QUALITY FUNCTION DEVELOPMENT-BASED SUSTAINABLE MANUFACTURING FOR REDUCING PLASTIC WASTE IN VACUUM CLEANERS

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ABSTRACT: In recent years, the urgency to address environmental sustainability has significantly influenced product development across various industries. One of the most pressing environmental concerns is plastic waste, posing severe ecological and health risks due to its non-biodegradable nature. This research paper focuses on the development of Quality Function Deployment (QFD) and the House of Quality (HoQ) methodology to design a sustainable and eco-friendly vacuum cleaner aimed at reducing plastic waste. The integration of customer needs into product design through QFD and HoQ ensures that the final product meets market demands while adhering to sustainability principles. The novelty of this research lies in its structured approach to incorporating eco-friendly materials and processes from the initial design phase, guided by QFD and HoQ methodologies. The objectives of the study include designing a vacuum cleaner that reduces plastic waste, enhances environmental conservation, and meets consumer needs for sustainable household appliances. The research employs a mixed-method approach, combining qualitative and quantitative analyses to gather customer requirements and translate them into design specifications through QFD and HoQ. The results demonstrate that integrating sustainability into product design significantly reduces the environmental footprint of vacuum cleaners. The contribution of this research provides practical insights for manufacturers aiming to minimize the environmental impact of their products. By addressing the urgent need to reduce plastic waste and developing a sustainable vacuum cleaner, this paper contributes to the broader discourse on environmental sustainability. It offers practical recommendations for designing eco-friendly household appliances that appeal to environmentally conscious consumers, thereby supporting the transition towards more sustainable consumption patterns.

KEYWORDS: Vacuum cleaner; sustainable manufacture; QFD; HoQ; plastic waste

1.0 INTRODUCTION

In recent years, the urgency to address environmental sustainability has significantly influenced product development across various industries. One of the most pressing environmental concerns is plastic waste, which poses severe ecological and health risks due to its non-biodegradable nature. The development of sustainable and eco-friendly products has therefore become imperative to mitigate these risks. This research paper focuses on the application of Quality Function Deployment (QFD) and the House of Quality (HoQ) methodology to design a vacuum cleaner aimed at reducing plastic waste.

The concept of QFD and HoQ provides a structured approach to integrating customer needs into product design, ensuring that the final product not only meets market demands but also adheres to sustainability principles. Recent trends in sustainable product development highlight the importance of incorporating eco-friendly materials and processes from the initial design phase. For instance, a study by Coruzzolo et al. [1]the need to integrate customer needs into the research and development processes of products and services requires the use of suitable tools for their detection and analysis. The objective of this paper is to describe the application of Quality Function Deployment and its House of Quality tool

to optimize a software for the management of waste recovery and disposal processes, with particular reference to the functions dedicated to Waste Electrical and Electronic Equipment (WEEE demonstrated the application of QFD in optimizing waste management software, emphasizing the importance of multi-user information to enhance system functionality and sustainability.

Moreover, the integration of sustainability in product design has been shown to significantly reduce environmental footprints. Upadhyay and Kumar [2] proposed a modified HoQ framework to incorporate sustainability dimensions at the design stage, ensuring that products are environmentally friendly and compliant with legislative guidelines. This methodology aligns with the broader goal of creating products that not only fulfill consumer needs but also contribute to environmental conservation.

In addition, Maraveas [3] illustrated the effectiveness of utilizing agro-waste to manufacture sustainable construction materials, highlighting the significance of eco-friendly alternatives. Similarly, Esthi [4] and Jung [5] emphasized the crucial role of education, knowledge sharing, and the use of eco-friendly materials in encouraging the adoption of sustainable technologies and addressing indoor air pollution. The management of plastic waste has emerged as a significant concern, as noted by Prajapati et al. [6], stressing the necessity to reduce plastic consumption and explore innovative solutions. Additionally, Bhayani [7] stressed the importance of energy-efficient systems and sustainable materials in improving environmental performance, aligning with the goals of developing eco-friendly vacuum cleaners.

The escalating environmental concerns and the urgent need to address plastic waste have spurred significant interest in developing sustainable and eco-friendly household appliances. Among these, vacuum cleaners stand out as essential yet frequently overlooked contributors to plastic pollution. Traditional vacuum cleaners often incorporate non-recyclable plastics in their construction, contributing to the growing environmental footprint. In response, the integration of QFD and HoQ methodology presents a promising approach to designing sustainable and eco-friendly vacuum cleaners that not only meet consumer needs but also mitigate plastic waste.

