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Investigating the Achievement of Sustainable Performance through Strategies and Sustainability Challenges Management Using the Fuzzy Quality Function Deployment (FQFD) Approach

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Abstract

Environmental instability and sustainability deficits remain critical threats to the continuity of small and medium-sized enterprises (SMEs), particularly in pollution-intensive sectors such as paints and resins. In Iran, the vulnerability of SMEs in this sector is largely rooted in unsustainable production practices and limited access to environmentally compatible raw materials. This study aims to identify and prioritize sustainability challenges and strategies, and to analyze their influence on sustainable performance criteria—integrating environmental, social, and economic dimensions. A two-phase fuzzy Quality Function Deployment (QFD) model was employed under uncertainty. In the first phase, relationships between sustainability strategies and challenges were examined, with the fuzzy SWARA method applied to determine the relative weights of strategies in Isfahan's paint and resin SMEs. The second phase analyzed interrelations between challenges and sustainable performance using the QFD "House of Quality" to map strategic leverage points. Findings from the fuzzy Delphi stage confirmed the validity of three primary constructs—strategies, challenges, and performance criteria. Results show that implementing sustainability strategies significantly mitigates core challenges such as financial constraints, volatility in raw-material supply, and competitive market pressures. The analysis further identified emission reduction, energy efficiency, and product quality and durability as the most influential sustainability performance criteria. The study concludes that enhancing access to sustainable raw materials, supported by green financing and policy incentives, enables SMEs to reduce pollutant and greenhouse gas emissions, optimize resource use, and improve product longevity. Overcoming financial and sourcing barriers fosters technological innovation and operational efficiency, strengthening firms' competitiveness in domestic and international markets. By integrating targeted fiscal, technological, and managerial interventions, Iran's paint and resin SMEs can advance toward sustainability while contributing to national environmental and economic objectives.

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Introduction

Small and medium-sized enterprises (SMEs) are widely recognized as major sources of employment and key drivers of economic growth (Mculela Kongolo, 2010; p. 2287). In line with established definitions, enterprises with fewer than 500 employees are classified as SMEs (Rezaei Monfared et al., 2023; p. 79). According to data from the Organisation for Economic Co-operation and Development (OECD), SMEs account for approximately 50–60 percent of total employment and economic growth across member states.

In Iran, statistics published by the Iran Chamber of Commerce, Industries, Mines, and Agriculture in 2023 indicate that SMEs contribute an estimated 60 percent to national employment and between 7 and 9 percent to the gross domestic product (GDP). Despite their economic significance, the growth trajectory of SMEs in Iran has encountered substantial challenges in recent years. Approximately half of these businesses fail within the first five years, largely due to restricted access to critical resources and the adverse environmental impacts associated with industrial activity (Al-Amin & Baldaji, 2024; p. 143460).

Among the various causes of instability, negative environmental effects are particularly prominent (Sabaghi et al., 2024). These impacts are especially acute in certain industrial sectors, including paints and resins (Shahin et al., 2024). Reports from the Iranian Color Research Institute highlight that small- and medium-sized firms in this sector contribute to atmospheric pollution and environmental degradation through the use of chemical compounds and volatile organic solvents. Such substances, employed during both the production and drying phases, release harmful gases that exacerbate ozone layer depletion and greenhouse gas accumulation.

Additionally, chemicals such as heavy metals and synthetic resins—introduced to enhance product quality—can cause severe pollution if inadequately managed. When these materials leach into local water sources and soil systems, they pose significant risks to environmental and public health (Alivand Zahmatkesh et al., 2023; p. 1458).

Untreated industrial wastewater often contains toxic compounds that can severely damage aquatic ecosystems (Mishra et al., 2022). Such environmental degradation has cascading consequences—heightening stakeholders' concerns over ecological risks, decreasing their satisfaction, increasing operational costs, lowering productivity, and ultimately destabilizing small- and medium-sized enterprises (SMEs) in the paint and resin sector (Farrokh et al., 2023; p. 5188).

The lack of sustainability among Iranian SMEs in this industry has far-reaching socioeconomic repercussions. One immediate impact is the reduction of employment, contributing to higher national unemployment rates. Firm closures also diminish industry-level competition and innovation, which erodes product quality and can shift the market structure toward monopolistic conditions. Furthermore, reduced domestic production combined with greater reliance on imported paint and resin products increases costs and inflicts harm on the national economy. Ensuring the long-term viability of SMEs in this sector is therefore of strategic importance.

Sustainable performance entails the integrated management of resources, materials, and information, with simultaneous attention to environmental, social, and economic dimensions (Sohail Shakeel et al., 2024; p. 123397). Achieving such sustainability is inherently challenging because SMEs face diverse and complex barriers: securing reliable supplies of high-quality, environmentally sustainable raw materials (Sicard Lourdes & Fasci, 2023; p. 38); adapting to frequent changes in health, safety, and environmental regulations, which increase operational complexity and compliance costs (Kelly, 2023; p. 6821); maintaining continuous innovation to support new product development amid the high costs of research and development (Akhtar et al., 2024; p. 21); and coping with market uncertainty (Wu et al., 2021; p. 4).

Effective strategies to address these challenges include fostering environmental awareness and a culture of sustainability (Mirzaei et al., 2021), prioritizing sustainable supplier selection (Granadero et al., 2023; p. 5), and implementing waste minimization and recycling programs

(Al-Amin & Baldaji, 2024; p. 4). In essence, reducing sustainability barriers through targeted strategies is critical to sustaining SME operations in the paint and resin sector.

