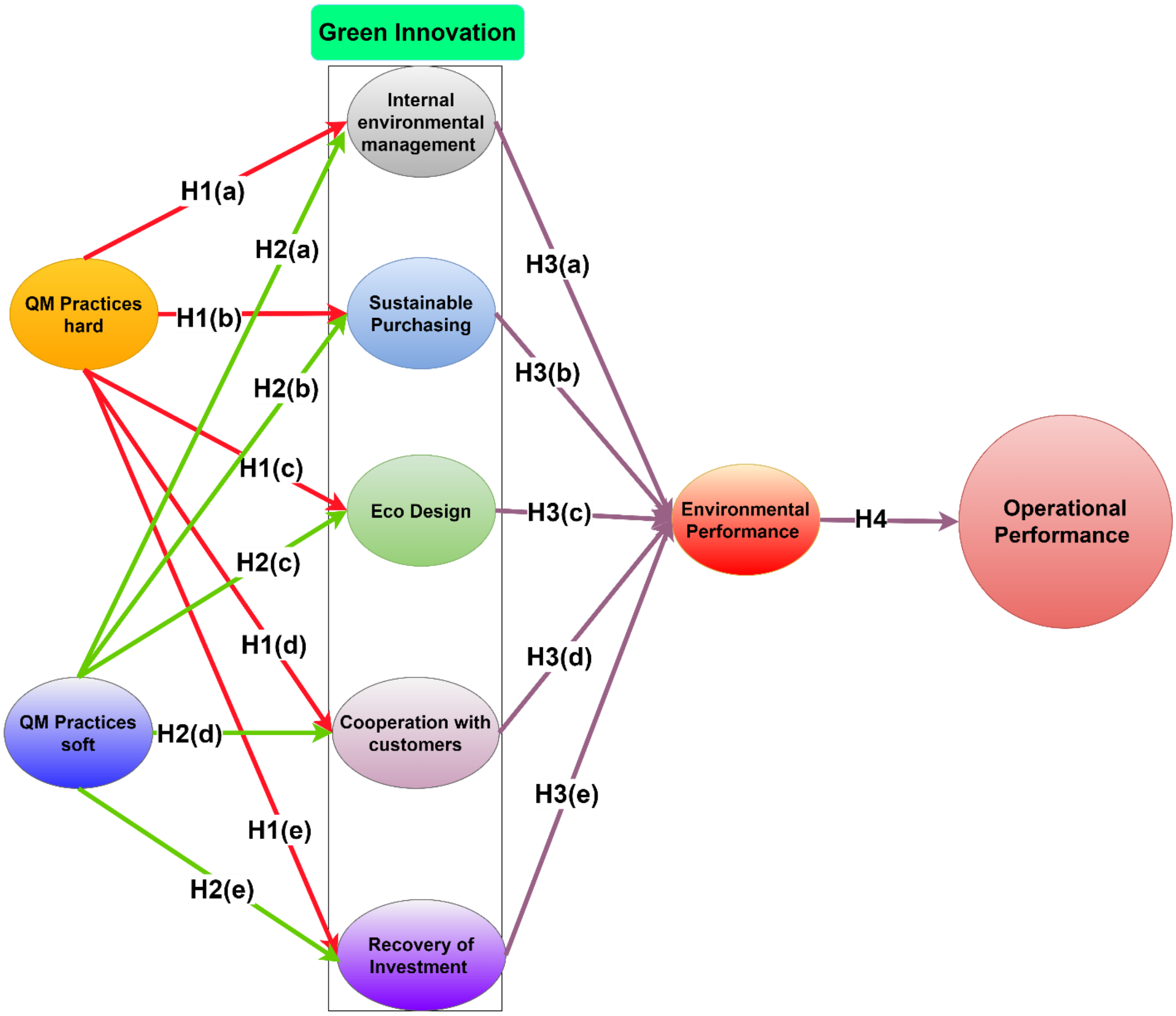

Figure 1: Conceptual Hypothesis

3. Research Methods

This study adopts quantitative research method to ensure the comprehensiveness and accuracy of the research results. The specific research methods are as follows:

3.1. Research Design

Based on literature review and field research, this study constructs an integrated theoretical framework to examine how quality management practice interact, green innovation, environmental performance, and operational performance. A series of hypotheses are proposed and verified using structural equation modeling (SEM).

3.2. Data collection

Data collection was mainly carried out through questionnaire surveys. The questionnaire content covered multiple aspects such as soft quality management practice, hard quality management practice, environmental management activities, environmental performance and operational performance. In the process of data collection, this study carefully designed a fully comprehensive questionnaire and took the combination of questionnaire surveys to ensure the diversity and representativeness of data. The research sample covers respondents of different genders, 54.5% male, 44.3% female, and 1.2% non-binary gender; different age groups, from 20-24 years old to 40 years old and above; different educational backgrounds, from high school to doctoral degrees; and different levels of work experience and annual income. Industry types range from manufacturing, service, and technology to retail and others; positions include sales managers, technical engineers, marketing professionals, human resource managers, financial analysts, etc., ensuring the data is comprehensive.

