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Application of Quality Function Deployment Method in Developing Eco-Friendly Cup Holder Design

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ABSTRACT

The rapid growth of Indonesia's food and beverage industry has increased the need for innovative and environmentally friendly packaging, especially for takeaway drinks. This study aims to develop a cup holder design to replace plastic bags by integrating customer needs using the Quality Function Deployment (QFD) method. QFD was chosen because it can translate the Voice of Customer (VoC) into measurable technical specifications through the House of Quality (HoQ) matrix. The research used a descriptive quantitative approach with 30 café customers selected through purposive sampling. Validity testing using the Pearson Product Moment showed that 11 out of 20 statements were valid ($r > 0.36$), and the reliability test achieved a Cronbach's Alpha value of 0.870, indicating high consistency. The results of the VoC and HoQ analysis identified eleven important customer needs such as capacity, ease of use, material strength, design, and price efficiency. Three alternative cup holder designs were evaluated using the Pugh Matrix, and the best concept scored +4, featuring a kraft paper material with 300 gsm thickness, moisture resistance, ergonomic shape, and the ability to hold four cups while displaying café branding. This design improves customer comfort, strengthens brand image, and reduces plastic waste. The study demonstrates how QFD can effectively link customer preferences to engineering design, offering a practical example for small and medium cafés to develop sustainable packaging that supports both product functionality and environmental responsibility.

Keywords: Quality Function Deployment, House of Quality, Pugh Matrix, Cup Holder, Sustainable Packaging

INTRODUCTION

The rapid growth of the food and beverage industry in Indonesia has intensified competition among cafés, compelling them to enhance both product quality and service innovation. In the takeaway beverage service system, packaging plays a vital role not only in maintaining drink stability and convenience but also as a medium of brand identity and sustainability awareness. Recent surveys show that the majority of café consumers in urban areas still use plastic bags as drink carriers, which are not environmentally friendly and often cause inconvenience when

transporting multiple beverages. This condition highlights the urgency of developing more ergonomic and sustainable packaging alternatives in the café industry.

Plastic bag usage in takeaway services contributes significantly to environmental waste. According to Indonesia's Ministry of Environment and Forestry, plastic waste from food and beverage packaging accounts for approximately 35% of urban solid waste. The lack of eco-friendly packaging innovations in small and medium cafés exacerbates this problem. Furthermore, many cafés continue to rely on conventional packaging that lacks ergonomic design and aesthetic value, reducing both user comfort and brand appeal. This situation where takeaway packaging still uses single-use plastic bags without proper cup holders, resulting in limited customer satisfaction and potential safety issues during drink transportation.

Several studies have explored sustainable packaging solutions; however, most have focused on food containers or paper cups rather than integrated carrier systems. For example, [1] designed paper cup packaging for Homwok Kopi, [2] analyzed coffee cup holders at Dotuku Kopi. Although both employed the Quality Function Deployment (QFD) method, their scope was confined to material development and design optimization. None specifically investigated how a cup holder can serve as a substitute for plastic bags while simultaneously enhancing café branding. This gap demonstrates a lack of studies addressing ergonomic, aesthetic, and environmental aspects in a unified design model for takeaway packaging.

This research is thus positioned to fill that gap by developing a cup holder design that integrates customer requirements into technical specifications using the Quality Function Deployment (QFD) approach. The selection of QFD is based on its systematic capability to translate the "Voice of Customer" (VoC) into measurable technical attributes through the House of Quality (HoQ) matrix, ensuring that product design decisions align with consumer expectations and sustainability principles. By adopting QFD, the design process can move beyond subjective intuition toward data-driven and customer-oriented decision-making.

Empirical data from a survey of 30 café consumers revealed that 93% of respondents still receive plastic bags when purchasing beverages, and the same proportion experience discomfort when carrying multiple cups. Moreover, all respondents expressed a willingness to switch to a cup holder if it is available. This quantitative evidence reinforces the market potential and customer readiness for adopting a cup holder innovation that enhances comfort, reduces plastic waste, and supports brand identity. Hence, the study responds directly to an urgent demand for practical and sustainable packaging innovation within Indonesia's growing café sector.