In recent literature, sustainable performance has been examined through multiple lenses. For instance, Nakra and Kashyap (2025), in a study entitled *Responsible Leadership and Organizational Sustainability Performance*, investigated the mediating role of sustainable human resource management. Their findings demonstrate that leadership engagement and top-management support exert a positive, significant impact on achieving sustainable performance, while sustainable HRM practices effectively mediate the leadership–performance relationship.

Artz et al. (2025) conducted a study entitled *The Impact of Big Data Analytics on Sustainable Performance*, involving 522 companies from the United States and Canada. Their findings demonstrated that big data analytics significantly influences all three dimensions of sustainable performance: economic, social, and environmental.

Nikseresht et al. (2024), in *Sustainable Green Logistics and Remanufacturing: A Bibliometric Analysis and Future Research Orientations*, analyzed 2,180 research and review articles published between 2008 and 2023 in the Scopus database. Their bibliometric mapping identified seven principal clusters within the sustainable green logistics and remanufacturing (SGLR) domain. The authors highlighted research gaps in three key areas: advancing digitalization, expanding research coverage, and developing efficient, carbon-neutral logistics and supply chain solutions.

Abako and Edimarha (2024) examined sustainable supply chain management in the medical sector, concluding that integrating environmental, social, and economic considerations is essential. They emphasized the role of technological innovation and stakeholder collaboration in enhancing medical supply chain sustainability.

Al-Amin and Baldaji (2024), in *A Quality Function Deployment (HoQ) Matrix-Based Optimization Model for Reducing Sustainable Supply Chain Management Adoption Challenges in Bangladesh Ready-Made Garment Industries*, proposed a hybrid optimization model combining Quality Function Deployment and the Analytical Hierarchy Process. The study identified 25 challenges and 16 strategies; implementing 12 strategies within a budgetary framework yielded a sustainability score of 0.4511, strengthening global competitiveness and offering a transferable model for other industries.

Lee and Wu (2020) analyzed *South Korea's New Green Deal Policy*, an evolution of the earlier green growth agenda with a stronger focus on sustainability. This policy targets green urban development, low-carbon energy, and innovative green industries, addresses achievements and shortcomings of the prior period, and underscores the need for a low-carbon, climate-neutral economy.

Waqas et al. (2023) investigated how governmental and customer pressures influence sustainable performance and customer satisfaction in China's manufacturing industry, finding that green production, creativity, brand innovation, and brand image are critical drivers. Similarly, Söderholm (2020) discussed technological transition challenges in moving toward a green economy, identifying five central issues: global environmental risk management, radical innovation in sustainable technologies, uncertainty within green capitalism, the role of policy design, and distributional impacts.

While these studies examine strategies and challenges affecting sustainable performance, they do not explicate how sustainable performance can be achieved, nor do they offer a comprehensive view of performance criteria. In contrast, the present research not only identifies sustainability performance criteria for SMEs in Isfahan's paint and resin sector but also analyzes the pathways for achieving them through targeted strategies and effective challenge management.

Recognizing that understanding the relationship between strategies and sector-specific challenges provides clearer, more actionable solutions, this study employs a two-stage fuzzy Quality Function Deployment (QFD) matrix under conditions of uncertainty. In the first stage, the relationships between proposed sustainability strategies and challenges are examined. Given the heterogeneous importance of strategies, their priority weights were determined using the Step-Wise Weight Assessment Ratio Analysis (SWARA) method in a fuzzy context, which is valued for its applicability in complex decision environments and its capacity to incorporate expert judgment.

In the second stage, the QFD matrix is applied to analyze the relationships between sustainability challenges and performance criteria, thereby mapping the complex interplay between customer needs, strategic responses, and operational barriers. This approach yields a structured, evidence-based framework for guiding SMEs toward measurable improvements in sustainable performance.

Materials and Methods

The present study is applied in its objective, causal in nature and methodological approach, and survey-based in terms of data collection. The sequential stages of the research implementation are depicted in Figure 1.