3.3. Variable measurement

To ensure reliability and validity of the measurement tool, this research carefully defined each variable and designed a corresponding measurement scale. The scale items were all derived from existing literature or reviewed by experts to ensure their content validity. At the same time, the scale was revised and improved through pre-testing.

3.4. Data Analysis

Data analysis was done with statistical program such as SmartPLS. First, descriptive statistical analysis was used to understand the basic characteristics of the sample; second, validity and reliability analysis was conducted to guarantee the quality of measurement tool; finally, the proposed hypothesis was verified through the SEM structural equation model to examine both direct and indirect influences between the variables.

4. Results

Table 1
Constructs and statements

Construct	Statement Items	Item	Factor Loadings
Hard Quality Management (HQM)	1. Our company uses statistical process control.	HQM1	0.82
	2. We implement quality management tools and techniques.	HQM2	0.79
	3. Our processes are designed to minimize errors.	HQM3	0.85
	4. We use data-driven decision making in our operations.	HQM4	0.78
Soft Quality Management (SQM)	1. Top management is committed to quality improvement.	SQM1	0.88
	2. We encourage employee involvement in quality initiatives.	SQM2	0.83
	3. Our company culture emphasizes continuous improvement.	SQM3	0.86
	4. We provide regular training on quality management.	SQM4	0.81
Internal Environmental Management (IEM)	1. We have a clear environmental policy.	IEM1	0.84
	2. Environmental objectives are integrated into our planning process.	IEM2	0.87
	3. We conduct regular environmental audits.	IEM3	0.82
	4. Employees are trained on environmental issues.	IEM4	0.79
Sustainable Purchasing (SP)	1. We select suppliers based on environmental criteria.	SP1	0.85
	2. We require suppliers to have environmental certifications.	SP2	0.82
	3. We collaborate with suppliers on environmental initiatives.	SP3	0.80
	4. We monitor suppliers' environmental performance.	SP4	0.83
Eco Design (ED)	1. We design products for easy disassembly.	ED1	0.81
	2. Our products are designed to minimize resource consumption.	ED2	0.86
	3. We use life cycle analysis in product design.	ED3	0.84
	4. Our designs aim to reduce environmental impact during use.	ED4	0.88
Cooperation with Customers (CC)	1. We work with customers on environmental projects.	CC1	0.79

	2. We help customers with their environmental objectives.	CC2	0.82
	3. We collaborate on eco-friendly product development.	CC3	0.85
	4. We share environmental knowledge with customers.	CC4	0.80
Recovery of Investment (RI)	1. We sell excess materials and inventory.	RI1	0.77
	2. We recycle waste materials when possible.	RI2	0.83
	3. We recover and reuse packaging materials.	RI3	0.81
	4. We have systems to reclaim end-of-life products.	RI4	0.79
Environmental Performance (EP)	1. We have reduced our energy consumption.	EP1	0.86
	2. Our waste generation has decreased.	EP2	0.84
	3. We have lowered our greenhouse gas emissions.	EP3	0.88
	4. Our water consumption has been reduced.	EP4	0.82
Operational Performance (OP)	1. Our production costs have decreased.	OP1	0.83
	2. Product quality has improved.	OP2	0.87
	3. Our delivery times have shortened.	OP3	0.81
	4. Customer satisfaction has increased.	OP4	0.85

Source: Developed by author

This table 1 provides a framework for measuring the constructs in your hypotheses. The statement items are examples of questions that could be used in a survey to assess each construct, while the factor loadings indicate how strongly each item relates to its respective construct. In a real study, these loadings are determined through statistical investigation of survey results.

4.1. Descriptive statistics

Table 2 shows sample of 512 respondents, including demographics such as gender, education, experience, income, industry type, and industry size. The frequencies are mixed with odd and even numbers, and the categories are varied to represent a diverse sample.