The objective of this research is to identify customer needs and translate them into a functional and aesthetic cup holder design that can replace plastic bags in takeaway systems at Café. Using the QFD method, this study systematically converts customer expectations into design specifications, producing a prototype that balances ergonomics, strength, aesthetics, and environmental friendliness. The proposed design aims to strengthen customer satisfaction, operational efficiency, and corporate image in alignment with sustainable business practices.

This study contributes to the expansion of QFD application in product design for the food and beverage service industry. It demonstrates how QFD can bridge customer perception with engineering design through structured decision matrices such as House of Quality and Pugh Matrix. The findings are expected to enrich the literature on sustainable product design while offering a practical reference for small- and medium-scale cafés seeking to integrate environmental responsibility into their branding strategy. In addition, this study provides a replicable model for developing eco-friendly takeaway packaging that harmonizes functionality, sustainability, and visual identity.

In conclusion, the research not only addresses environmental challenges caused by excessive plastic bag use but also aligns with Indonesia's sustainable development agenda by promoting innovation in small business packaging systems. By combining ergonomic design, environmental awareness, and brand differentiation through the QFD framework, this study

positions Kelas Pagi Café as a pioneering case of green innovation in the local café industry—bridging the gap between customer satisfaction, sustainability, and competitive advantage.

METHOD

This research employed a quantitative descriptive approach combined with a product design and development method using Quality Function Deployment (QFD) as the main analytical framework [3], [4]. The QFD method was selected because it allows a systematic translation of customer requirements (Voice of Customer) into technical characteristics (Engineering Characteristics), ensuring that product designs are aligned with customer needs, ergonomics, and sustainability. The study aimed to develop a cup holder prototype as an alternative to plastic bags in the takeaway beverage system.

The population of this research comprised consumers who had used takeaway beverage services. Using a purposive sampling technique, a total of 30 respondents were selected based on their familiarity with takeaway service systems [5]. This sample size was deemed adequate for identifying customer expectations and priorities within the framework of preliminary product design studies.

Data Types and Sources

The study used both primary and secondary data.

- Primary data were collected from customer surveys through structured questionnaires designed to identify consumer preferences, comfort levels, and expectations related to the use of cup holders.
- Secondary data included references from previous studies, journals, and literature related to QFD applications in packaging and service design. These data supported the theoretical basis for constructing the House of Quality (HoQ) model.

Data were collected through several stages:

- Questionnaire distribution to 30 café customers to obtain customer expectations and perceptions.
- Observation of existing takeaway packaging processes to identify operational challenges related to plastic bag use.

Validity and Reliability Testing

Instrument testing used Pearson's Product-Moment Correlation for validity and Cronbach's Alpha for reliability. The results indicated that 11 out of 20 items were valid with correlation coefficients exceeding the r-table value (0.36), while the reliability coefficient reached 0.870, indicating high internal consistency. These results confirm that the questionnaire accurately measured customer needs and satisfaction related to takeaway packaging [6].

Quality Function Deployment (QFD) Stages

The QFD process was carried out through three structured stages:

1. **Voice of Customer (VoC):**
   Identification and classification of customer expectations derived from the survey responses. Eleven customer attributes were identified, including capacity, convenience, size adaptability, design aesthetics, durability, and material sustainability.
2. **House of Quality (HoQ):**
   Construction of the House of Quality matrix to link customer requirements with technical specifications. Each attribute was assigned weights, goals, and improvement ratios, leading to prioritized technical responses. This stage ensured that every customer requirement was represented in measurable design criteria.
3. **Technical Response and Concept Selection (Pugh Matrix):**
   The final stage involved generating several design alternatives based on technical specifications obtained from the HoQ. The Pugh Matrix method was then applied to evaluate these alternatives by comparing each design against reference criteria. The design that

achieved the highest net score (+4) was selected as the optimal solution—namely, a cup holder capable of carrying four cups, made of kraft paper with a minimum thickness of 300 gsm, moisture-resistant, and ergonomically shaped [7], [8].