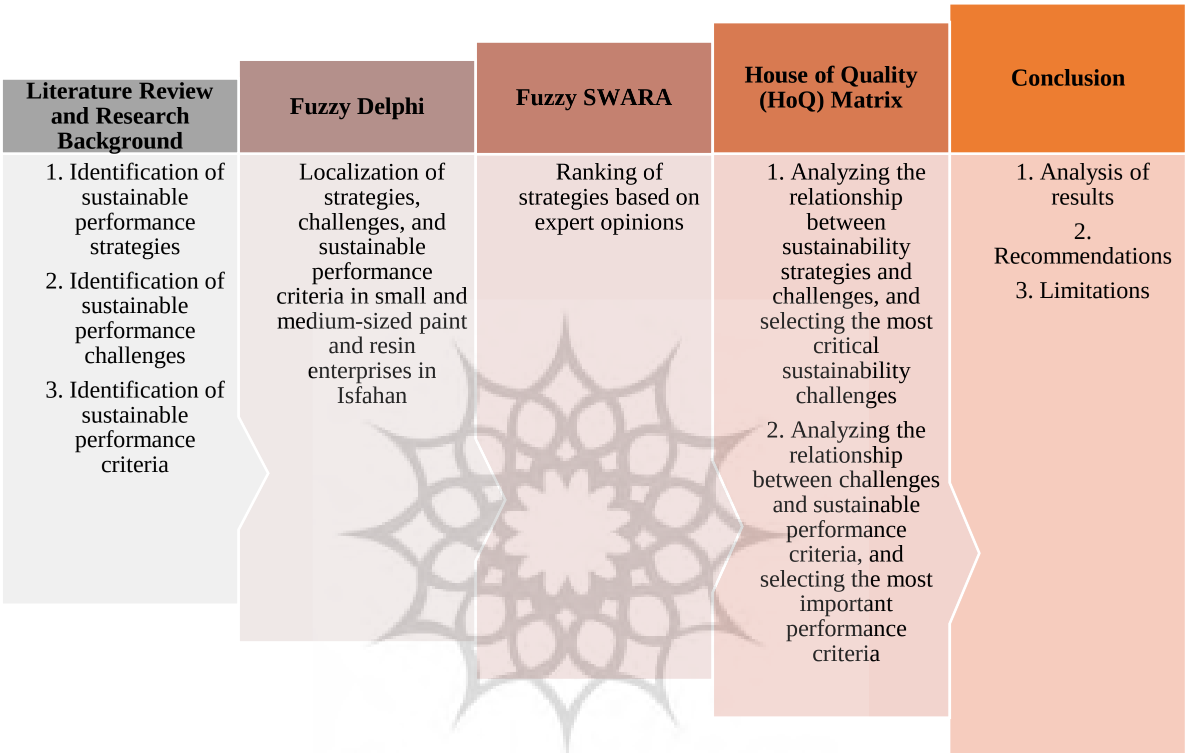

Figure 1. Stages of research implementation.

Step 1: Literature Review and Research Background

In the first step, sustainability strategies, challenges, and performance criteria were identified using a review of the literature and research background, as shown in Table 5.

Step 2: Delphi Method

In the second step, the identified sustainability strategies, challenges, and performance criteria from the literature review were localized using the opinions of managers of small and medium-sized paint and resin companies in Isfahan. The fuzzy Delphi approach continues until no factor falls below the threshold. Also, to compare the experts' viewpoints, if the difference in the defuzzified values of their opinions for each factor in the new round is less than 0.1 compared to the previous round, that factor is confirmed. The steps of the fuzzy Delphi approach are as follows (Ahmadi et al., 1403 [2024]; 17):

Step 1: Gathering Expert Opinions

Expert opinions were collected based on linguistic variables (Table 1). The experts in this research included managers of small and medium-sized paint and resin companies in Isfahan, and 23 people were selected using the snowball sampling method.

Table 1. Corresponding Linguistic Terms and Triangular Fuzzy Numbers

No.	Linguistic Variables	Corresponding Fuzzy Numbers
1	Very Important	(0.7, 0.9, 1)
2	Important	(0.5, 0.7, 0.9)
3	Medium Importance	(0.3, 0.5, 0.7)
4	Low Importance	(0.1, 0.3, 0.5)
5	Very Low Importance	(0, 0.1, 0.3)

Step 2: Calculating the Fuzzy Value of Each Question

After gathering expert opinions, the various opinions of experts are converted into a consensus matrix. It is worth noting that the fuzzy value of each question is displayed as $\tilde{A} = (L_j, M_j, U_j)$ Lj is the lower bound, Mj is the middle bound, and Uj is the upper bound. Xij is also the value assigned by the experts. The consensus matrix of expert opinions is formed based on the following relations:

$$L_j = Min(x_{ij}) \qquad i = 1, 2, \ldots, n \qquad j = 1, 2, \ldots, m$$

$$M_j = (\prod_{i=1}^{n.m} x_{ij})^{\frac{1}{n}} \qquad i = 1, 2, \ldots, n \qquad j = 1, 2, \ldots, m$$

$$U_j = Max(x_{ij}) \qquad i = 1, 2, \ldots, n \qquad j = 1, 2, \ldots, m$$

Step 3: Defuzzification

In various studies, several relations have been used to defuzzify fuzzy numbers. In this study, was used for defuzzification.

$$S_j = \frac{L_j + 2M_j + U_j}{4}$$

Step 4: Evaluating Factors or Questions Based on the Threshold

In this step, factors are confirmed or rejected based on determining a threshold. One method of determining the threshold is to ask experts, and in this study, a value of 0.6 was considered for determining the threshold.

Fuzzy SWARA Method

The steps of the fuzzy SWARA approach are as follows:

Step 1: Ranking Criteria in Descending Order

In the first step, based on expert opinions, the criteria determined for selecting sustainability strategies are ranked in descending order. Given the presence of more than one expert, the criteria are arranged in descending order based on the frequency and calculation of the corresponding percentage.

Step 2: Determining the Relative Importance Ratio (Sj)

In the second step, starting from the second criterion, the relative importance of criterion j to the previous criterion (j-1) is obtained. This process continues until the last criterion. It is worth noting that the calculation of the relative importance ratio is not performed for the first criterion. To determine the relative importance, experts were asked for their opinions based on linguistic variables based on fuzzy conditions (Table 2).

Table 2. Linguistic Variables

No.	Linguistic Variables	Corresponding Fuzzy Numbers
1	Equal Importance	(1, 1, 1)
2	Relatively Less Important	(0.667, 0.775, 1)
3	Less Important	(0.4, 0.5, 0.667)
4	Much Less Important	(0.285, 0.333, 0.4)
5	Very Less Important	(0.222, 0.25, 0.285)

Step 3: Consensus of Expert Opinions

In the third step, the opinions of the 23 selected experts in this study are converted into a consensus matrix using Relations 1, 2, and 3. It is worth noting that the fuzzy value of each question is displayed as, where Lj is the lower bound, Mj is the middle bound, and Uj is the upper bound.

