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Consumer Preferences for Eco-Friendly Products to Support Environmental Sustainability

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Abstract: ***Environmental degradation and unsustainable consumption have become urgent global issues, with consumer behaviour responsible for nearly 70% of all greenhouse gas emissions. Although awareness of eco-friendly lifestyles has grown, the actual use of green products remains low. This research uses the Quality Function Deployment (QFD) method to identify and rank consumer preferences for environmentally sustainable products. Unlike previous studies that examined individual features separately, this work combines consumer perception data from the Delhi National Capital Region (NCR) with expert industrial evaluations to close the gap between design and policy implementation. The findings show that consumers value non-toxic, biodegradable, and recyclable materials most, followed by accessibility, emission reduction, and clean energy use. The study offers a structured QFD-based prioritisation model that converts consumer preferences into practical design guidelines for sustainable product development. Policymakers and manufacturers in emerging economies can replicate this framework to better align environmental objectives with consumer demands.***

Keywords: Quality Function Deployment, Green Consumer Preferences, Biodegradable Materials, Sustainability, Environmental Product Design

1. Introduction

Over recent decades, unprecedented resource consumption has caused increasing environmental pressures. Rapid economic growth, globalisation, and product demand are driving pollution, climate change, and biodiversity loss (Steffen et al., 2007; Clark, 2007; Scheel et al., 2020). Energy consumption and carbon footprints are rising sharply (Li et al., 2017). If these trends remain unchecked, the impacts on ecosystems and human well-being could be severe.

With the growth of economies and industry development, consumption has also increased. It has a significant harmful effect on the environment, as no products are completely ecological (Akhtar et al., 2021; Perez-Castillo & Vera-Martinez, 2021). Although consumerism has brought prosperity to society, achieving true sustainability remains challenging. During development and production, waste is generated at various stages of manufacturing and final disposal (Dyllick & Rost, 2017; Bravo et al., 2022). Fonseca et al. (2020) stated that responsible consumption and production promote sustainable patterns. Green products designed to minimise adverse environmental impacts across their life cycles offer a pathway towards balancing economic growth with environmental responsibility. Although awareness of green lifestyles is increasing, turning this awareness into product adoption remains a challenge. Previous research shows gaps between environmental concern and actual purchasing behaviour (Kollmuss & Agyeman, 2002; Kumar et al., 2021). Understanding what consumers value most in green products is vital for bridging this gap.

This study fills these research gaps by using Quality Function Deployment (QFD) to rank consumer preferences for eco-friendly products. It combines consumer survey data from Delhi NCR with expert insights from manufacturing industries to create a clear connection between consumer needs ("WHATs") and engineering design features ("HOWs"). This combined approach improves both the scientific understanding and industrial application of QFD in sustainability efforts.

The specific objectives of this study are to:
1) Identify and prioritise main consumer preferences for eco-friendly product features that promote environmental sustainability; and
2) Create a flexible QFD-based framework that manufacturers and policymakers can adopt to synchronise product innovation with environmental goals.

This approach builds on existing QFD methods by incorporating sustainability goals into the initial product design stages, offering new perspectives on implementing consumer-driven sustainability within the Indian industrial environment.

The paper is structured as follows: Section 2 reviews the relevant literature, Section 3 describes the methodology, Section 4 presents the results and analysis, and Section 5 offers conclusions and implications.

2. Literature Review

Population projections estimate that nearly 10 billion people will be living by 2050 (UN, 2023), implying continued increases in resource use, waste, and pollution. Studies show that sustainable manufacturing —creating durable, eco-efficient products —can help reduce some environmental pressures (Machado et al., 2020; Fonseca et al., 2020). Key drivers are tighter environmental regulations, stakeholder

expectations, consumer preferences, and cost benefits from waste minimisation (Sartal et al., 2020).

Green products are generally characterised by their minimal environmental impact throughout their life cycle, the use of non-harmful materials, energy efficiency, and eco-friendly disposal methods (Ljungberg, 2007; Ghazali et al., 2018; Sun et al., 2018). Earlier studies also highlight factors such as emotional value, perceived quality, eco-labels, price sensitivity, brand image, accessibility, and aesthetics as key influences on the adoption of green products (Yadav & Pathak, 2017; Sharma & Foropon, 2018; Goncalves et al., 2016).