RESULTS

Validity Test and Reliability Test

To determine whether the statements in the questionnaire are valid or not, a validity test is carried out based on the number of statements in the questionnaire.In this calculation, the r table value for N = 30 with a significance level of 5% is 0.36. This value is compared with the Pearson Correlation results in the total N column for each statement. There are 11 valid statements:

Table 1. Validity Test

	P1	P4	P5	P6	P9	P11
Pearson Total Correlation	0.491	0.504	0.549	0.414	0.407	0.366
	P13	P14	P17	P18	P20	
Pearson Total Correlation	0.401	0.385	0.459	0.440	0.467	

Based on the results*output*reliability statistics, it is known that the number of items tested is 20 statements, according to the value displayed in the N of Items column. Meanwhile, the Cronbach's Alpha column shows a reliability value of 0.870. Because this value is greater than 0.6, the data is declared reliable.

Voice of Customer (VOC)

Table 2 summarizes the results of the customer expectation analysis, which identifies key attributes influencing consumer satisfaction toward the proposed cup holder design. This stage is part of the Voice of Customer (VoC) process, where customer needs are translated into technical responses for product improvement. Each attribute represents a dimension of perceived value—covering functional, ergonomic, aesthetic, and economic aspects—that guide the formulation of design specifications. The purpose of this mapping is to ensure that every technical feature developed aligns directly with what customers value most, thereby increasing product acceptance and competitiveness in the market.

Table 2. Customer Expectations

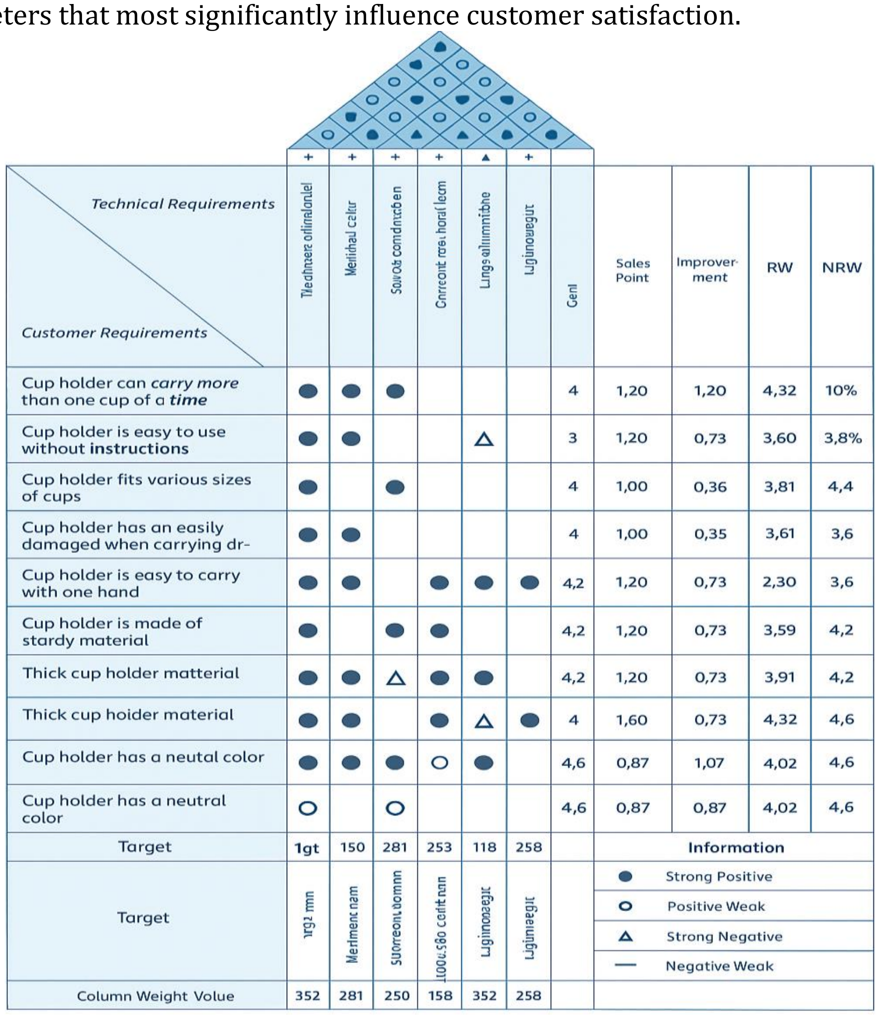
Customer Expectations (Whats)			
No	P	Customer Attributes	Technical Response
1	P1	Capacity	Cup holdercan carry more than one glass at a time
2	P4	Convenience	Cup holder is easy to use without any special instructions.
3	P5	Size	Cup holder fits various sizes of cups
4	P6	Design	Cup holder has an easily recognizable cafe identity
5	P9	Resilience	Cup holder is not easily damaged when carrying drinks
6	P11	Form	Cup holder is easy to carry with one hand
7	P13	Strength	Cup holder is made of sturdy material
8	P14	Material	Cup holder made of paper material
9	P17	Material	Thick cup holder material
10	P18	Design	Cup holder has attractive colors
11	P20	Price	Cup holders do not add any additional cost to consumers.