The objective of this research paper is to develop the design a sustainable and eco-friendly vacuum cleaner through QFD and HoQ metholodogies. By addressing these objectives, the paper has attempted to contribute to the broader discourse that has existed within sustainable product development while offering practical insights for a manufacturer looking to minimize the environmental footprint. The findings of this research shall not only develop the theoretical understanding of QFD and HoQ but also lead to practical recommendations with regards to the way forward in the design of eco-friendly vacuum cleaners which will appeal to environmentally conscious customers.

2.0 METODOLOGI PENELITIAN

This research aims to explore the application of Quality Function Deployment (QFD) in the development of a sustainable and eco-friendly vacuum cleaner. QFD is a systematic approach used to integrate customer requirements into every aspect of product development, ensuring that the final product meets or exceeds customer expectations. The HoQ is a central tool in QFD, providing a visual representation of customer desires and technical requirements. Data collection was carried out by distributing questionnaires to 50 respondents. The purpose of these questionnaires was to identify the attributes needed and desired by consumers in product design and to assess the importance or priority scale of vacuum cleaner attributes for consumers.

To ensure the reliability of the questionnaire, a pilot test will be conducted, and Cronbach's alpha will be calculated to assess internal consistency. Construct validity will be evaluated to determine the extent to which the accuracy of a measure fulfills its intended measurement

function. Both the reliability and validity tests will be conducted using SPSS software.

The HoQ will be utilized to systematically translate customer requirements into technical specifications. The following steps will be taken:

a) Identify Customer Requirements (Whats): Based on qualitative and quantitative data, key customer requirements for a sustainable and eco-friendly vacuum cleaner will be identified.
b) Determine Design Requirements (Hows): This matrix will prioritize customer needs related to sustainability, such as energy efficiency, recyclable materials, and low environmental impact. Technical solutions will be developed to address these needs, ensuring that the final product meets both customer expectations and sustainability standards.
c) Relationship Matrix: The relationship between customer requirements and design requirements will be analyzed and documented in the HoQ matrix.
d) Technical Assessment: A competitive assessment of how well current market products meet these requirements will be conducted.
e) Prioritization: Prioritize technical specifications based on customer importance ratings and technical difficulty.

Once the House of Quality (HoQ) matrix is completed, the next step in developing a sustainable and eco-friendly vacuum cleaner design involves translating the identified technical requirements into actionable product specifications. The HoQ matrix provides a clear understanding of customer priorities, such as energy efficiency, use of recyclable materials, and low environmental impact. These priorities are then transformed into specific design parameters that guide the engineering and design teams.

3.0 RESULTS AND DISCUSSION

3.1 Results

The initial phase of the research involved identifying key customer requirements through opened questionnaires. The most frequently mentioned requirements included attractive design, ease of use, safety of use, an environmentally friendly approach, ergonomic features and an ease of cleaning in hard-to-reach places.

Using the HoQ, these customer requirements (Whats) were systematically translated into technical specifications (Hows). The relationship matrix (please refer to Figure 1) highlighted several key technical specifications necessary to meet the identified customer requirements:

a) Attractive design: Provide batik design with two colour options (pink and brown)
b) Ease of use: Easy to clean, and efficient dust storage system
c) Safety of use: Lengthable size
d) An environmentally friendly approach: Made from environmentally friendly materials (from recycled plastic waste)
e) Ergonomic features: The design is based on anthropometric measurements
f) An ease of cleaning in hard-to-reach places: Lengthable size

