Jurnal Sistem Teknik Industri
Journal homepage: https://talenta.usu.ac.id/jsti



Creating Adaptive Design Through Quality Function Deployment Approaches

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ARTICLE INFO

Article history:
Received 20 April 2026
Revised 18 July 2026
Accepted 20 August 2026
Available online 31 October 2026

E-ISSN: 2527-9408
P-ISSN: 1411-5247

How to cite:
V. Frans, Rosnani Ginting and Aulia Ishak, "Creating Adaptive Design Through Quality Function Deployment Approaches", *J. Sist. Tek. Ind.*, vol. 28, no. 4, pp. 211–222, October 2026.

ABSTRACT

Across many product categories, one persistent challenge is the limited ability of tools to function effectively under varying usage conditions. This study focuses on the adaptability limitations commonly found in conventional whisk mixers, which typically operate efficiently only within specific container sizes. To address this issue, QFD was applied to translate customer requirements into technical design specifications through HoQ. Data was collected from active whisk mixer users and engineering experts using questionnaires and interviews. The results indicate that the highest-priority customer requirements were the ability of the whisk to reach the entire bowl area (27.25%), stability across different bowl sizes (16.93%), and adjustable whisk position (16.83%). The HoQ analysis identified the most influential technical characteristics that should be prioritized for design improvement. Based on these findings, an adaptive whisk mixer concept was developed featuring an adjustable whisk head span and adjustable whisk length to accommodate different container diameters and depths. The proposed design demonstrates how a customer-driven QFD approach can improve product adaptability, usability, and functional flexibility.

Keyword: *Design Innovation, House of Quality, User-Centered Design, Quality Function Deployment*

ABSTRAK

Di berbagai kategori produk, salah satu tantangan yang terus muncul adalah keterbatasan kemampuan alat untuk berfungsi secara efektif dalam berbagai kondisi penggunaan. Penelitian ini berfokus pada keterbatasan adaptabilitas yang umum ditemukan pada whisk mixer konvensional, yang umumnya hanya bekerja secara optimal pada ukuran wadah tertentu sehingga menimbulkan ketidakefisienan dan gangguan dalam alur kerja pengguna. Untuk mengatasi permasalahan tersebut, metode QFD diterapkan guna menerjemahkan kebutuhan pelanggan menjadi spesifikasi teknis melalui HoQ. Data penelitian diperoleh dari pengguna aktif whisk mixer dan pakar teknik melalui kuesioner serta wawancara. Hasil penelitian menunjukkan bahwa kebutuhan pelanggan dengan prioritas tertinggi adalah kemampuan whisk menjangkau seluruh area wadah (27,25%), kestabilan pada berbagai ukuran wadah (16,93%), serta kemampuan penyesuaian posisi whisk (16,83%). Analisis HoQ juga mengidentifikasi karakteristik teknis utama yang perlu diprioritaskan dalam pengembangan desain. Berdasarkan hasil tersebut, dikembangkan konsep whisk mixer adaptif yang dilengkapi dengan mekanisme pengaturan lebar kepala whisk dan pengaturan panjang whisk sehingga mampu menyesuaikan berbagai diameter dan kedalaman wadah. Konsep yang diusulkan menunjukkan bahwa pendekatan QFD berbasis kebutuhan pelanggan dapat meningkatkan adaptabilitas, kemudahan penggunaan, dan fleksibilitas fungsional produk.

Keyword: Desain Berpusat pada Pengguna, Inovasi Desain, Rumah Mutu, Quality Function Deployment

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http://doi.org/10.32734/jsti.v28i4.25278

1. Introduction

Product-related challenges occur across many sectors, and one recurring issue involves how well a product can adapt to varying usage conditions [1]. When a product lacks adaptability, it often struggles to accommodate different environments, user habits, or functional demands [2]. This limitation can reduce user comfort, impact performance, and shorten the product's functional lifespan, making adaptability an increasingly important design consideration [3]. The culinary field provides a clear illustration of this issue. Although it is only one example, it highlights how quickly operating conditions can change from dealing with light mixtures to tougher ingredients, and from being handled by casual users to professional cooks [4]. Kitchen tools are expected to function reliably under these shifting demands. When a tool cannot adjust, users must compensate with additional effort or technique modifications, which may lead to inconsistent results and diminished user satisfaction [5]. Current mixer designs still rely on fixed geometries, creating a gap between product capability and user expectations for adaptability.