Most studies tend to focus either on narrow product categories or on individual preferences in isolation. There is less research that systematically combines multiple consumer preferences and ranks them comprehensively to guide product design directly. The QFD method has been used only sparingly but shows promise in linking consumer input with engineering features, especially in sustainability contexts. Biswas and Roy (2023) demonstrated that specific product attributes, such as packaging, functionality, and perceived value, significantly influence green product choices. The various customer preferences identified from the literature are listed in Table 1.

Table 1: Customers' Preferences for Green Products

S. No.	Customer's preferences	Sources	Preference explanation
1.	Price (P)	Ghazali et al., 2020; Kumar et al., 2021	Customers will prefer green products if their prices are lower than those of normal products.
2.	Quality (Q)	Joshi and Rahman, 2015; Kumar et al., 2021	Perceived product quality attracts customers to buy green products.
3.	Quick Service Support (S)	Tseng et al., 2019; Kumar et al., 2021	Responsiveness to customer complaints increased their orientation towards green products.
4.	Eco-labelling (E)	Jad'ud'ová et al., 2020; Song et al., 2020	Provide green information on the packaging so customers can differentiate between green and non-green products.
5.	Product Life Cycle (L)	Kumar et al., 2021; Machado et al., 2019	Long life and low environmental impact during the whole product life cycle attract customers.
6.	Aesthetic look (A)	Ghazali et al., 2020	Appearance plays an important role in attracting customers to purchase the product.
7.	Brand (B)	Kumar et al., 2021; Dinh et al., 2021	The product's popularity attracts customers.
8.	Accessibility of the product (As)	Young et al., 2010; Dinh et al., 2021	Easy access to the products influences customers' buying behaviour.
9.	Environmental impact (EI)	Dinh et al., 2021	Sensitive customers consciously consider the product's environmental rating.
10.	Easy to use (U)	Ackermann, 2018; Ghazali et al., 2021, Mustafa et al., 2022	Easily repairable, upgradable, and independent functions attract customers.

3. Research Methodology

To promote conscious consumerism, it is essential to incorporate customers' preferences for eco-friendly products into the design and production of products. However, balancing multiple preferences can be challenging due to cost and other limitations. Several methods exist for ranking these preferences, such as various MCDM techniques and BWM. Nonetheless, quality function deployment (QFD) is more suitable here because it boosts customer satisfaction by incorporating their feedback and requires less time and expense. Therefore, this study employs QFD techniques to prioritise the preferences.

3.1 Research Design & Sample

Data were gathered through consumer surveys in Delhi NCR. To achieve a representative sample, respondents were chosen based on age, income, education, and gender. Furthermore, manufacturing experts were consulted to convert consumer needs into design features.

3.2 Quality Function Deployment (QFD) Framework

QFD was initially developed in Japan during the late 1960s under the framework of total quality control (Akao, 1997). Since then, it has been adopted by numerous companies worldwide, including IBM, Motorola, and DuPont, across various industries like automotive (e.g., General Motors, Toyota, Ford), education, healthcare, and software development (Burn, 1994; Dika, 1995; Foster, 2001; Chan & Wu, 2002; Pai, 2002). QFD can help reduce quality-related problems (PMI, 2008). Its benefits include recognising customer needs and expectations, planning, and reducing uncertainty (Tran & Sherif, 1995). The QFD method helps identify customer requirements and translate them into design solutions (Xie et al., 2003). Every organisation with customers aims to determine the actions needed to satisfy or delight them, and QFD is the preferred tool for this purpose. Quality professionals often refer to QFD by various names, such as matrix product planning, decision matrix, and customer-driven engineering. Customer expectations are expressed through the Voice of the Customer. QFD is a customer-centred quality management and product development approach. It involves listening to customer feedback, converting it into detailed engineering specifications, and planning the production of products that meet their expectations.