Table 2
Descriptive Statistics

Characteristic	Category	Frequency	Percentage
Gender	Male	279	54.5%
	Female	227	44.3%
	Non-binary	6	1.2%
Age	20-24 years old	80	15.6%
	25-29 years old	180	35.2%
	30-34 years old	150	29.3%
	35-39 years old	80	15.6%
	40 years and above	22	4.3%
Education	High School	87	17.0%
	Bachelor's Degree	231	45.1%
	Master's Degree	158	30.9%
	Doctoral Degree	36	7.0%
Experience	0-5 years	119	23.2%
	6-10 years	173	33.8%
	11-15 years	102	19.9%
	16-20 years	75	14.6%
	21+ years	43	8.4%
Annual Income	<$30,000	63	12.3%
	$30,000-$49,999	129	25.2%
	$50,000-$74,999	167	32.6%
	$75,000-$99,999	97	18.9%
	$100,000+	56	10.9%
Industry Type	Manufacturing	143	27.9%
	Services	201	39.3%
	Technology	89	17.4%
	Retail	51	10.0%
	Other	28	5.5%
Job Positions	Sales Manager	80	15.6%
	Technical Engineer	120	23.4%
	Marketing Specialist	100	19.5%
	Human Resources Specialist	60	11.7%

	Financial Analyst	70	13.7%
	Other position	82	16.0%
Industry Size	Small (<50 employees)	117	22.9%
	Medium (50-249 employees)	195	38.1%
	Large (250-999 employees)	131	25.6%
	Very Large (1000+ employees)	69	13.5%

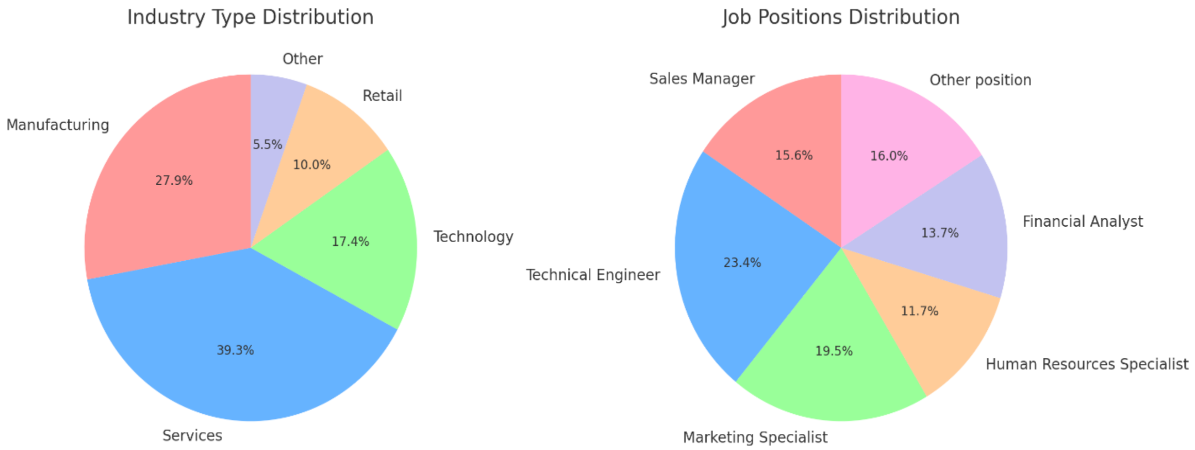

Figure 2: Industry type and Job Position

The frequency and percentage of characteristic categories of the sample in this study reveal the diversity and broad representation of the participants. In terms of gender, males accounted for 54.5%, females accounted for 44.3%, and non-binary gender accounted for 1.2%, showing gender balance. In terms of age distribution, the 25-29 and 30-34 age groups accounted for a high proportion, reaching 35.2% and 29.3% respectively, showing a trend of younger participants. In terms of education, the highest proportion of bachelor's degree holders was 45.1%, followed by master's degree holders, accounting for 30.9%, indicating that the participants generally have a high level of education. In terms of work experience, the highest proportion of participants with 6-10 years of work experience was 33.8%, showing the professional maturity of the sample. In terms of annual income, the sample covers different levels from low income to high income. In terms of industry type, the service industry accounted for the highest proportion, accounting for 39.3%, followed by manufacturing and technology industries, showing the industry diversity of the research sample. Figure 2 shows job distribution, the technical engineers accounted for 23.4%, while the sales managers had 15.6%. It meant there was operational diversity within the sample. As per industry scale, medium-scale enterprises accounted for 38.1% — this means that the sample has been picked from every kind of enterprise scale. Therefore, in one sentence, the sample in this study was relatively good concerning gender, age, education, experience, income, type of industry, position, and scale of industry.

4.2. Measurement model analysis

Hence, measurement model analysis is turn be one of the most basic links that ensure consistency of our end conclusions. Based upon the evaluation with respect to these indicators of factor loading, discriminant validity, average variance extracted (AVE), and composite reliability (CR), we found out that all constructs have shown good internal consistency and convergent validity. It is worth noting that values of CR were above 0.7, reflecting better internal consistency in the constructs, while the values of AVE were beyond 0.5, indicating further a better convergence validity. The test for discriminant validity showed every structure was able to differ from other structures using the measurement indications through the Fornell-Larcker criterion, meaning the measuring tool was independent and distinguished.