In culinary settings, effective mixing depends not only on motor or whisk quality but also on how well the tool fits different containers [6]. Yet, many existing designs are made for specific bowl types, limiting flexibility in daily use [7]. This forces users to adjust their workflow, transfer ingredients, and spend more time and effort, reducing efficiency in dynamic kitchen environments [8], [9]. The issue becomes clearer when containers vary in diameter, depth, or material, as many tools cannot adapt, resulting in uneven performance and reduced comfort [10]. This gap between user expectations and product capability highlights the need for a design that accommodates diverse container conditions. The main problem addressed in this study is the limited practicality of fixed designs, and enabling adjustment to various bowl sizes would greatly improve usability and productivity [11]. This mismatch underscores the absence of an adaptive mixing mechanism in existing tools.

Adaptability concerns also extend beyond culinary applications to consumer electronics, household tools, and personal devices [12]. Modern users expect products that respond smoothly to different situations rather than forcing them to adjust their behavior. A product that performs well only under fixed conditions becomes outdated quickly, motivating designers to incorporate flexibility, modularity, or responsive mechanisms into their solutions [13]. The novelty of this study lies in offering a compact adaptive whisk concept combining adjustable length and wire span, which is not yet common in current designs.

To address these challenges effectively, designers must balance user expectations with technical and manufacturing constraints. Methods such as Quality Function Deployment (QFD) help translate diverse user needs into structured technical requirements. By understanding where adaptability is most critical, designers can develop products that remain reliable, comfortable, and efficient across a wide range of usage scenarios [14], [15]. To systematically address this gap, the QFD method is applied as the primary framework [16], [17]. QFD translates user needs into measurable technical specifications, ensuring that design decisions remain grounded in user expectations while still accommodating engineering constraints [18], [19]. This structured process enhances communication between designers and engineers, resulting in solutions that are both technically feasible and user-oriented [20]. Through this engineering approach, QFD ensures that adaptability requirements are converted directly into targeted design parameters.

The purpose of this research is to create a design solution capable of adapting to varying container conditions while maintaining ergonomic comfort and functional performance. Using QFD, this study systematically converts user needs into technical requirements to address the limitations commonly found in conventional tools [21], [22]. Ultimately, this research contributes to the broader advancement of kitchen-related product development by emphasizing usability, functionality, and user-centered engineering within an integrated design process [23].

2. Method

This study employs an engineering design research approach aimed at solving a specific functional limitation found in conventional whisk mixers, namely the inability to adapt to different container sizes. The research is categorized as applied research, as it focuses on developing a practical product solution rather than generating theoretical models. A descriptive quantitative design is used to systematically capture customer requirements, evaluate their importance, and translate them into measurable engineering characteristics [2].

QFD serves as the core methodological framework, enabling a structured transformation of user expectations into design specifications through the construction of the House of Quality [24]. This approach ensures that the resulting product concept is grounded in empirical user data and supported by rational technical decision-making [25], [26].

2.1. Data Collection

Data for this study is collected using judgment sampling and quota sampling to ensure relevance and adequacy of respondent expertise. Customer Requirements are gathered from bakery production shops selected through judgment sampling, with the criterion that respondents must be active users of whisk mixers and frequently handle variations in mixing volume [27]. This ensures inputs come from users directly facing mixing challenges.

Technical inputs are obtained using quota sampling from a set number of professionals in product design, mechanical engineering, and manufacturing, with the criterion that each respondent has direct experience in designing, analyzing, or producing mixer-related components [28]. This secures balanced and essential engineering perspectives. This dual-source approach ensures that both user requirements and technical considerations are accurately represented in the design process [29].

2.2. Construction of the House of Quality

The House of Quality (HoQ) translates customer requirements (CR) into prioritized technical characteristics (TC) for a flexible whisk mixer. It begins by identifying CR (WHATs) from bakery operators, capturing expectations such as adaptability to different container sizes, ease of use, ergonomics, and better mixing performance and forming the foundation of the HoQ [21]. The next step involves establishing the *Technical Requirements* (TR) or HOWs, which describe measurable engineering parameters that correspond to customer needs [31], [32]. These include aspects such as motor torque, whisk geometry, connector mechanisms, ergonomic handle design, and compatibility features for multiple container dimensions. The purpose of the HOWs is to translate user-oriented language into technical specifications that can guide the engineering and design process [33].