QFD is visually represented and used to link consumer requirements ("WHATs") with design or engineering features ("HOWs"). The House of Quality (HOQ) enables converting qualitative consumer preferences into quantifiable, weighted features. The connections between WHATs and HOWs are categorised (strong, medium, weak) to calculate their relative importance. House of Quality (HOQ), with its different regions shown in Figure 1.

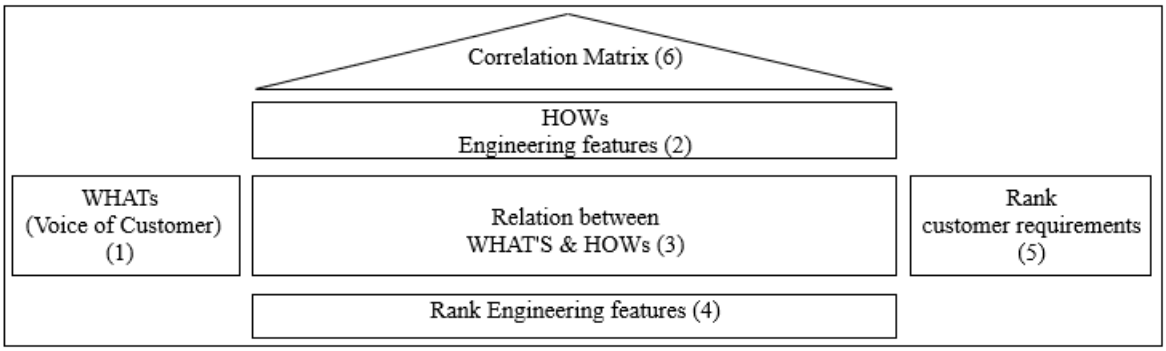

Figure 1: House of Quality

Region 1: It is also called "What region". It represents the customer's requirements and the importance of each of them, β_i.
Region 2: It is also known as "How region". It represents the design specifications and the way of its development.
Region 3: It shows the relationship between 'how' and 'what'. The relationship is shown by the numbers Nij = 0, 1, 3..., 9.
Region 4: This region shows the combination of the design specification and its acceptance level, and the score

$$A_j = \sum(\beta_i * N_{ij}) \quad (1)$$

Region 5: The comparison of the product and competitors and the fulfilment of customer needs.
Region 6: The comparison between design specifications and their improvement affects each other.

Then, after identifying the customer needs, complete the preparation of the HOQ and after completion start to create the next matrix by placing all the important needs of the HOQ on the left side of the second matrix and their properties on the right side of the next matrix to facilitate communication and ensure that targets are not lost, The QFD matrix phases shown in Figure 2.

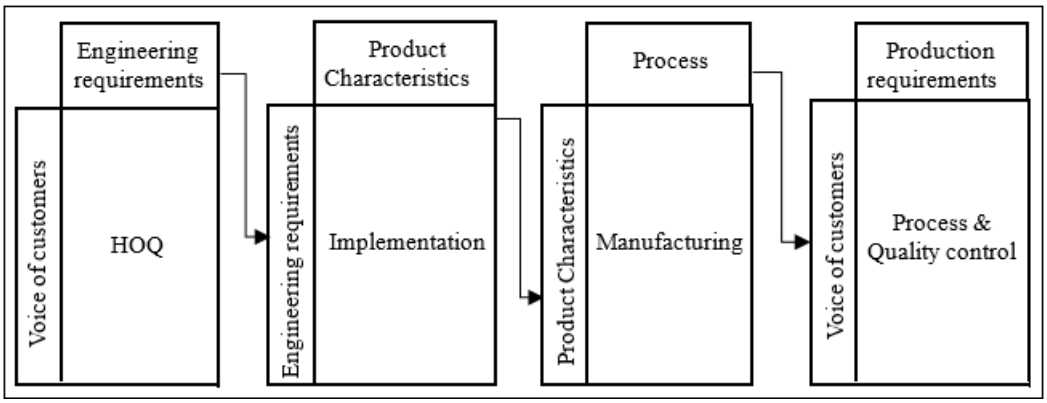

Figure 2: The QFD matrix phases (Benner et al., 2003; Rubert et al., 2023; Ginting & Ishak, 2020)

3.3 Data Analysis

- Identifying consumer preferences from literature and survey responses.
- Selection of relevant engineering and design features through expert consultation.
- Development of an interrelationship matrix using a weighting scale (9-3-1).
- Computation of relative importance and ranking of consumer preferences.