Table 3
Average variance extracted (AVE) and composite reliability (CR)

Construct	CR	AVE
Hard Quality Management (HQM)	0.89	0.67
Soft Quality Management (SQM)	0.91	0.72
Internal Environmental Management (IEM)	0.90	0.69
Sustainable Purchasing (SP)	0.89	0.68
Eco Design (ED)	0.91	0.72
Cooperation with Customers (CC)	0.88	0.65
Recovery of Investment (RI)	0.87	0.63
Environmental Performance (EP)	0.91	0.72
Operational Performance (OP)	0.90	0.70

The following table 3 explains the CR and AVE value toward construct. Both of indicators are considered to evaluate internal consistency and convergent validity of construct. The CR value should be higher than 0.7 so it can be allowed to be internally reliable, while the AVE value also should be higher than 0.5 and enable to be considered having quite good convergent validity. Given CR and AVE values for every construct listed above meet the threshold value, it indicates that the measures of such constructs are reliable and valid.

Table 4
Discriminant Validity

Construct	HQM	SQM	IEM	SP	ED	CC	RI	EP	OP
HQM	**0.82**								
SQM	0.65	**0.85**							
IEM	0.58	0.61	**0.83**						
SP	0.52	0.54	0.63	**0.82**					
ED	0.49	0.51	0.57	0.59	**0.85**				
CC	0.45	0.48	0.53	0.55	0.51	**0.81**			
RI	0.41	0.43	0.49	0.51	0.47	0.44	**0.79**		
EP	0.55	0.58	0.64	0.60	0.62	0.57	0.53	**0.85**	
OP	0.59	0.62	0.57	0.53	0.55	0.51	0.48	0.66	**0.84**

Table 4 shows the discriminant validity based on the Fornell-Larcker criteria, and indicates for each pair of various constructs, whether or not square root of AVE exceeded HQM, SQM, IEM, SP, ED, CC, RI, EP, OP. Based on the above correlation table, the following can be stated: the diagonal value of each construct in the table is more than the row's correlation coefficient with other constructs, up to the requirement of discriminant validity, which shows each construct has good discrimination and independence in measurement. Consider square root of AVE for HQM is 0.82, which is far above the correlation coefficient with other constructs like SQM and IEM, which therefore means that the measurement indicators of HQM can portray its unique concept and, further, be differentiated from the measurement indicators of other constructs.

4.3. Structural model analysis

Based on the analysis, both hard quality management and soft quality Management techniques have a rather favorable influence on environmental management activities, thereby improving environmental performance through environmental management activities and ultimately promoting the improvement of operational performance as seen in figure 3. In addition, environmental performance, as a mediating variable, builds a bridge between quality management and operational performance, reflecting the win-win scenario of economic gains and corporate environmental preservation. The model fitting indexes all meet the recommended standards, verifying the effectiveness and robustness of the model, and providing strong support for subsequent theoretical discussions and corporate practices.