The interrelationships among TR are then evaluated using the *Correlation Matrix* located at the roof of the HoQ. Its function is to help designers anticipate synergistic effects and avoid technical conflicts during product development [34]. This matrix identifies whether certain technical characteristics reinforce or contradict one another, using symbols such as [30]: (1) V/4 = strong positive correlation, (2) v/3 = moderate positive correlation, (3) x/2 = moderate negative correlation, (4) X/1 = strong negative correlation, (5) -/0 = no relationship. Following this, the *Relationship Matrix* is used to assess how strongly each TR supports each CR. This matrix provides the basis for calculating technical priority weights and determines which engineering characteristics contribute most significantly to fulfilling CR. The relationships are quantified using numerical weights [30], [35]: (1) 9 = strong positive relationship, (2) 3 = moderate positive relationship, (3) 1 = weak positive relationship, (4) 0 = no relationship.

The *Planning Matrix* adds strategic context by incorporating elements such as CR, Total Score, Satisfaction Level, Importance Level, Improvement Ratio, Sales Point, Absolute Weight, and Relative Weight [36]. This matrix prioritizes customer requirements by assessing expected improvements, their influence on purchase decisions, and the resulting absolute and relative weights that guide which needs should receive the most design focus [37]. The final HoQ stage normalizes technical priorities into relative percentages to identify the key requirements, then conducts basic benchmarking to compare existing products against customer needs [38]. These steps reveal performance gaps and confirm the need for targeted improvements. The Technical Matrix then ensures a balanced design by considering technical priority, implementation difficulty, and cost [39].

1. Level of Difficulty (D); Reflects the complexity of implementing a particular design feature.

2. Degree of Importance (I); Represents the calculated priority of each technical parameter based on the Relationship Matrix.

3. Estimated Cost (C); Provides insight into the economic implications of integrating each technical feature.

To determine the key technical requirements needed to address the mixer's limitation in adapting to various container sizes, HoQ evaluates and prioritizes the TC through a structured technical matrix. In this stage, the technical matrix calculated as:

$$\text{Level of Difficulty} = \frac{\text{(TC)-i}}{\sum \text{TC}} \times 100\% \quad (1)$$

$$\text{Degree of Importance} = \frac{\text{(TC-CR)-i}}{\sum \text{(TC-CR)}} \times 100\% \quad (2)$$

$$\text{Estimated Cost} = \frac{\text{Difficulty Score-i}}{\sum \text{Difficulty Scores}} \times 100\% \quad (3)$$

The technical matrix parameters, namely Level of Difficulty and Estimated Cost, were evaluated by technical experts from product design, mechanical engineering, and manufacturing backgrounds using a five-point assessment scale. A score of 1 represented very low difficulty or cost, while a score of 5 represented very high difficulty or cost. The final value for each parameter was determined based on the consensus of expert evaluations. Degree of Importance was calculated directly from the relationship matrix results in the House of Quality.