As shown in Table 2, the main customer expectations emphasize usability, durability, and aesthetics. Attributes such as capacity and convenience indicate that consumers prioritize functionality—expecting the cup holder to carry multiple cups and to be easy to use without prior instruc-

tion. Meanwhile, design and form reflect a desire for ergonomic handling and visual appeal, aligning with the need for practical yet attractive products. Material-related factors (strength and thickness) highlight the importance of sturdiness and sustainability, suggesting a preference for eco-friendly paper-based materials. Finally, price remains a critical determinant of consumer acceptance, with respondents expecting cost efficiency without compromising quality. These findings form the foundation for subsequent stages of the Quality Function Deployment (QFD) process, ensuring that technical solutions effectively meet customer-driven priorities.

House of Quality

Figure 6 illustrates the House of Quality (HoQ) matrix, which integrates customer expectations with corresponding technical responses in the product development process. The HoQ serves as the core analytical framework of Quality Function Deployment (QFD), translating the Voice of Customer (VoC) into quantifiable engineering characteristics. The vertical axis represents customer requirements—such as capacity, convenience, strength, and design—while the horizontal axis details the technical specifications that can fulfill these needs. The strength of the relationship between each pair is symbolized by weighted correlation indicators, allowing prioritization of key technical parameters that most significantly influence customer satisfaction.



Technical Requirements
Customer Requirements
Sales Point
Improver-ment
RW
NRW
Cup holder can carry more than one cup of a time
4 1,20 1,20 4,32 10%
Cup holder is easy to use without instructions
3 1,20 0,73 3,60 3,8%
Cup holder fits various sizes of cups
4 1,00 0,36 3,81 4,4
Cup holder has an easily damaged when carrying dr-
4 1,00 0,35 3,61 3,6
Cup holder is easy to carry with one hand
4,2 1,20 0,73 2,30 3,6
Cup holder is made of stardy material
4,2 1,20 0,73 3,59 4,2
Thick cup holder matterial
4,2 1,20 0,73 3,91 4,2
Thick cup hoider material
4 1,60 0,73 4,32 4,6
Cup holder has a neutal color
4,6 0,87 1,07 4,02 4,6
Cup holder has a neutral color
4,6 0,87 0,87 4,02 4,6
Target
1gt 150 281 253 118 258
Information
Target
Strong Positive
Positive Weak
Strong Negative
Negative Weak
Column Weight Value
352 281 250 158 352 258

Figure 1. House of Quality (HOQ) Cup holder

The analysis of the HoQ matrix reveals that the most influential customer attributes are capacity, durability, and design appeal, each demonstrating a strong positive correlation with mul-

tiple technical parameters. Among these, material thickness, ergonomic form, and product dimensions exhibit the highest relative weight values, indicating their dominant contribution to overall customer satisfaction. The improvement ratio and normalized relative weight (NRW) values further highlight that enhancing the structural strength and usability features provides the greatest potential for product improvement.

Additionally, aesthetic and branding-related features, such as color neutrality and café identity integration, also play a supportive role in differentiating the product in a competitive market. The resulting prioritization underscores the strategic importance of balancing functional reliability with visual attractiveness to achieve an optimal design outcome. This HoQ framework thus provides a clear, data-driven foundation for guiding subsequent design refinement, prototype testing, and market validation phases.