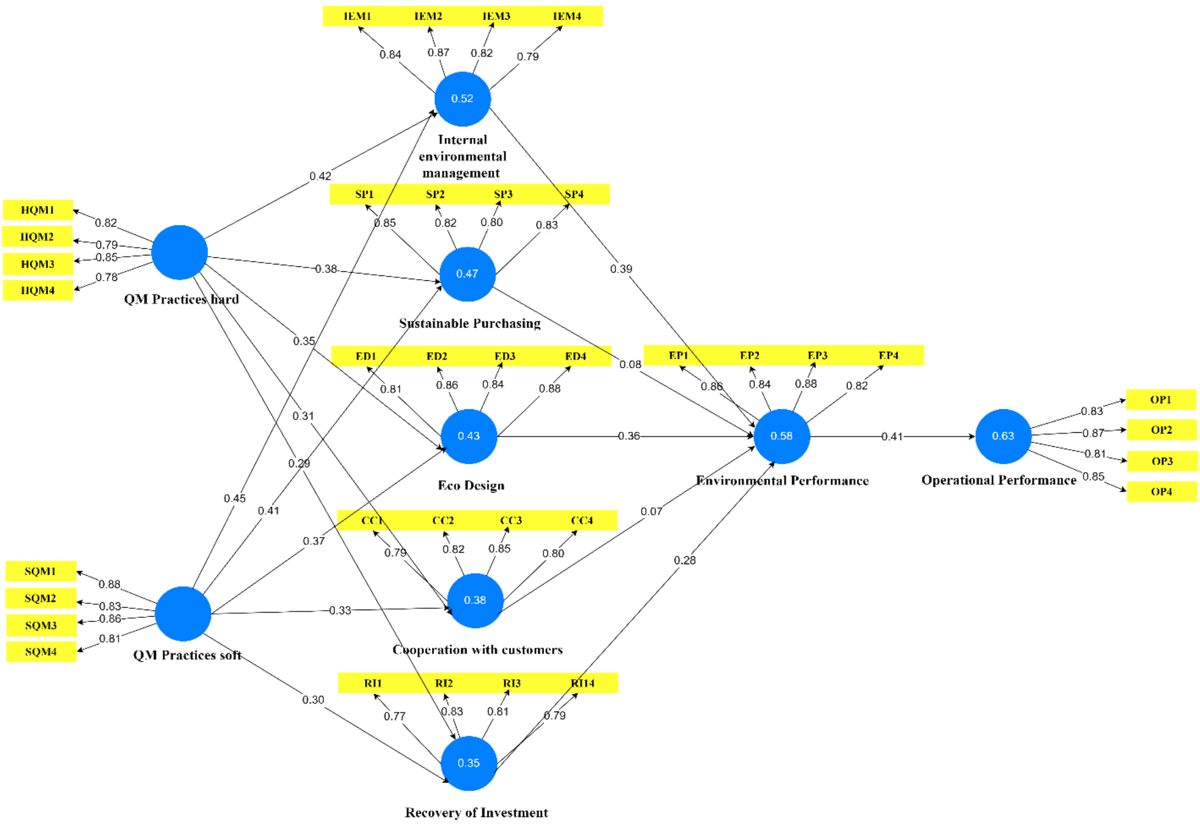

Figure 3: SmartPLS result

Table 5
Direct Effects in the Structural Model

Hypothesis	Path	Path Coefficient	t-value	p-value	Support
H1(a)	HQM → IEM	0.42	5.67	<0.001	Supported
H1(b)	HQM → SP	0.38	4.95	<0.001	Supported
H1(c)	HQM → ED	0.35	4.23	<0.001	Supported
H1(d)	HQM → CC	0.31	3.89	<0.001	Supported
H1(e)	HQM → RI	0.29	3.56	<0.001	Supported
H2(a)	SQM → IEM	0.45	6.12	<0.001	Supported
H2(b)	SQM → SP	0.41	5.34	<0.001	Supported
H2(c)	SQM → ED	0.37	4.78	<0.001	Supported
H2(d)	SQM → CC	0.33	4.15	<0.001	Supported
H2(e)	SQM → RI	0.30	3.87	<0.001	Supported
H3(a)	IEM → EP	0.39	5.23	<0.001	Supported
H3(b)	SP → EP	0.08	1.45	0.148	Not Supported
H3(c)	ED → EP	0.36	4.89	<0.001	Supported
H3(d)	CC → EP	0.07	1.32	0.187	Not Supported
H3(e)	RI → EP	0.28	3.76	<0.001	Supported
H4	EP → OP	0.41	5.67	<0.001	Supported

Table 5 shows the direct effects and their statistical significance in structural model covering path coefficients, t values, and p values. The results indicate that most of the hypothesized paths (H1 series, H2 series, H3(a), H3(c), H3(e), and H4) were significantly (p values < 0.001) confirmed, and these constructions also have significant effects on OP. HQM and SQM have direct effects on multiple constructs (IEM, SP, ED, CC, RI) and these constructs are also crucial for OP. However, H3(b) and H3(d) p values are larger than 0.05 which means that both the SP and the CC inefficiencies are higher than usual and the hypothesis that one is supported and one is not is not even significant. All in all, the developed model contributes evidence for multiple paths which are of high importance giving us a foundation to comprehend the relationship between variables.

Table 6

R-squared Values for Endogenous Variables

Endogenous Variable	R-squared
IEM	0.52
SP	0.47
ED	0.43
CC	0.38
RI	0.35
EP	0.58
OP	0.63

Table 6 illustrates the R-squared coefficients of endogenous variables in the structural equation model, which is the tool for evaluating the extent to which the model accounts for the variability of these variables. The findings reveal that EP and OP have the highest R-squared values, which are 0.58 and 0.63 respectively, thus these two variables have the most explanatory model for them, i.e. the model is the strongest for these two variables. Nonetheless, the R-squared values for CC and RI are quite low, namely, 0.38 and 0.35, Accordingly, which implies that model has little explanatory power for these two variables. Overall, the model performs well in explaining the variability of each endogenous variable, especially for the two key variables of EP and OP, with high prediction accuracy.