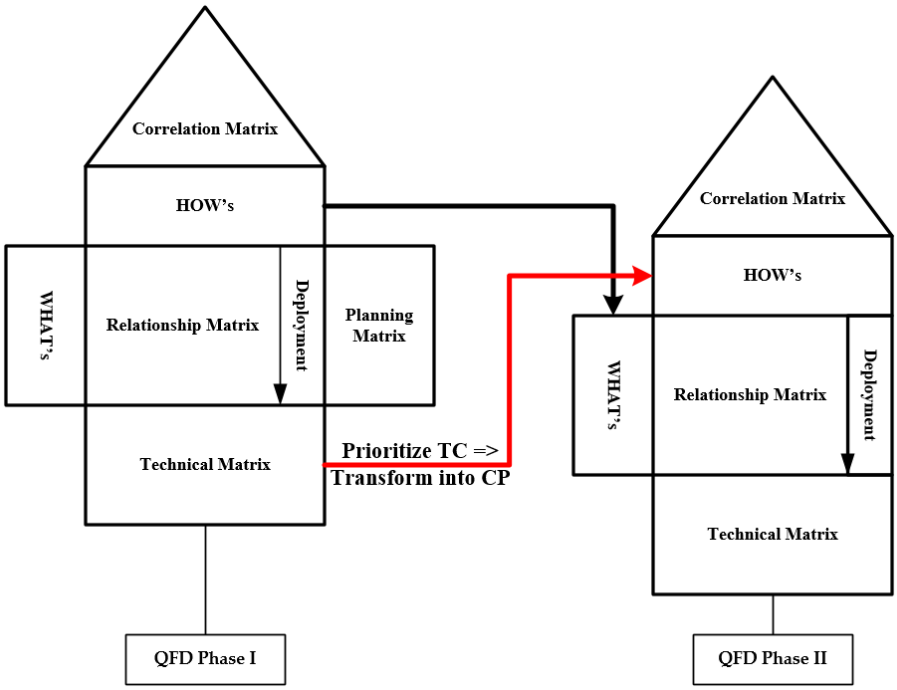


Figure 1. House of Quality (HoQ) Structure

By integrating the WHATs, HOWs, and all related matrices, the HoQ offers a structured framework that aligns user expectations with technical and economic feasibility [30]. Figure 1 above shows the complete HoQ structure and the interactions among its elements.

2.3. Concept development based on QFD

Concept development was carried out using the QFD framework to ensure that the design solution directly reflects CR. In QFD Phase I, CRs were translated into TC and prioritized based on their weighted contributions, allowing the identification of the most influential design parameters. QFD Phase II then expanded these priorities into CP, which guided the selection of components that required improvement [40].

The combined outputs from both QFD phases were used to generate alternative design concepts, with emphasis placed on components that received the highest priority scores [41]. These prioritized elements

became the foundation for formulating targeted design solutions that addressed the key functional issues highlighted by customers. This systematic approach ensured that the resulting concept effectively translated user needs into actionable technical design improvements [42].

3. Result and Discussion

The process begins with gathering what users expect from the mixer. Needs such as ease of use, ergonomic handling, the ability to process various dough types, operational safety, and material durability are compiled into a set of CR.

3.1. Customer Requirements (CR) Identification

The identification of CR was carried out through an open-ended questionnaire adapted from the approach proposed by Kevin Otto and Kristin Wood. The responses were then refined into a closed-ended questionnaire using a Likert scale to quantify the importance of each requirement. The resulting data were tested using the Product Moment correlation method and Cronbach's alpha to ensure validity and reliability. Because the Likert scale produces ordinal data, the Method of Successive Intervals was applied to convert the responses into interval values suitable for further analysis (Table 1). The final set of CR derived from this process is presented in Table 2**Error! Reference source not found.**.

Table 1. Interval Values Obtained Using the Method of Successive Intervals (MSI)

	Scale				
Scale Value	1	2	3	4	5
	1	2.0498	2.7612	3.6419	4.8632

Table 2. Results of CR Identification

CR		CR	
1.	Ergonomic body & handle / vibration damping	5.	Whisk reaches whole bowl area
2.	Adjustable whisk angle/position	6.	Easy disassembly for cleaning/maintenance
3.	Stable on varied bowl sizes	7.	Durable, corrosion-resistant, food-grade material
4.	Motor performance stable across speed/load	8.	Secure locking between whisk & motor

In this step, the planning matrix is developed to determine the priority level of each CR using converted questionnaire data and benchmarking against similar products. The planning matrix consists of the following components [43]:

1. Total Score, obtained by summing all respondent evaluations for each CR based on the rating scale in Table 1. This score serves as the numerical basis for further calculations.

2. Satisfaction Level, calculated as the Weighted Average Performance (WAP) using Eq. (4). where $n_i$is the number of respondents selecting performance value v_i, and $N$is the total number of respondents. This value represents the current perceived performance of each CR.

$$\mathrm{WAP} = \frac{\sum(\mathrm{n_i} \times \mathrm{v_i})}{\mathrm{N}} \tag{4}$$

3. Importance Level (L), representing how strongly customers value each requirement. This value is directly derived from respondent ratings and forms the core weighting factor for priority determination.