Step 4: Determining the Growth Coefficient (Kj)

In the fourth step, the growth coefficient of the j-th criterion is calculated using Equation The growth coefficient for the first criterion is assumed to be 1 by default.

$$K_j = \begin{Bmatrix} 1 & j=1 \\ S_j \oplus 1\% & j>1 \end{Bmatrix}$$

Step 5: Determining the Importance of the j-th Criterion (qj)

In this step, the importance of the j-th criterion is calculated using Equation. The importance of the first criterion is assumed to be 1 by default.

$$q_j = \begin{Bmatrix} 1 & j=1 \\ \frac{q_{j-1}}{K_j} & j>1 \end{Bmatrix}$$

Step 6: Determining the Fuzzy Relative Weight

To determine the fuzzy relative weight of the j-th criterion, Equation is used.

$$W_j = \frac{q_j}{\sum_{j=1}^{n} q_j}$$

After determining the fuzzy relative weight, the definite weight of each criterion is calculated using Equation.

$$W_j = \frac{W_{Lj} + W_{Mj} + W_{Uj}}{3}$$

In Equation, and represent the lower, middle, and upper bounds of the final weight fuzzy number, respectively.

Step 7: Fuzzy Quality Function Deployment (QFD) Matrix

The Quality Function Deployment matrix is used to translate customer needs into technical specifications. The Quality Function Deployment matrix translates the voice of the customer (whats) into design requirements (hows). The fuzzy Quality Function Deployment matrix is superior to the traditional Quality Function Deployment matrix because it considers the ambiguity in expert opinions and provides more accurate results. In this study, a two-stage fuzzy Quality Function Deployment matrix was used, and its implementation steps are presented below:

Step A: Determining Customer Wants and Needs and Technical and Engineering Requirements

In the first step, customer wants and needs and technical and engineering requirements are identified and placed in the rows of the Quality Function Deployment matrix. In this study, in the first stage of the Quality Function Deployment matrix, sustainability strategies are the customer wants and needs, and sustainability challenges are the technical and engineering requirements. In the second stage of the Quality Function Deployment matrix, sustainability challenges are considered as customer wants and needs, and sustainability performance criteria are considered as technical and engineering requirements. In addition, in the first and second stages of the Quality Function Deployment matrix, weight and importance are considered for sustainability strategies and challenges, respectively. The weight of sustainability strategies is obtained using the fuzzy SWARA approach. Also, the weight of sustainability challenges is obtained from the first stage of the fuzzy Quality Function Deployment matrix.

Step B: Determining the Relationship Between Customer Needs and Technical and Engineering Requirements

In the second step, the relationship between the i-th need and the j-th service is determined and denoted by Rij. For this purpose, fuzzy linguistic variables are used as shown in Table 3.

Table 3. Linguistic Variables

No.	Linguistic Variables	Corresponding Fuzzy Numbers	Symbol
1	Strong Relationship	(0.7, 1, 1)	△
2	Medium Relationship	(0.3, 0.5, 0.7)	○
3	Weak Relationship	(0, 0, 0.3)	□

According to Table 3, each expert was asked to identify the relationship between strategies and sustainability challenges in the first stage of the Quality Function Deployment matrix and the relationship between sustainability challenges and sustainability performance criteria in the second stage of the Quality Function Deployment matrix. To integrate expert opinions and given the use of triangular fuzzy numbers, the geometric mean was used.

Step C: Determining the Relationship and Correlation Between Technical and Engineering Requirements

In the third step, the correlation between technical and engineering requirements is determined at the top of the Quality Function Deployment matrix. In the first stage of the Quality Function Deployment matrix, the technical and engineering requirements are the sustainability challenges; in the second stage of the Quality Function Deployment matrix, the technical and engineering requirements are the sustainability performance criteria. The relationship between technical and engineering requirements will be determined through Table 4.

Table 4. Correlation Linguistic Variables of Technical and Engineering Requirements

No.	Correlation Linguistic Variables	Corresponding Fuzzy Numbers	Symbol
1	Very Positive Correlation	(0.3, 0.5, 0.7)	⊕
2	Positive Correlation	(0, 0.3, 0.5)	✚
3	Negative Correlation	(-0.5, -0.3, 0)	⊖
4	Very Negative Correlation	(-0.7, -0.5, -0.3)	▭

Step D. Determining the Importance of Technical and Engineering Requirements

In the fourth step, the importance of technical and engineering requirements, which are sustainability challenges in the first stage of the Quality Function Deployment matrix and sustainability performance criteria in the second stage, is determined. This value is denoted by RIj and is obtained from Equation.

$$RI_j = \sum_{i-1}^{m} W_i \otimes RI_{ij} \qquad j = 1, \dots, n$$

After determining the importance of technical and engineering requirements, their final weight (RIj*) must be calculated. To determine the final weight of the technical and engineering requirements in each stage of the Quality Function Deployment matrix, Equation is used.

$$RI_j^* = RI_j \oplus \sum_{j \neq j'} T_{jj'} \otimes RI_{j'} \qquad j = 1, \dots, n$$

In Equation, is the correlation of the m-th technical and engineering requirement with the j-th technical and engineering requirement.

Step E: Defuzzification

$$\text{crispvalue} = \frac{L+2M+U}{4}$$

Research Findings

By reviewing the literature and research background, sustainability strategies, challenges, and performance criteria have been identified as shown in Table 5.