Technical Response Creation

Table 3 presents the Technical Response Matrix derived from the translation of customer expectations into engineering specifications. Each customer attribute identified from the Voice of Customer (VoC) analysis was converted into a measurable design or material parameter. The aim of this stage is to ensure that every customer requirement is addressed through a corresponding technical feature that can be objectively evaluated and implemented during the product development process. The responses reflect the design intent to enhance functionality, durability, ergonomics, sustainability, and aesthetic appeal of the cup holder while maintaining production efficiency and cost-effectiveness.

Table 3. Technical Response

No	Customer Attributes	Technical Response
1	Capacity	Cup holdercan carry 4 cups of drinks.
2	Convenience	Easy to carry, the top gap is designed to fit the size of your hand grip.
3	Size	It doesn't use holes, but rather boxes so it fits all sizes.
4	Design	There is a logo on the cup holder.
5	Resilience	Moisture resistant material, not easy to tear.
6	Form	Has an attractive handle and shape
7	Strength	Using high thickness cardboard and layered structure
8	Material	Environmentally friendly kraft paper material
9	Material	Minimum thickness 300 gsm
10	Design	Cup holderthe exterior is cream colored
11	Price	Low production costs, included in the price of the drink

Cup Holder Design Results

The evaluation of the three alternative cup holder designs aims to determine the most optimal concept that aligns with customer expectations, technical feasibility, material efficiency, and aesthetic appeal. Each design was assessed based on the Technical Response Matrix derived from the House of Quality (HoQ) analysis. The selection process follows a multi-criteria decision approach, incorporating qualitative and quantitative assessments to identify the design that best satisfies both functional and economic requirements.

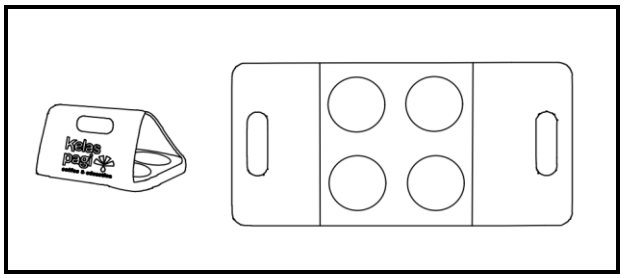


Figure 2. Image Cup Holder Design 1

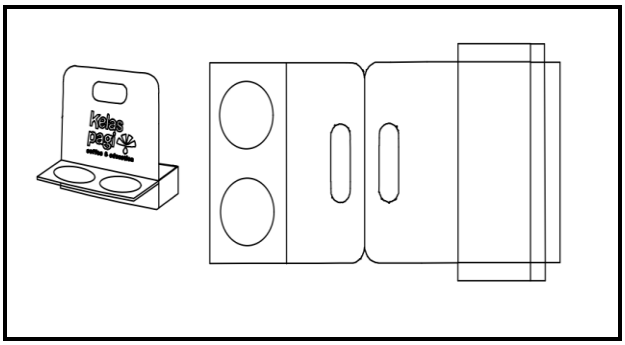


Figure 3. Image Cup Holder Design 2

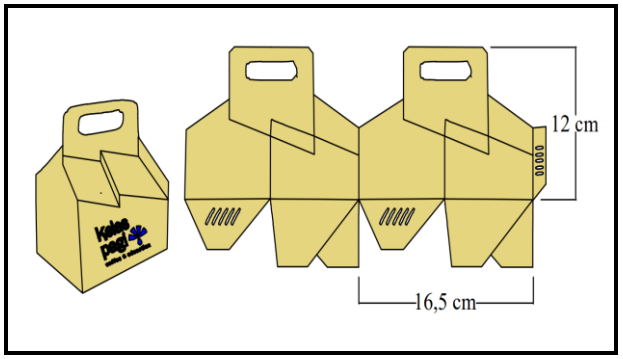


Figure 4. Image Cup Holder Design 3 (Selected)

a. Design 1 adopts a simple folding structure with minimal components, prioritizing compactness and low material usage. However, its limited ergonomic grip and structural rigidity reduce its load-bearing capacity, making it less suitable for carrying multiple beverages.
b. Design 2 improves upon ergonomics by incorporating a central handle and extended base area for improved cup stability. Nonetheless, the design remains constrained by limited resistance to moisture and lacks sufficient aesthetic differentiation.
c. Design 3, in contrast, introduces an integrated structure with interlocking panels and a self-supporting base. The design's geometry provides enhanced strength, while the ergonomic top handle allows for safe one-handed transport. Additionally, the surface accommodates branding placement, contributing to both marketing value and product identity.