4. Improvement Ratio (I), computed using Eq. (5). showing the degree of improvement needed to meet expected performance targets

$$\mathrm{I} = \frac{\mathrm{L}}{\mathrm{WAP}} \tag{5}$$

5. Sales Point (S), assigned as 1.0, 1.2, or 1.5, indicating the potential impact of each CR on increasing product competitiveness and sales.

6. Absolute Weight (AW), calculated using Eq. (6). reflects the total adjusted priority of each CR after considering improvement needs and market impact.

$$AW = L \times I \times S \tag{6}$$

7. Relative Weight**,** determined using Eq. (7).

$$\text{Relative Weight} = \frac{AW_i}{\sum AW} \times 100\% \tag{8}$$

expressing each CR's proportion within the overall priority structure and identifying which requirements should guide the technical design focus. These values collectively establish a structured prioritization of customer needs, forming the foundation for translating CRs into technical characteristics in the subsequent QFD phases. Detailed results are presented in Table 3.

Table 3. Planning Matrix of QFD Phase I

CR	Scale Value					Total Score	WAP	L	I	S	AW	Relative Weight
	1	2	3	4	5							
1	0	4	1	3	2	33.2841	6.6568	2	0.3004	1	0.6009	3.38%
2	0	3	2	5	0	32.0764	6.4153	4	0.6235	1.2	2.9929	16.83%
3	1	2	2	4	1	31.8808	6.3762	4	0.6273	1.2	3.0112	16.93%
4	0	1	5	2	2	35.0831	7.0166	3	0.4276	1	1.2827	7.21%
5	0	1	3	2	4	38.6757	7.7351	5	0.6464	1.5	4.8480	27.25%
6	0	2	5	1	2	33.4633	6.6927	3	0.4483	1.2	1.6137	9.07%
7	0	1	2	4	3	38.4096	7.6819	4	0.5207	1	2.0828	11.71%
8	0	2	4	3	1	33.1972	6.6394	3	0.4518	1	1.3555	7.62%

3.2. Development of Technical Characteristics (TC) and Establishing Relationships

User needs were then translated into a set of TC that validated through interviews with professionals experienced in mixer manufacturing. In this step, the relationships among TC (Table 4) and the relationships between TC and the CR (Table 5**Error! Reference source not found.**) were mapped simultaneously. These relationships were summarized into a planning matrix and a technical matrix that highlights which engineering parameters have the strongest influence on user satisfaction.

Table 4. TC–TC Relationship Matrix

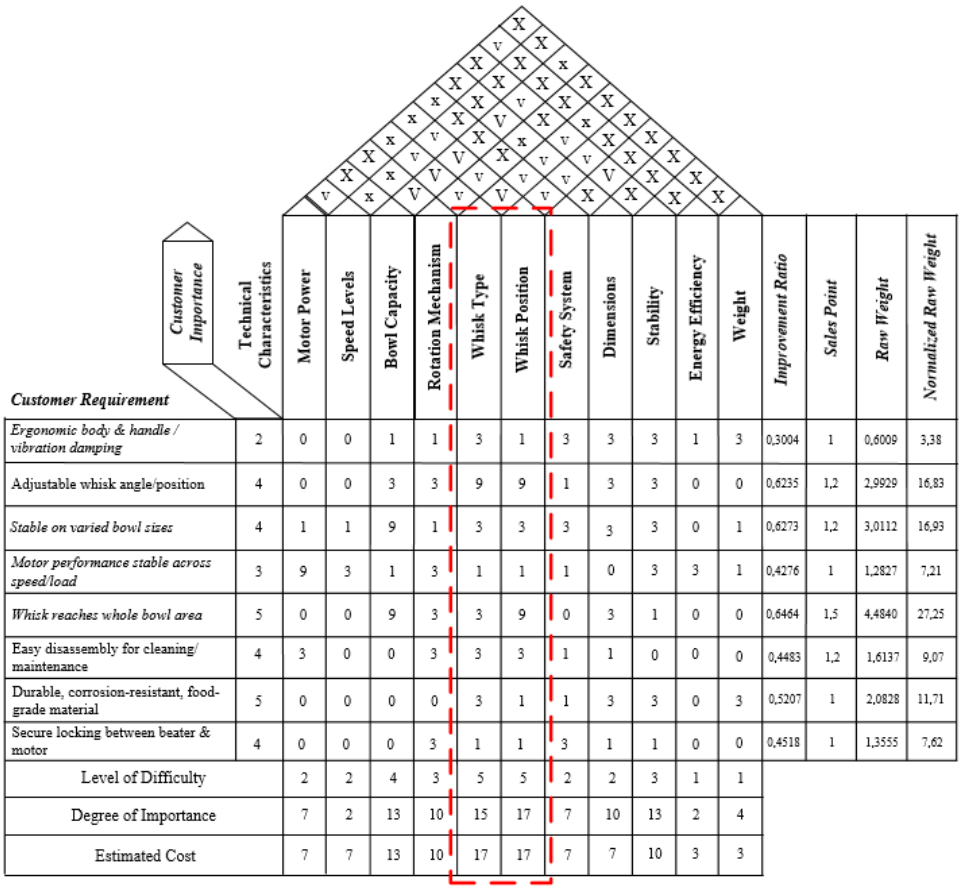
TC\TC	MP	SL	BC	RM	WT	WP	SS	D	ST	EE	W
Motor Power (MP)	0	3	1	1	2	2	2	1	1	3	1
Speed Levels (SL)	3	0	2	2	3	3	1	1	1	1	1
Bowl Capacity (BC)	1	2	0	4	4	4	1	4	3	1	2
Rotation Mechanism (RM)	1	2	4	0	3	3	1	2	1	1	1
Whisk Type (WT)	2	3	4	3	0	4	3	3	3	2	1
Whisk Position (WP)	2	3	4	3	4	0	3	3	3	1	1
Safety System (SS)	2	1	1	1	3	3	0	1	4	1	1
Durability (D)	1	1	4	2	3	3	1	0	1	1	1
Stability (S)	1	1	3	1	3	3	4	1	0	1	1
Energy Efficiency (EE)	3	1	1	1	2	1	1	1	1	0	1
Weight (W)	1	1	2	1	1	1	1	1	1	1	0