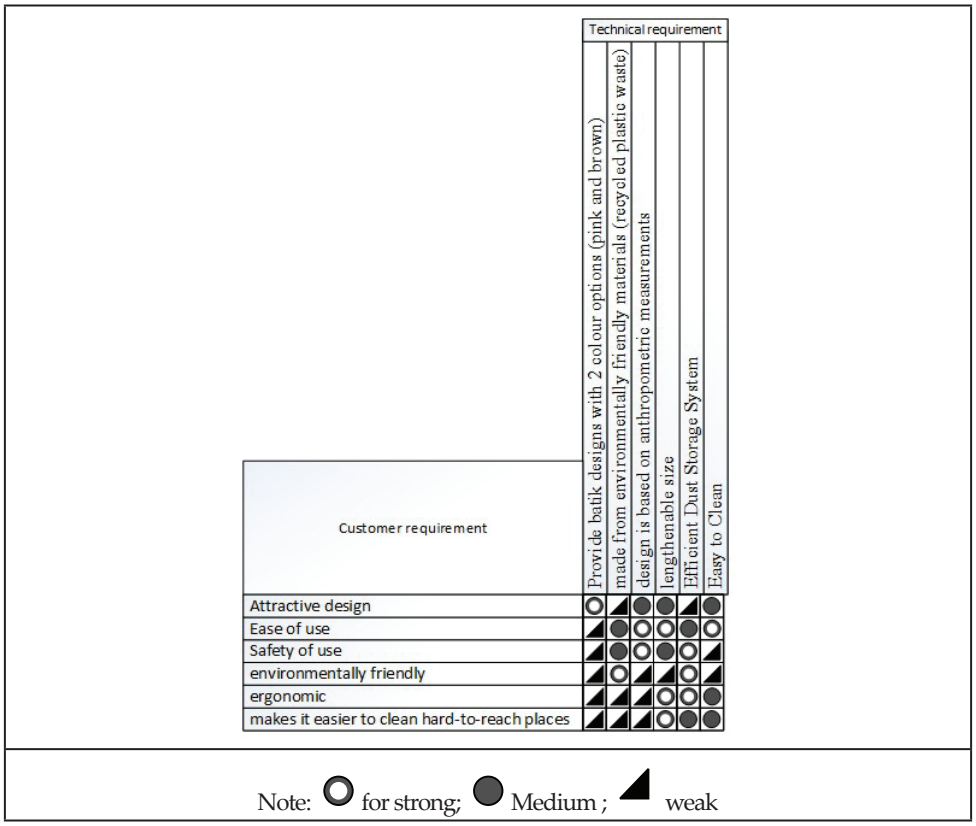


Figure 1. The relationship matrix

The HoQ also prioritized these technical specifications based on customer importance ratings and technical difficulty, as shown in Table 1. The highest priorities are given to features that significantly enhance functionality and usability, such as adjustable size and efficient dust storage, while aesthetic choices, though important, are given lower priority. This prioritization ensures that the development process focuses on delivering the most critical features first, aligning with customer needs and sustainability goals.

Table 1. The prioritization of technical requirements

Technical requirement	Relative weight	Prioritization
Provide batik design with two colour options (pink and brown)	9.68%	6
Made from environmentally friendly materials (from recycled plastic waste)	11.52%	5
The design is based on anthropometric measurements	17.83%	3
Lengthable size	23.88%	1
Efficient dust storage system	22.81%	2
Easy to clean	14.27%	4

From the House of Quality matrix shown in Figure 2, it can be understood that the customer inputs can serve as a valuable reference for the company in designing a sustainable and eco-friendly vacuum cleaner (please refer to Figure 3).