The decision matrix (Table 8) evaluates each design using eleven technical criteria, including capacity, convenience, resilience, material strength, sustainability, and production cost. The results indicate that **Design 3 achieves the highest overall score (Net Score: +4)**, outper-

forming Design 1 (–3) and Design 2 (–5). The superiority of Design 3 is attributed to its ability to satisfy multiple technical responses simultaneously:

- **Functional Excellence:** Supports four cups and maintains balance during transport.
- **Material Efficiency:** Utilizes 300 gsm *kraft paperboard* with moisture resistance and structural reinforcement through folded layers.
- **Aesthetic and Ergonomic Appeal:** Features a cream-colored exterior and compact foldable structure that enhances user comfort.
- **Economic Viability:** Achieves low production cost through efficient material cutting and minimal waste.

  These aspects collectively demonstrate Design 3's compliance with both the *Voice of Customer (VoC)* and *Quality Function Deployment (QFD)* outcomes, ensuring an optimal balance between quality, usability, and manufacturability.

Table 4. Comparison of Design Concepts

Technical Response	Design 1	Design 2	Design 3
Cup holdercan carry 4 cups of drinks.	0	0	0
Easy to carry, the top gap is designed to fit the size of your hand grip.	0	0	0
It doesn't use holes, but rather boxes so it fits all sizes.	-	-	+
There is a logo on the cup holder.	0	0	0
Moisture resistant material, not easy to tear.	0	-	0
Has an attractive handle and shape	-	0	+
Using high thickness cardboard and layered structure	-	-	+
Environmentally friendly kraft paper material	0	0	0
Minimum thickness 300 gsm	0	-	+
Cup holderthe exterior is cream colored	-	-	0
Low production costs, included in the price of the drink	+	0	0
Total (0)	6	6	7
Number (+)	1	0	4
Amount (-)	4	5	0
Net Score	-3	-5	4
Rank	2	3	1
Decision	-	-	Selected

Based on the evaluation, Design 3 was selected as the final concept due to its superior combination of mechanical strength, ergonomic efficiency, sustainability, and aesthetic appeal. The use of eco-friendly kraft paper aligns with contemporary sustainability standards while maintaining sufficient durability to support multiple cups. The ergonomic top handle enhances portability and reduces user fatigue, while the folded triangular geometry reinforces load stability. In addition, the design's modular pattern facilitates efficient mass production and simplified assembly processes, thereby reducing labor time and manufacturing costs. This integrated approach reflects a convergence of engineering design, industrial aesthetics, and sustainable material application, making Design 3 not only functionally robust but also commercially feasible.

DISCUSSION

This study evaluates the design of Cup holders as an alternative to plastic bags in the takeaway system at Cafe using the Quality Function Deployment (QFD) approach. A survey of 30 respondents showed that most consumers feel uncomfortable carrying more than one drink using plastic bags, and are willing to switch to Cup holders if provided. Through the stages in the QFD method such as Voice of Customer (VoC), House of Quality (HoQ), and Pugh Matrix analysis, the researcher managed to identify eleven important aspects that are customer needs, such as capacity, material strength, ease of use, and design appearance. The final result of this study produced a Cup holder design that can hold four cups, made of environmentally friendly kraft paper, and reflects the visual identity of the cafe. Overall, this study concludes that the Cup holder innovation not only provides convenience and effectiveness in takeaway services, but also strengthens brand image and supports sustainability principles that can increase the competitiveness.

Based on the results of the validity and reliability test, 11 statements out of a total of 20 statements were declared valid with a Pearson correlation value greater than r-table (0.36), and the results of the reliability test showed a Cronbach's Alpha value of 0.870. This shows that the research instrument has consistency and accuracy in measuring customer perceptions and needs for cup holders. Good validity and reliability ensure that the data collected is worthy of being used as a basis for the product design process. This study is in line with the findings of [9], [10], [11] which state that validity measures the extent to which an instrument is in accordance with what is measured, while reliability reflects the consistency of measurement results. [12], [13] also emphasize the importance of reliability in maintaining data consistency, as well as validity to ensure measurement accuracy. [14] explain that validity can be tested using the Corrected Item to Total Correlation method, while reliability through Cronbach's Alpha, with a value above 0.60 indicates good reliability. All three sources emphasize the importance of validity and reliability in ensuring the accuracy of research.