Table 5. CR-TC Relationship Matrix

CR\TC	MP	SL	BC	RM	WT	WP	SS	D	ST	EE	W
Ergonomic body & handle	0	0	1	1	3	1	3	3	3	1	3
Adjustable whisk angle/position	0	0	3	3	9	9	1	3	3	0	0
Stable on varied bowl sizes	1	1	9	1	3	3	3	3	9	0	1
Motor performance stable across speed/load	9	3	1	3	1	1	1	0	3	3	1
Whisk reaches whole bowl area	0	0	9	3	3	9	0	3	1	0	0
Easy disassembly for cleaning/maintenance	3	0	0	3	3	3	1	1	0	0	0
corrosion-resistant and food-grade material	0	0	0	0	3	1	1	3	3	0	3
Secure locking between whisk & motor	0	0	0	3	1	3	3	1	1	0	0

3.3. House of Quality QFD Phase I

The HoQ Phase I results identified Whisk Position, Whisk Type, and Stability as the most influential technical characteristics. These technical characteristics directly affect the mixer's ability to adapt to containers with different diameters and depths. Whisk Position and Whisk Type determine the coverage and flexibility of the mixing area, while Stability contributes to consistent operational performance under varying usage conditions. Therefore, these technical characteristics were selected as the primary inputs for QFD Phase II. Figure 2 shows the priority ranking.



Customer Requirement	Customer Importance	Motor Power	Speed Levels	Bowl Capacity	Rotation Mechanism	Whisk Type	Whisk Position	Safety System	Dimensions	Stability	Energy Efficiency	Weight	Improvement Ratio	Sales Point	Raw Weight	Normalized Raw Weight
Ergonomic body & handle / vibration damping	2	0	0	1	1	3	1	3	3	3	1	3	0,3004	1	0,6009	3,38
Adjustable whisk angle/position	4	0	0	3	3	9	9	1	3	3	0	0	0,6235	1,2	2,9929	16,83
Stable on varied bowl sizes	4	1	1	9	1	3	3	3	3	3	0	1	0,6273	1,2	3,0112	16,93
Motor performance stable across speed/load	3	9	3	1	3	1	1	1	0	3	3	1	0,4276	1	1,2827	7,21
Whisk reaches whole bowl area	5	0	0	9	3	3	9	0	3	1	0	0	0,6464	1,5	4,4840	27,25
Easy disassembly for cleaning/ maintenance	4	3	0	0	3	3	3	1	1	0	0	0	0,4483	1,2	1,6137	9,07
Durable, corrosion-resistant, food-grade material	5	0	0	0	0	3	1	1	3	3	0	3	0,5207	1	2,0828	11,71
Secure locking between beater & motor	4	0	0	0	3	1	1	3	1	1	0	0	0,4518	1	1,3555	7,62
Level of Difficulty		2	2	4	3	5	5	2	2	3	1	1				
Degree of Importance		7	2	13	10	15	17	7	10	13	2	4				
Estimated Cost		7	7	13	10	17	17	7	7	10	3	3				