Table 5. Sustainability Strategies, Challenges, and Sustainable Performance Criteria

Row		Sustainability Strategies, Challenges, and Performance Criteria	Definition	Source
1	Sustainability Strategies	Government Policies and Incentives	Government policies and incentives refer to the set of programs and strategies implemented by governments to achieve sustainable development and reduce carbon emissions.	Lee and Wu (2020)
2		Environmental Standards and Certifications	Environmental standards and certifications are a set of criteria and requirements that oblige organizations to adhere to environmental principles in their processes and products. These standards, such as environmental certifications, help companies reduce their environmental impacts and simultaneously adhere to their social responsibility commitments.	Moser et al. (2013)
3		Sustainable Supplier Selection	Sustainable supplier selection refers to the responsible and efficient identification and procurement of raw materials in a way that prevents damage to the environment and enables the long-term supply of these materials.	Holl et al. (2023)
4		Green Technology-Based Research and Development	Green technology-based research and development refers to the process of innovation and development of technologies aimed at reducing environmental pollution, improving energy efficiency, using renewable energy sources, and creating products and processes that have fewer negative impacts on the environment.	Fang (2023)
5		Production Process Management	Production process management and product lifecycle sustainability mean optimizing the stages of production to consumption to reduce waste and greenhouse gases.	Sakib et al. (2024)
6		Education, Culture Building, and Social Responsibility	Education, culture building, and social responsibility refer to processes that strengthen responsible and sustainable behaviors in society by raising awareness and promoting knowledge. These processes are carried out in management education to train leaders aware of social, environmental, and economic issues for achieving sustainable development.	Azmat et al. (2023)
7		Supply Chain Transparency	Supply chain transparency, through information sharing and coordination among partners, improves efficiency, reduces costs, and strengthens trust.	Li et al. (2023)
8		Stakeholder Collaboration	Stakeholder collaboration refers to the active participation of various groups in sustainable business model processes. This collaboration includes stakeholder interaction in various aspects of the value stream (including intent, proposal, creation, delivery, and value capture), which helps facilitate sustainable development and strengthen the organization's relationships with stakeholders.	Attanasio et al. (2021)
9		Waste Management	Waste management and pollution reduction involve the use of innovative approaches in waste resource management with the aim of conserving resources, reducing environmental impacts, and increasing resilience to climate change. These approaches are	Dada et al. (2024)

Row		Sustainability Strategies, Challenges, and Performance Criteria	Definition	Source
			also designed based on the principles of the circular economy and the use of technological innovations.	
10		Green Logistics	Green logistics refers to the optimization and sustainable management of logistics and supply chain processes, which aims to reduce negative environmental impacts, such as reducing greenhouse gas emissions and using green solutions.	Nikseresht et al. (2023)
1	Sustainability Challenges	Financial Challenges	Financial challenges in sustainability refer to the financial constraints that companies, especially small and medium-sized enterprises, face in securing the necessary resources to invest in green innovations, adapt to social and environmental pressures, and achieve sustainable goals.	Yadegaridehkordi et al. (2023)
2	Sustainability Challenges	Access to Sustainable Raw Materials	Access to sustainable raw materials means having access to resources that are extracted, processed, and transported in an environmentally friendly and socially responsible manner.	Abako and Edimarha (2024)
3	Sustainability Challenges	Competitive Challenges and Market Fluctuations	. Competitive challenges and market fluctuations refer to the difficulties that companies face in maintaining their market share and profitability due to factors such as increased competition, price volatility, and changes in customer demand.	Ijomah et al. (2024)
4	Sustainability Challenges	Cultural and Behavioral Challenges	Cultural and behavioral challenges include resistance to change, lack of awareness and knowledge about sustainability, and the need to change organizational culture and individual behaviors.	Isensee et al. (2020)
5	Sustainability Challenges	Environmental Challenges	Environmental challenges include issues such as climate change, pollution, waste generation, and resource depletion, which companies must address to minimize their negative environmental impact.	Amjad et al. (2021)
6	Sustainability Challenges	Technological Challenges	Technological challenges include the lack of access to or high cost of up-to-date green technologies, which hinders the adoption of sustainable practices.	Söderholm (2020)
7	Sustainability Challenges	Legal Challenges	Legal challenges include complexities and changes in environmental laws and regulations, which can increase operational costs and uncertainties for companies.	Sisodia et al. (2020)
1	Sustainability Performance Criteria	Reducing Environmental Pollutant Emissions	Reducing environmental pollutant emissions refers to efforts to minimize the release of harmful substances into the air, water, and soil, which helps improve environmental quality and protect public health.	Lutfi et al. (2023)
2	Sustainability Performance Criteria	Reducing Energy Consumption	Reducing energy consumption means using energy more efficiently and reducing the need for energy, which helps conserve resources and decrease greenhouse gas emissions.	Pradhan et al. (2024)
3	Sustainability Performance Criteria	Product Quality and Durability	Product quality and durability refer to the characteristics of products that meet customer needs and expectations and can function effectively for a long period of time, which reduces the need for replacements and waste.	Waqas et al. (2023)
4	Sustainability Performance Criteria	Social Responsibility	Social responsibility means the commitment of organizations to ethical behavior and contributing to the economic development of the community while improving the quality of life of the workforce and their families as well as the local community and society at large.	Xu and Wang (2024)
5	Sustainability Performance Criteria	Innovation	Innovation refers to the development and implementation of new ideas, products, services, and processes, which can improve efficiency, competitiveness, and sustainability.	Surya et al. (2021)
6	Sustainability Performance Criteria	Employee Satisfaction	Employee satisfaction refers to the positive feelings and attitudes of employees towards their job and work environment, which increases motivation, productivity, and retention.	Juliadi et al. (2023)

Row	Sustainability Strategies, Challenges, and Performance Criteria	Definition	Source
7	Produced waste	Produced waste refers to the waste and residues resulting from companies' production and service activities and processes.	Qian et al. (2023)
8	Profitability	Profitability refers to the positive financial performance of companies, achieved through the implementation of sustainability measures, including attention to the environment, society, and sustainable development goals, and which is maintainable in the long term.	Muhmad and Muhamad (2020)

After completing the questionnaires by the experts and conducting the steps related to the Fuzzy Delphi Method, the calculations were performed based on the obtained values using the mentioned formulas, and the results are presented in Table 6.