4. Results

Customer expectations should be integrated into the product's design and manufacturing phases. A meeting has been convened with industry experts to determine how customer preferences can influence product development. Five experts from manufacturing industries A, B, C, D, and E have been invited. Industry A is based in Gurgaon (Haryana), Industry B in Bahadurgarh (Haryana), Industries C and D in Delhi, and Industry E in Mohali (Punjab). Industries A, B, and C produce medical equipment, while D and E manufacture auto parts for companies like Telco and Swaraj. Once customer preferences are translated, product design can proceed to meet these expectations. During development, customer preferences and environmental considerations should both be prioritised. Environmental impact can be minimised by adopting zero-carbon footprint manufacturing, utilising eco-efficient, reusable, recyclable, biodegradable, and non-toxic materials, expanding market demand to lower prices, implementing tighter tolerances, and adhering to regulatory sustainability guidelines. Strong top management commitment is also vital to achieving these goals. The extracted consumer preferences and related design features are summarised in Table 2.

Table 2: The parameters required to meet the customers' preferences

S No	Preference (WHAT)	Sources	Design Feature(s) (HOW)
1.	Non-toxic, biodegradable and recyclable materials (H1)	Ghazali et al., 2021; Sohn et al., 2019; Khan et al., 2018;	Material sourcing & processing
2.	Clean/ non-conventional energy (H2)	Gafurovich & Sotivoldievich, 2021; Sultonboevich et al., 2022	Energy type in operations
3.	Reducing emissions (H3)	Ghazali et al., 2020; Liu et al., 2022	Process optimisation/ emissions control
4.	Providing a good market (access & availability) (H4)	Li et al., 2020	Distribution channels, economies of scale
5.	Tighter tolerance (durability & precision) (H5)	Mohagheghian et al., 2021; Jadayel & Khameneifar, 2020	Manufacturing precision, design robustness
6.	Regulatory compliance (H6)	Becker et al., 2022	Adherence to standards & certifications
7.	Latest technology (H7)	Kumar et al., 2021;	Incorporation of advanced production methods
8.	Top management commitment (H8)	Kumar et al., 2021	Organisational strategy, resource allocation

4.1 Interrelationship matrix

The third room of the HOQ illustrates the interconnection between the WHATs and the HOWs. These relationships are classified as 'strong', 'medium', 'weak', or 'none' for each pair of WHATs and HOWs, based on the extent to which the parameters contribute to meeting the VOC. A standard ratio is 9-3-1, where 9 indicates strong links, 3 indicates moderate links, and 1 indicates weak links. In the relationship matrix, these are shown by the symbols ○ (9), □ (3), and △ (1). The interrelationship matrix of WHATs and HOWs is displayed in Table 4, while the House of Quality, detailing various quality functions, is in Figure 3. The feature rankings derived from the QFD are listed in Table 5.

Table 4: The interrelationship matrix

S. No.	Customers' Preferences (WHATs)	Weight	It can be achieved through (HOWs)							
			H1	H2	H3	H4	H5	H6	H7	H8
1.	P	5	○	○	○	○	□	□	□	
2.	Q	4	○				○	△	□	
3.	S	3				□				△
4.	E	3	□			△		□		△
5.	L	3	○			□		△		
6.	A	4				○			□	
7.	B	4	□	□	□	□	□	△	□	
8.	As	3				□				
9.	EI	4	○	○	○		□	○	□	□
10	U	1							△	