Figure 2. House of Quality QFD Phase I

3.4. House of Quality QFD Phase II

In this phase, the prioritized TC from QFD Phase I is translated into CP that must be improved or redesigned. The CP are identified through interviews with industry professionals and a review of relevant literature, ensuring technically accurate and practice-based component selection. The procedure follows the same steps as Phase I, but the structure is reversed: the WHAT elements consist of the selected TC, while the HOW elements represent the CP. Relationship assessments are then performed between TC and CP, as well as among CP, to determine their contribution to the design goals. A technical matrix is again produced using the same calculation method as in Phase I, but QFD Phase II does not include a planning matrix because customer

weighting has already been defined. As in the previous phase, only CPs with the highest priority scores are retained to ensure focus on the most influential components. The resulting HoQ for QFD Phase II is presented in Figure 3.

Based on the prioritized CR, TC and CP obtained from the QFD analysis, the proposed design concept was developed by aligning the product features with these identified priorities. As a result, the redesigned concept focuses on two key components, which is *Whisk Head* and *Whisk Length* that are adjusted to better meet market expectations. Conventional stand mixers typically use AISI 304 or 316 stainless steel for the shaft and whisk wires, but the adjustable mechanism in the redesigned mixer requires materials with better wear resistance, elasticity, and durability. To address this, 17-4PH stainless steel is selected for the shaft to increase strength and wear resistance, spring-grade stainless steel (17-7PH or 302/304) is used for the whisk wires to improve elasticity and fatigue life [44], and food-grade low-friction polymers (PEEK/PTFE) are applied as interface liners to minimize wear and maintain hygiene [45]. A detailed justification of these material choices is provided in Table 6**Error! Reference source not found.**.