Table 6. Calculations of the Fuzzy Delphi Method

Strategies

Title	L	M	U	Defuzzified Value	Result
Government policies and incentives	0.5	0.813925625	1	0.781962812	Approved
Environmental standards and certifications	0.3	0.723652756	1	0.686826378	Approved
Selection of sustainable suppliers	0.5	0.813925625	1	0.781962812	Approved
Green technology-based R&D	0.3	0.688178859	1	0.669089429	Approved
Production process management	0.5	0.774026497	1	0.762019248	Approved
Training, awareness, and social responsibility	0.5	0.855881454	1	0.802940727	Approved
Supply chain transparency	0.3	0.643392093	1	0.646696047	Approved
Stakeholder collaboration	0.3	0.688178859	1	0.669089429	Approved
Waste management	0.5	0.736083248	1	0.743041624	Approved
Green logistics	0.3	0.723652756	1	0.686826378	Approved

Challenges

Title	L	M	U	Defuzzified Value	Result
Financial challenges	0.7	0.9	1	0.875	Approved
Resource supply and access to sustainable raw materials	0.5	0.855881454	1	0.802940727	Approved
Competitive challenges and market fluctuations	0.5	0.813925625	1	0.781962812	Approved
Cultural and organizational challenges	0.1	0.621343239	1	0.585671619	Approved
Environmental challenges	0.3	0.723652756	1	0.686826378	Approved
Technical challenges	0.3	0.676557345	1	0.663278673	Approved
Governmental rules and regulations	0.3	0.760955244	1	0.705477622	Approved

Performance Criteria

Title	L	M	U	Defuzzified Value	Result
Environmental pollutant emissions	0.3	0.7609552	1	0.705477622	Approved
Energy consumption	0.3	0.7609552	1	0.705477622	Approved
Product quality and durability	0.5	0.8558815	1	0.802948727	Approved
Compliance with regulations and social responsibilities	0.5	0.7360832	1	0.743041624	Approved
Innovation	0.3	0.7609552	1	0.705477622	Approved
Employee job satisfaction	0.7	0.9	1	0.875	Approved
Waste generated	0.5	0.7740265	1	0.762013248	Approved
Profitability	0.5	0.7740265	1	0.762013248	Approved

Based on the confirmation of all sustainability strategies, challenges, and performance criteria by the managers of small and medium-sized paint and resin enterprises in Isfahan, there is no need to proceed with the second round of the fuzzy Delphi approach. Subsequently, and according to the experts' opinions, the values of S (the relative importance ratio), K (the growth coefficient), and Q (the importance level of the criteria) were calculated as shown in Table 7.

Table 7. Calculation of S, K, and Q values in the fuzzy SWARA approach

Strategy	S			K			Q		
	L	M	U	L	M	U	L	M	U
Government Policies and Incentives	–	–	–	1	1	1	1	1	1
Environmental Standards and Certifications	1	1	1	2	2	2	0.5	0.5	0.5
Sustainable Supplier Selection	0.667	0.926383	1	1.667	1.926383	2	0.25	0.259554	0.29994
R&D Based on Green Technology	0.4	0.766381	1	1.4	1.766381	2	0.125	0.146941	0.214243
Production Process Management	0.667	0.858185	1	1.667	1.858185	2	0.0625	0.079078	0.12852
Training, Awareness, and Social Responsibility	0.285	0.686577	1	1.285	1.686577	2	0.03125	0.046886	0.100016
Supply Chain Transparency	0.4	0.684398	1	1.4	1.684398	2	0.015625	0.027836	0.07144
Stakeholder Collaboration	0.667	0.903068	1	1.667	1.903068	2	0.007813	0.014627	0.042855
Waste Management	0.4	0.842593	1	1.4	1.842593	2	0.003906	0.007938	0.030611
Green Logistics	0.4	0.697063	1	1.4	1.697063	2	0.001953	0.004678	0.021865
							1.998047	2.087537	2.409489

After completing Table 7 and calculating the S, K, and Q values using Equation, the final weights of the sustainability strategies were obtained as shown in Table 8.

Table 8. Final Weighting of Sustainability Strategies

Strategy	W (L)	W (M)	W (U)	W
Government Policies and Incentives	0.415026	0.479033	0.500489	0.464849
Environmental Standards and Certifications	0.207513	0.239517	0.250244	0.232425
Sustainable Supplier Selection	0.103756	0.124335	0.150117	0.126069
R&D Based on Green Technology	0.051878	0.07039	0.107226	0.076498
Production Process Management	0.025939	0.037881	0.064323	0.042714
Training, Awareness, and Social Responsibility	0.01297	0.022460	0.050057	0.028495
Supply Chain Transparency	0.006485	0.013334	0.035755	0.018525
Stakeholder Collaboration	0.003252	0.007007	0.021449	0.010566
Waste Management	0.001621	0.003803	0.01532	0.009615
Green Logistics	0.000811	0.002241	0.010943	0.004665

As shown in Table 8, the three strategies of Government Policies and Incentives, Environmental Standards and Certifications, and Sustainable Supplier Selection were identified as the most important sustainability strategies for performance in small and medium-sized paint and resin enterprises in Isfahan. After determining the importance of each sustainability strategy, the results of the relationship between the strategies and sustainability challenges, based on the first matrix of the House of Quality, are presented in Table 9.