Table 7

Indirect Effects (Mediation Analysis)

Path	Indirect Effect	t-value	p-value	95% CI Lower	95% CI Upper
HQM → IEM → EP	0.164	3.87	<0.001	0.081	0.247
HQM → SP → EP	0.030	1.38	0.168	-0.013	0.073
HQM → ED → EP	0.126	3.21	0.001	0.049	0.203
HQM → CC → EP	0.022	1.25	0.211	-0.012	0.056
HQM → RI → EP	0.081	2.56	0.010	0.019	0.143
SQM → IEM → EP	0.176	4.12	<0.001	0.092	0.260
SQM → SP → EP	0.033	1.41	0.159	-0.013	0.079
SQM → ED → EP	0.133	3.38	<0.001	0.056	0.210
SQM → CC → EP	0.023	1.27	0.204	-0.012	0.058
SQM → RI → EP	0.084	2.65	0.008	0.022	0.146
HQM → EP → OP	0.173	4.23	<0.001	0.093	0.253
SQM → EP → OP	0.184	4.45	<0.001	0.103	0.265

Source: Developed by author

Table 7 displays results of indirect effect analysis in model, including multiple paths that affect EP and OP through mediating variables. The results show that the indirect effect of HQM and SQM on EP through IEM is the most significant ($p < 0.001$), representing IEM is vital in process of HQM and SQM affecting EP. In addition, HQM and SQM also have significant indirect effects on EP through ED. Conversely, the indirect effects through SP and CC are weak and innocuous. Seen from the fact that HQM and SQM have strong indirect effects on OP through EP as well, it is evident that EP is not only a major mediating variable but also a crucial link joining HQM, SQM and OP. Overall, the indirect effect analysis further reveals the complex relationship network between the variables in the model.

Table 8
Model Fit Indices

Fit Index	Obtained Value	Recommended Threshold	Interpretation
Chi-square (χ^2)	523.67	-	-
Degrees of Freedom (df)	412	-	-
χ^2/df	1.27	< 3.00	Good
p-value	0.078	> 0.05	Good
Comparative Fit Index (CFI)	0.968	> 0.95	Good
Tucker-Lewis Index (TLI)	0.962	> 0.95	Good
Normed Fit Index (NFI)	0.943	> 0.90	Good
Incremental Fit Index (IFI)	0.969	> 0.95	Good
Root Mean Square Error of Approximation (RMSEA)	0.037	< 0.08	Good
RMSEA 90% CI Lower Bound	0.028	-	-
RMSEA 90% CI Upper Bound	0.046	-	-
p-value for RMSEA < 0.05	0.998	> 0.05	Good
Standardized Root Mean Square Residual (SRMR)	0.042	< 0.08	Good
Goodness of Fit Index (GFI)	0.931	> 0.90	Good
Adjusted Goodness of Fit Index (AGFI)	0.918	> 0.90	Good

The model fit index table 8 shows that the structural equation The model fit is decent. Among them χ^2/df value is 1.27 (less than 3.00) and the p value is 0.078 (greater than 0.05), both showing that the model fits the facts rather nicely and there is no significant difference. In addition, the comparative and incremental fit indices such as CFI, TLI, NFI, and IFI all exceed recommended threshold of 0.95, showing a high degree of fit consistency. The RMSEA value is 0.037 (less than 0.08), and its ninety percent confidence interval upper limit is 0.046, which also indicates that the model fits well. Although the p value of RMSEA is less than 0.05, it is usually concerned about its size and confidence interval, and here it is still judged as good in combination with other indicators. Besides the already mentioned ones, the SRMR, GFI, AGFI, etc. are also within the specified limit that is required, which further determines that the model is robust in terms of the fit degree. Thus, all these fit indices indicate that it is very likely our model performs rather nicely for the data. The respective of the unresolved issues are put into the recommended band, besides, they are exceeded by the data, hence, the validity of the formula is considerable. This means that the interrelations you have put into your structural module will be credible and aligned with the detected events.

5. Discussion

This paper revealed the great impact of soft and hard quality management practices on corporate environmental management activities, environmental performance, and operational performance. Concretely, hard quality management practices such as statistical process control and quality management tools led to the company’s internal environmental management, sustainable procurement, and eco-design practices, thus improving environmental performance. Top quality management practices such as leadership involvement and employee engagement have a major impact on corporate eco-design projects and internal environmental management through the creation of a culture of continuous improvement. Furthermore, the study discovered internal environmental management, eco-design, recovery of investments activities is directly related to environmental performance, which is finally, in turn, operational performance of the company.

5.1. Theoretical significance

This study is the first in the area of the interaction among environmental performance, green innovation, quality management, and operational performance. It also provides a new theoretical point of view and support for related fields. The study not only finds but also fills the gaps in these related areas. By building a non-segmented theoretical framework, the study brings out to light the very core and mechanism of the behavior of different variables, thus forming a very firm theoretical base, and laying it down for future researchers.

5.2. Practical significance

The outcome of this research has direct guiding significance for corporate practice. Enterprises can improve environmental performance and operational performance by integrating quality management and green innovation practices, and formulate scientific and reasonable environmental management strategies, so obtaining a win-win scenario of environmental protection and financial gains. In addition, the research results also emphasize the importance of leadership and employee participation in promoting environmental management activities, and provide direction for enterprises to improve their internal management mechanisms.