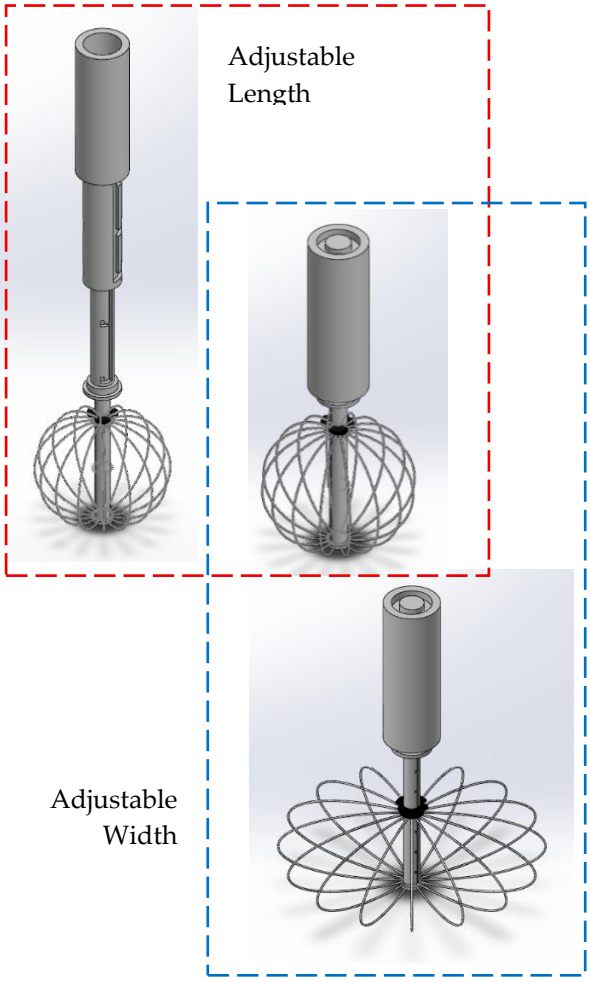


Figure 3. HoQ QFD Phase II and Proposed Design

Table 6. Material Substitution for Adjustable Whisk Mechanism

Component	Common Material	Selected Material	Key Properties Required
Shaft	AISI 304 SS	17-4PH SS	High strength, wear resistance
Whisk Wires	AISI 304/316 SS	17-7PH / 302/304 Spring Wire	Elasticity, fatigue resistance
Interface Liner	— (none)	PEEK / PTFE	Low friction, wear resistance
Connector/Lock	AISI 304 SS	17-4PH SS	Hardness consistency, corrosion resistance

The QFD Phase I results identified the most critical technical characteristics affecting product adaptability, which were subsequently translated into component-level improvements through QFD Phase II. Based on these priorities, the proposed design focuses on the whisk head and whisk length, both of which incorporate adjustable mechanisms to accommodate variations in container diameter and depth. The adjustable whisk head allows the wire span to expand or contract according to container width, while the adjustable whisk length enables effective operation across different container depths. To support the functionality and durability of these mechanisms, material substitutions were introduced, including 17-4PH stainless steel for the shaft, spring-grade stainless steel for the whisk wires, and food-grade PEEK/PTFE liners to improve wear resistance, elasticity, hygiene, and long-term operational reliability.

The prioritization of whisk-related characteristics indicates that the primary limitation of conventional whisk mixers lies in their fixed geometry, which restricts effective mixing performance when used with containers of different sizes. This finding is consistent with previous studies showing that mixing efficiency is strongly influenced by the interaction between mixing components and container geometry, as well as the operating conditions under which the mixer is used [7], [10]. The result also supports the broader concept of product adaptability, where products are expected to accommodate varying usage conditions without requiring users to modify their workflow [1], [2]. Therefore, incorporating adjustable whisk dimensions provides a practical solution for improving mixing coverage, maintaining operational effectiveness, and enhancing user convenience across a wider range of container configurations. A comparison between the original configuration and the proposed adjustable design is presented in Table 7.

Table 7. Summary of Initial and Proposed Design

Aspect	Initial Design	Proposed Design	Key Benefit
Whisk Length	Fixed	Adjustable height	Fits various bowl depths
Whisk Geometry	Fixed wire spread	Adjustable wire spread	Better mixing coverage
Whisk Wire Material	AISI 304/316	17-7PH or 302/304 spring steel	Higher elasticity & fatigue life
Shaft Material	Standard stainless steel	17-4PH stainless steel	Greater strength & wear resistance
Interface Contact	Metal-to-metal	PEEK/PTFE liners	Lower friction & improved hygiene
Bowl Compatibility	Limited	Multi-size adaptable	More flexible operation
Durability	Moderate	Improved	Longer component lifespan

4. Conclusion

This study addressed the key limitations of conventional whisk mixers, namely their inability to adapt to containers with varying diameters and depths due to fixed geometric configurations. Such limitations often reduce operational efficiency, require additional user effort, and lead to inconsistent mixing performance. To overcome this issue, the study employed the Quality Function Deployment (QFD) method to systematically translate customer requirements into prioritized technical characteristics and component-level design improvements. The results of QFD Phase I identified stability, safety system, and whisky attachment as the most critical technical characteristics influencing the adaptability and operational reliability of the mixer.

Based on these priorities, QFD Phase II translated the technical characteristics into specific component redesigns, particularly the whisk head and whisk length. The proposed concept introduces an adjustable whisk head capable of modifying wire span according to container diameter, combined with a variable whisk length that allows the mixer to reach different container depths. These mechanisms directly address the core user requirement for flexibility while improving mixing coverage and usability. In addition, targeted material substitutions including 17-4PH stainless steel for the shaft, spring-grade stainless steel for the whisk wires, and food-grade low-friction liners enhance durability, elasticity, and wear resistance of the adjustable mechanism. Overall, the integration of QFD-based analysis with engineering design considerations produced a more adaptable and functionally robust whisk mixer concept. However, this study is limited to conceptual design and analytical evaluation; therefore, future research should focus on prototyping, experimental performance testing, and ergonomic validation under real mixing conditions to further verify the effectiveness of the proposed design.

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