Table 9. Results of the First Fuzzy House of Quality Matrix

Row	Sustainability Challenges	RI	RI*	Normalized RI
1	Financial challenges	0.731	2.39	0.238
2	Access to sustainable raw materials	0.809	2.04	0.204
3	Competitive challenges and market fluctuations	0.674	1.64	0.164
4	Cultural and organizational challenges	0.376	1.22	0.122
5	Environmental challenges	0.925	1.37	0.137
6	Technical challenges	0.075	0.615	0.061
7	Governmental laws and regulations	0.790	0.709	0.070

According to the values presented in Table 9, the top three challenges are financial issues, securing resources and access to sustainable raw materials, and competitive challenges and market fluctuations, ranked first to third, respectively. After determining the importance of each sustainability strategy, the results of the relationship between the strategies and the performance sustainability criteria, based on the second matrix of the House of Quality, are presented in Table 10.

Table 10. Results of the Second Fuzzy House of Quality Matrix

Row	Performance Sustainability Criteria	RI	RI*	Normalized RI
1	Level of environmental pollutant emissions	0.482	2.55	0.1296
2	Energy consumption	0.633	2.60	0.1290
3	Product quality and durability	0.678	2.487	0.1289
4	Compliance with regulations and social responsibilities	0.531	2.41	0.1275
5	Innovation	0.790	2.57	0.1268
6	Employee job satisfaction	0.535	2.486	0.1264
7	Waste generated	0.659	2.610	0.1217
8	Profitability	0.760	2.611	0.1096

According to the values presented in Table 10, the top three criteria are environmental standards, energy consumption, and product quality and durability, ranked first to third, respectively.

Discussion and Conclusion

Small and medium-sized enterprises (SMEs) constitute a foundational pillar of employment generation and industrial production in advanced economies, and their relevance has been increasingly recognized across developing contexts. Their comparatively low start-up costs and operational agility relative to large-scale industries are key drivers behind the widespread appeal of establishing and expanding such enterprises. In addition to bolstering gross domestic product (GDP), SMEs generate substantial employment opportunities, prompting governments to actively support this sector through targeted policies, resource provision, and institutional reforms aimed at facilitating its growth.

Despite their potential, SMEs encounter persistent operational challenges encompassing constrained access to financial capital, limited availability of high-quality raw materials, exposure to environmental risks, and other sector-specific vulnerabilities. Such pressures undermine their long-term viability, with the majority failing to sustain operations beyond a five-year horizon. This study examines pathways for achieving sustainable performance within SMEs operating in the paint and resin industry in Isfahan, with emphasis on strategic interventions to address sustainability-related challenges.

Drawing on prior scholarship and empirical evidence, the research first identified relevant sustainability strategies, critical challenges, and key performance criteria. The literature reveals strategies including: government incentives and policy frameworks; adherence to environmental standards and certification schemes; selection of sustainable suppliers; investment in green technology-based research and development; optimization of production processes; targeted education and awareness initiatives; strengthened corporate social responsibility; transparency throughout the supply chain; multi-stakeholder collaboration; integrated waste management; and adoption of green logistics.

The analysis further extracted principal sustainability challenges: financial constraints; restricted access to sustainable inputs and raw materials; competitive pressures and market instability; cultural and organizational barriers; environmental degradation; technical limitations; and compliance with regulatory requirements. In turn, sustainability performance criteria were distilled as follows: emissions of environmental pollutants; energy consumption levels; product quality and durability; regulatory and social responsibility compliance; innovative capacity; employee job satisfaction; production waste minimization; and profitability.

Using the Fuzzy Delphi method, the sustainability strategies, operational challenges, and performance criteria were validated by a panel of experts drawn from SMEs in the paint and resin sector of Isfahan Province. The verified strategies were subsequently prioritized through expert scoring using the Fuzzy Step-wise Weight Assessment Ratio Analysis (SWARA) technique. The ranking results identified *government policies and incentives*, *environmental standards and certifications*, and *sustainable supplier selection* as the most critical strategies for advancing sustainability in this sector.

Governments, in particular, can play a decisive role in meeting the fundamental needs of SMEs—especially financial requirements—through targeted policies, supportive regulations, and direct financial assistance. As emphasized by Li and Wu (2020), such support may include low-interest loans, subsidies, and dedicated financial facilities, enabling SMEs to invest in sustainable technologies and production process enhancements.

The first stage of the Fuzzy Quality Function Deployment (QFD) analysis demonstrated that the implementation of sustainability strategies exerts a substantial impact on overcoming critical barriers to sustainable performance. Specifically, strategies geared toward sustainability were found to address financial constraints, improve access to sustainable raw materials, and mitigate risks associated with market competition and volatility. For example, the deliberate selection and expansion of sustainable supplier networks can substantially improve the procurement of environmentally responsible raw materials—an observation consistent with the findings of Hall et al. (2023). Reliable access to sustainable inputs in turn facilitates process upgrades and the manufacture of products that more effectively meet environmental compliance standards.

Such measures simultaneously address raw material scarcity and enhance market competitiveness by fostering the production of eco-friendly goods that align with consumer expectations and sustainability imperatives. This dual benefit not only drives sales growth in domestic and international arenas but also reinforces the competitive positioning and brand image of SMEs committed to environmental responsibility.