5.3. Comparison with previous studies

In comparison to previous studies, this one will be more thorough and cover more ground. Previous studies typically examine certain effect of a particular dimension, on the contrary, this one covers a more comprehensive approach on quality management practices towards environmental management activities, the environmental performance, and the operational performance. Also, this study introduces leadership as a moderator, and thus, e-p's role in environmental performance improvement is viewed in a new light, further aiding in the provision of the ideas for the next researches.

6. Conclusion

By way of a systematic analysis, the study adduces evidence that the limited practice of hard quality management and flexible embrace of soft quality management by the organization explains the enhanced performance in environmental management, environmental sustainability, and efficient processes. The study found that both hard quality management practices as well as soft quality management practices highly contribute to corporate internal and sustainable procurement environmental management, eco-design, and the recovery of investments other environmental management activities, thereby improving environmental performance and operational performance. In addition to Initiatives directly affecting environmental performance include internal environmental management, eco-design, and investment recovery strategies have also facilitated the development of the operational performance that internal environmental management, green design and recovery operations have direct impact to a great extent on environmental performance which in turn has driven the improvement of the operational performance. At the same time, The study findings give businesses a theoretical foundation to help them to formulate scientific and reasonable environmental management strategies, which helps to promote enterprises to better fulfill their environmental protection and social responsibilities while pursuing economic benefits.

6.1. Limitations of the Research

Although this study has achieved certain results in revealing the interaction between operational performance and environmental performance and quality management strategies, there are still some limitations. For example, there may be certain deviations in the selection of research samples and data collection, resulting in the research results not being able to fully represent the actual situation of all enterprises. In addition, this study mostly concentrates on the effect of internal factors on corporate performance, while external environmental factors such as policies and market demand may also have an important impact on corporate performance, which needs to be further explored in future research.

6.2. Suggestions for future research

The study sample may be widened and the number of data sources may be increased in order to introduce generalized and universal research results. Meanwhile, new external variables, for instance, policy environment and market demand, might be considered to scrutinize their possible impact on corporate performance. In addition, the differences and commonalities in quality management practices, environmental performance and operational performance between enterprises of different industries and sizes can be explored in depth to provide reference for enterprises to formulate more targeted management strategies.

Reference

Aboelmaged, M. (2018). The drivers of sustainable manufacturing practices in Egyptian SMEs and their impact on competitive capabilities: A PLS-SEM model [Article]. *Journal of Cleaner Production*, *175*, 207-221. https://doi.org/10.1016/j.jclepro.2017.12.053

Abualfaraa, W., AlManei, M., Kaur, R., Al-Ashaab, A., McLaughlin, P., & Salonitis, K. (2023). A Synergetic Framework for Green and Lean Manufacturing Practices in SMEs: Saudi Arabia Perspective [Article]. *Sustainability*, *15*(1), Article 596. https://doi.org/10.3390/su15010596

Agi, M. A. N., & Nishant, R. (2017). Understanding influential factors on implementing green supply chain management practices: An interpretive structural modelling analysis [Article]. *Journal of Environmental Management*, *188*, 351-363. https://doi.org/10.1016/j.jenvman.2016.11.081

Ahmed, N., Assadi, M., Ahmed, A. A., & Banihabib, R. (2023). Optimal design, operational controls, and data-driven machine learning in sustainable borehole heat exchanger coupled heat pumps: Key implementation challenges and advancement opportunities [Review]. *Energy for Sustainable Development*, *74*, 231-257. https://doi.org/10.1016/j.esd.2023.04.004

Ali, Y., Younus, A., Khan, A. U., & Pervez, H. (2021). Impact of Lean, Six Sigma and environmental sustainability on the performance of SMEs [Article]. *International Journal of Productivity and Performance Management*, *70*(8), 2294-2318. https://doi.org/10.1108/ijppm-11-2019-0528

AlQershi, N. A., Saufi, R. B. A., Muhammad, N. M. N., Bin Yusoff, M. N. H., & Thurasamy, R. (2023). Green creativity, TQM and business sustainability of large manufacturing firms in Malaysia [Article]. *Tqm Journal*, *35*(4), 924-945. https://doi.org/10.1108/tqm-10-2021-0309

Ball, P., & Lunt, P. (2020). Lean eco-efficient innovation in operations through the maintenance organisation [Article]. *International Journal of Production Economics*, *219*, 405-415. https://doi.org/10.1016/j.ijpe.2018.07.007

Gaikwad, L., & Sunnapwar, V. (2021). Development of an integrated framework of LGSS strategies for Indian manufacturing firms to improve business performance: an empirical study [Article]. *Tqm Journal*, *33*(1), 257-291. https://doi.org/10.1108/tqm-05-2020-0110