WHATs (VOC)	Wt	HOWs								Competition	
		H1	H2	H3	H4	H5	H6	H7	H8	Green Product	Normal product
P	5	○	○	○	○	□	□	□		5	3
Q	4	○				○	△	□		4	3
S	3				□				△	3	3
E	3	□			△		□		△	1	1
L	1	○			□		△			3	1
A	4				○			□		3	4
B	4	□	□	□	□	□	△	□		3	3
As	3				□					1	4
EI	4	○	○	○		□	○	□	□	5	1
U	1							△		1	3
										Total	
Importance of Weight		147	93	93	117	75	69	64	18	676	
Relative importance		21.7 %	13.8 %	13.8 %	17.3 %	11 %	10.2%	9.5%	2.7%		
Ranking		1	3	3	2	4	5	6	7		

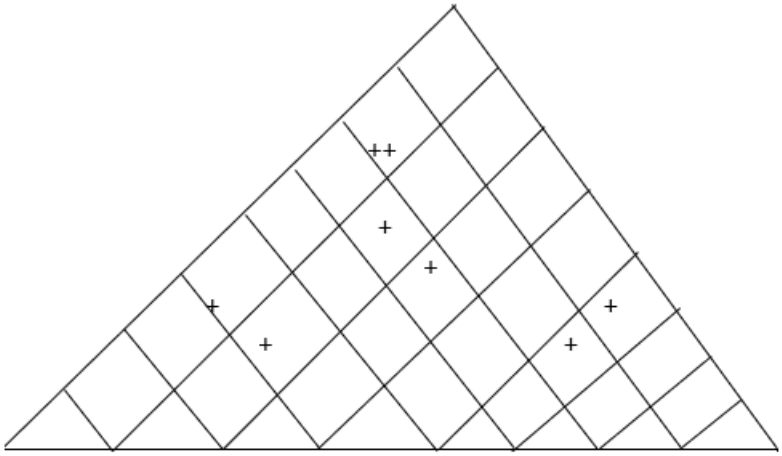

Figure 3: Describing various functions of the House of Quality

Table 5: The prioritized ranking

Rank	Feature	Relative Importance (%)
1	Non-toxic, biodegradable, recyclable materials	~22%
2	Providing good market/accessibility	~17%
3 (tie)	Use of non-conventional energy & reducing emissions	~14% each
4	Tighter tolerances (durability, precision)	~11%
5	Regulatory compliance	~10%
6	Latest technology	~9%
7	Top management commitment	~3%

4.2 Interpretation

Consumers prioritise environmental safety and material recyclability most. Market access is a key secondary factor, indicating that even eco-friendly product designs face barriers like limited availability or high costs. While emission reduction and clean energy are also important, consumers perceive them as slightly less urgent than material safety and market access.

5. Conclusion & Implications

This study introduces an innovative framework that connects consumer preferences with engineering design parameters using the QFD method, aiming to support sustainable product development. Results show that material safety—especially the use of non-toxic, biodegradable, and recyclable materials—remains the top consumer priority. Concerns about market accessibility, emissions control, and the use of renewable energy follow.

This research is original in combining consumer and expert feedback within a structured QFD matrix, thereby providing thorough prioritisation of sustainability-focused product features. Unlike earlier QFD studies that treated environmental factors more abstractly, this study demonstrates how green consumer insights can be translated into measurable, design-related metrics.

Practical Implications:

- **For manufacturers:** prioritise using safe, recyclable materials; enhance supply chains to improve accessibility; and adopt technologies that reduce emissions**.**
- **For Policymakers:** Develop incentives and regulations to promote eco-friendly materials, enhance infrastructure for distributing green products, and simplify standards and certifications.
- **For future research:** consider conducting comparative studies across various regions or product categories, tracking preferences over time as awareness and technology develop, and integrating pricing and willingness-to-pay trade-offs more thoroughly.

Overall, this research enhances sustainable manufacturing by offering an empirically validated, repeatable framework that translates consumer preferences into practical design and policy recommendations for developing economies.

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Author's Contribution

Dr. Manoj Kumar Singh (Author 1)
Conceptualised and designed the research framework, conducted experimental investigations, gathered and analysed data, interpreted the results, and drafted the initial version of the manuscript.

Roshan Kumar (Author 2)
Validated the experimental data, reviewed and improved the analysis, formatted the research paper according to journal guidelines, and contributed to the critical revision and finalisation of the manuscript.

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