The second phase of the Fuzzy Quality Function Deployment (QFD) analysis revealed that *environmental pollutant emissions*, *energy consumption*, and *product quality and durability* rank as the most critical sustainability performance criteria for SMEs in the paint and resin sector of Isfahan Province. The results underscore that achieving these performance outcomes is feasible when sustainability challenges are systematically addressed through targeted strategic interventions.

For instance, overcoming the challenge of limited access to sustainable raw materials—among the most critical barriers—can be facilitated by strategies such as prioritizing the selection of sustainable suppliers and deploying green technologies to identify and qualify such suppliers. Reliable access to sustainable inputs directly contributes to performance gains, including reductions in greenhouse gas emissions and lower energy consumption.

This relationship is particularly salient in paint and resin manufacturing, where production processes often depend on synthetic petrochemical compounds that generate considerable environmental burdens. Substituting fossil-based inputs with plant-derived resins or natural pigments can markedly decrease carbon dioxide and other greenhouse gas emissions. In parallel, adopting these bio-based or naturally sourced materials frequently enables production methods that are less energy-intensive, thereby diminishing reliance on fossil fuel-derived energy streams.

Collectively, these measures not only advance environmental performance metrics but also align the sector with broader sustainability objectives, strengthen regulatory compliance, and enhance competitiveness by responding to rising market demand for eco-friendly products.

Sourcing sustainable raw materials contributes substantially to the quality and durability of products manufactured by small and medium-sized paint and resin enterprises in Isfahan. Sustainable inputs typically originate from natural and renewable resources produced under controlled conditions and in compliance with environmental standards, thereby ensuring higher inherent quality. Such materials are generally free from harmful chemical additives and synthetic compounds that could compromise product integrity. In addition, products made with environmentally responsible inputs often exhibit enhanced physical properties, improving resilience and longevity. For example, plant-based paints and resins have demonstrated superior resistance to weathering and abrasion, resulting in extended service life and reduced deterioration over time. This enhanced quality and durability not only fosters greater consumer satisfaction but also lowers long-term maintenance and replacement costs.

Empirical evidence supports these outcomes: Elamin and Baldaji (2024) found that firms able to secure sustainable raw materials frequently redesign production processes to minimize greenhouse gas emissions, as many such inputs inherently entail lower environmental impacts. Addressing financial challenges through targeted sustainability strategies—such as government incentive programs, stakeholder collaboration, and employee-driven cost-saving initiatives—further advances environmental performance. Adequate financial support enables SMEs to invest in green technologies and energy-efficient production systems. For instance, with sufficient capital, paint and resin manufacturers in Isfahan can adopt vapor recovery units, low-carbon production methodologies, and upgraded energy-efficient machinery, thereby reducing energy consumption and associated emissions.

Moreover, sustainable raw materials, which often carry higher acquisition costs, become economically viable for SMEs when complemented by effective financial assistance mechanisms. This facilitates the production of paints and resins that are both high-quality and environmentally benign. Overcoming financial barriers thus creates a synergistic effect—enabling process improvements, lowering environmental footprints, enhancing product durability, reducing greenhouse gas emissions, and elevating customer satisfaction—all of which collectively advance critical sustainability performance indicators.

Yadegari Dehkordi *et al.* (2023) demonstrated that the provision of adequate financial resources and investment in advanced technologies—such as automated temperature and pressure control systems within industrial processes—enhances energy efficiency and reduces waste generation. Integrating sustainable raw materials and ensuring compliance with environmental standards can significantly reduce both pollutant and greenhouse gas emissions. Addressing financial constraints enables firms to adopt modern, eco-friendly technologies that simultaneously lower energy consumption, improve operational efficiency, and minimize environmental impacts. The deployment of advanced equipment and machinery further contributes to superior product quality and enhanced durability, which in turn elevates customer satisfaction, reduces waste, and promotes optimal resource utilization—outcomes that yield both environmental and economic benefits.

The implementation of these measures positions SMEs in Isfahan's paint and resin sector to advance along a path toward sustainability while strengthening their competitiveness in domestic and global markets. The findings further reveal that overcoming competitive pressures and mitigating market volatility are pivotal for achieving key sustainability performance criteria. Strategic selection of sustainable suppliers helps insulate firms from raw material price fluctuations, as such suppliers often rely on renewable and stable sources that reduce cost variability. Complementary governmental policies can foster a competitive, sustainability-oriented environment by incentivizing the adoption of green technologies and environmentally responsible practices. Reduced market volatility enables firms to better plan production schedules and material procurement, thereby optimizing operations and minimizing waste. Ijomah *et al.* (2024) similarly observed that under conditions of market stability, firms are more inclined to invest in energy-efficient technologies, leading to decreases in energy consumption and productivity gains.

This study is subject to certain limitations. First, the identification of sustainability performance criteria was hampered by the limited availability of prior research and the fragmented nature of existing evidence. Second, its geographical focus on paint and resin SMEs in Isfahan means that generalization to other industries or regions should be approached with caution. Future studies should explore the integration of emerging Industry 4.0 technologies—such as digitalized process monitoring, smart supply chains, and AI-based energy optimization—to further advance sustainable performance across diverse industrial sectors. Moreover, given that sustainability policy-making and governmental incentives emerged as the most influential strategies in this research, subsequent investigations should examine the underlying drivers, institutional contexts, and policy mechanisms that shape the effectiveness of these interventions.

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