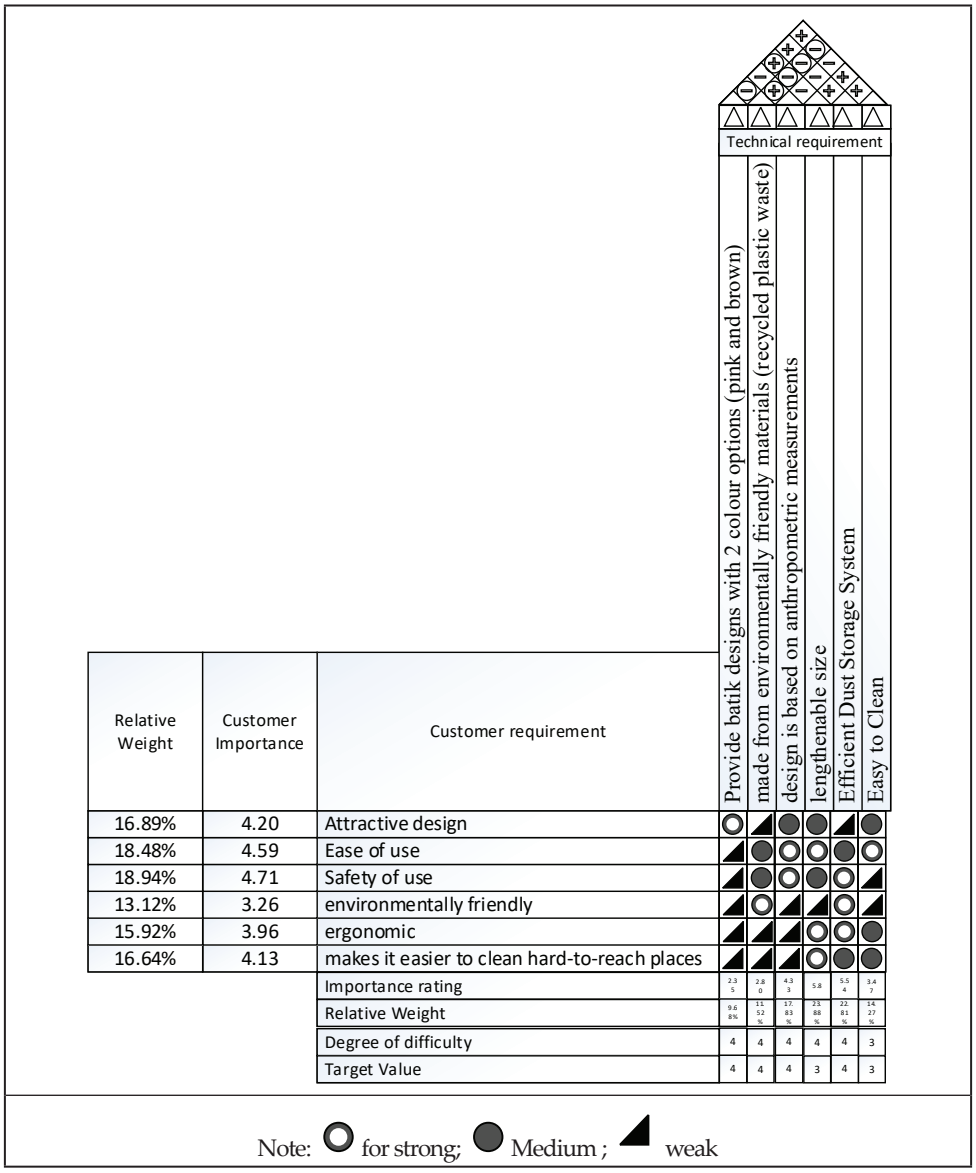
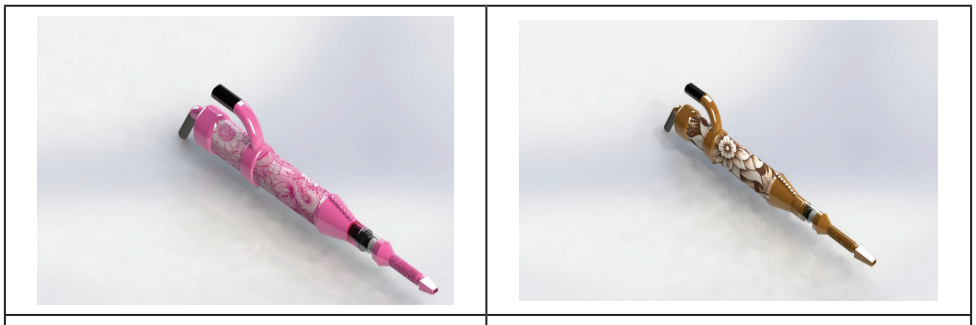


Figure 2. House of quality matrix



(a) Pink (b) Brown

Figure 3. The design of sustainable and eco-friendly vacuum cleaner

3.2 Discussion

The development of a sustainable and eco-friendly vacuum cleaner using recycled materials by using QFD and HOQ methodologies, represents a significant advancement in the field of environmentally conscious product design. The integration of eco-friendly materials in innovative vacuum cleaner has a substantial positive impact on the environment.

The implementation of QFD and HOQ ensured that the vacuum cleaner design met customer expectations while adhering to sustainability principles. QFD was instrumental in identifying critical customer requirements such as durability, suction power, and ease of use. These requirements were then translated into technical specifications using the HOQ matrix. The structured approach facilitated by HOQ enabled the prioritization of design features that have the greatest impact on customer satisfaction and environmental performance [8].

The use of recycled materials in the manufacturing of vacuum cleaners addresses the pressing issue of plastic waste management. Recent studies have shown that incorporating recycled materials not only reduces the environmental footprint but also promotes a circular economy [9]. In this research, various types of recycled plastics were tested for their mechanical properties and suitability for vacuum cleaner components. The results indicated that recycled materials can provide comparable performance to virgin plastics, which aligns with findings from similar studies [10].

4.0 CONCLUSION

The objective of this research paper is to develop a sustainable and environmentally friendly vacuum cleaner design through QFD and HoQ methodologies. The results demonstrated that the sustainable and environmentally friendly vacuum cleaner was designed in accordance with the customer's needs and with consideration of environmental aspects. Future research should focus on developing standardised processes for recycling and reusing materials to improve product consistency and performance. Furthermore, it is recommended that the supply chain of recycled materials be optimised, and that the methodology be continuously refined, in order to enhance the quality of the product and consumer acceptance.

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