From the Voice of Customer (VoC) data, there are eleven customer need attributes that have been identified, including cup holder capacity, ease of use, flexible size, design that reflects the cafe's identity, resistance to load and humidity, ergonomic shape, material strength, environmentally friendly material type, material thickness, attractive colors, and prices that do not burden consumers. These attributes reflect consumer expectations regarding the function, comfort, aesthetics, and sustainability of the cup holder to be used. The results of this study support the findings of [15] which show that VoC plays an important role in innovation and increasing company competitiveness. [16] used factor analysis to reduce VoC, and showed its important role in understanding customer needs. In line with that, [17], [18] stated that VoC is a key aspect in product development with the QFD approach, which is able to translate consumer desires into design specifications.

In the processing of House of Quality (HoQ), customer needs are processed to determine the appropriate technical specifications. This process involves steps such as determining the level of customer importance, improvement ratio, selling points, and technical weighting. With this systematic approach, the relationship between customer desires and technical characteristics can be mapped logically and comprehensively, this study is consistent with (Zulkarnain, et al., 2023) who emphasize the importance of HoQ in improving product quality and customer satisfaction through training and work procedures. [19], [20], [21] stated that the integration of HoQ with green marketing strategies can increase business competitiveness. [22], [23], [24] also stated that the selection of raw materials and operator training are important to improve product quality, similar to the approach used in this study.

Based on the HoQ analysis, the technical responses determined include the design of a cup holder that can carry four cups at once, is easy to hold, does not use holes but a flexible box, and uses kraft paper material with a minimum thickness of 300 gsm which is moisture-resistant and not easily torn. In addition, the cup holder is designed to have a cafe logo, an attractive cream color, and maintains cost efficiency so as not to add to the burden on the selling price of drinks. Regarding the

technical response, [25], [26], [27] emphasizes the importance of choosing materials, durability, and design for user satisfaction. [28], [29] state that service quality can be improved through the right materials and ergonomic design. [30], [31] show that improving technical systems such as databases and API systems plays a role in improving service quality. Meanwhile, [32], [33], [34]state that choosing a design based on technical parameters such as mass, mobility, and yield strength is important for user comfort and satisfaction.

The Pugh matrix shows the assessment of product design based on technical responses, starting from design 1, design 2, design 3. Where from the results of the Pugh matrix, design 3 has the largest net score of 4, followed by design 2 with a net score of -3 and design 3 is -5. The assessment ranking shows that the selected concept is shown by design 3. So the cup holder design that will be developed as a replacement for plastic bags is cup holder design 3. According to research [35], this method allows the selection of the best concept based on the net score of various design alternatives and emphasizes the importance of concept screening to ensure that the product meets customer needs and has optimal visual appeal and functionality. The study [36] also stated that this method is effective in selecting the best concept by comparing the specifications of reference products with competitors.

CONCLUSION

The application of this structured approach successfully linked customer needs with technical specifications in the development of an eco-friendly cup holder design to replace plastic bags in café takeaway services. The validity and reliability test results showed that the research instrument was suitable for use with a high level of consistency (Cronbach's Alpha = 0.870), confirming the validity of the data on which the product design was based. Through the Voice of Customer (VoC) and House of Quality (HoQ) stages, eleven key attributes were identified as having the most influence on customer satisfaction, namely capacity, ease of use, size flexibility, material durability, ergonomics, design aesthetics, and price efficiency. From the results of the *Pugh Matrix*, the third design was selected as the best concept with the highest score (+4), using **300 gsm thick kraft paper** that is moisture-resistant, ergonomic, and displays the cafe's brand identity. This design not only meets functional and aesthetic demands but also supports the principles of sustainability and the circular economy by reducing the use of single-use plastics. Thus, this study proves that QFD can be a strategic tool in creating environmentally friendly products that align with consumer needs, strengthen brand image, and enhance the competitiveness of the beverage industry in Indonesia towards sustainable business practices.

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