Govindan, K., Rajeev, A., Padhi, S. S., & Pati, R. K. (2020). Supply chain sustainability and performance of firms: A meta-analysis of the literature [Article]. *Transportation Research Part E-Logistics and Transportation Review*, *137*, Article 101923. https://doi.org/10.1016/j.tre.2020.101923

Gupta, A., & Singh, R. K. (2020). Managing operations by a logistics company for sustainable service quality: Indian perspective [Article]. *Management of Environmental Quality*, *31*(5), 1309-1327. https://doi.org/10.1108/meq-11-2019-0246

Huang, Y., Bai, F., Shang, M., & Ahmad, M. (2023). On the fast track: the benefits of ESG performance on the commercial credit financing [Article]. *Environmental Science and Pollution Research*, *30*(35), 83961-83974. https://doi.org/10.1007/s11356-023-28172-x

Kazancoglu, Y., Sagnak, M., Kayikci, Y., & Mangla, S. K. (2020). Operational excellence in a green supply chain for environmental management: A case study [Article]. *Business Strategy and the Environment*, *29*(3), 1532-1547. https://doi.org/10.1002/bse.2451

Khan, S. A. R., Godil, D. I., Jabbour, C. J. C., Shujaat, S., Razzaq, A., & Yu, Z. (2021). Green data analytics, blockchain technology for sustainable development, and sustainable supply chain practices: evidence from small and medium enterprises [Article; Early Access]. *Annals of Operations Research*. https://doi.org/10.1007/s10479-021-04275-x

Layaoen, H. D., Abareshi, A., Abdulrahman, M. D.-A., & Abbasi, B. (2024). Impacts of institutional pressures and internal abilities on green performance of transport and logistics companies [Article; Early Access]. *International Journal of Logistics Management*. https://doi.org/10.1108/ijlm-09-2023-0382

Lazaroiu, G., Bogdan, M., Geamanu, M., Hurloiu, L., Ionescu, L., & Stefanescu, R. (2023). Artificial intelligence algorithms and cloud computing technologies in blockchain-based fintech management [Review]. *Oeconomia Copernicana*, *14*(3), 707-730. https://doi.org/10.24136/oc.2023.021

Le, T. T., Vo, X. V., & Venkatesh, V. G. (2022). Role of green innovation and supply chain management in driving sustainable corporate performance [Article]. *Journal of Cleaner Production*, *374*, Article 133875. https://doi.org/10.1016/j.jclepro.2022.133875

Lim, A.-F., Ooi, K.-B., Lee, V.-H., Tan, G. W.-H., & Sohal, A. (2025). Examining the nexus: supply chain quality management, knowledge sharing, organizational innovation and strategic business performance. Industrial Management & Data Systems. https://doi.org/10.1108/imds-05-2024-0441

Nath, V., & Agrawal, R. (2020). Agility and lean practices as antecedents of supply chain social sustainability [Article]. *International Journal of Operations & Production Management*, *40*(10), 1589-1611. https://doi.org/10.1108/ijopm-09-2019-0642

Parmar, P. S., & Desai, T. N. (2020). Evaluating Sustainable Lean Six Sigma enablers using fuzzy DEMATEL: A case of an Indian [Article]. *Journal of Cleaner Production*, *265*, Article 121802. https://doi.org/10.1016/j.jclepro.2020.121802

Rupasinghe, H. D., & Wijethilake, C. (2021). The impact of leanness on supply chain sustainability: examining the role of sustainability control systems [Article]. *Corporate Governance-the International Journal of Business in Society*, *21*(3), 410-432. https://doi.org/10.1108/cg-06-2020-0217

Tetteh, F. K., Nyantakyi, B., Owusu Kwateng, K., & Osei, H. V. (2024). The mediation role of innovation in the relationship between total quality management and performance of small and medium scale enterprises. *International Journal of Quality & Reliability Management, 42*(2), 676–705. https://doi.org/10.1108/ijqrm-12-2021-0427

Zaid, A. A., & Sleimi, M. (2023). Effect of total quality management on business sustainability: the mediating role of green supply chain management practices [Article]. Journal of

Environmental Planning and Management, 66(3), 524-548. https://doi.org/10.1080/09640568.2021.1997730

Yu, W., Chavez, R., Jacobs, M., & Wong, C. Y. (2020). Innovativeness and lean practices for triple bottom line: testing of fit-as-mediation versus fit-as-moderation models [Article]. International Journal of Operations & Production Management, 40(10), 1623-1647. https://doi.org/10.1108/ijopm-07-2019-0550

Wang, J., & Feng, T. (2023). Supply chain ethical leadership and green supply chain integration: a moderated mediation analysis [Article]. International Journal of Logistics-Research and Applications, 26(9), 1145-1171. https://doi.org/10.1080/13675567.2021.2022640