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*Research Article*

# The Conceptual Integration of Quality Function Deployment and Value Engineering for Product Development: A Case Study of Water Dispenser

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**Abstract:** Nowadays, product development is crucial for ensuring the survival of products in the market. This article focuses on the redesign of water dispenser products based on consumer problems and desires. It aims to provide products at real prices that align with customers' perceived value. Improvements were made using the integration of the Quality Function Deployment and Value Engineering methods. QFD is used to obtain attributes of customer needs and prioritize technical requirements and critical parts. Meanwhile, the VE method aimed to enhance product value and reduce costs based on the priority improvements identified through the QFD method. QFD Phase 1 gives priority to the technical requirements, which are durability, and QFD Phase 2 gives priority to critical parts, namely hoses, and thermostats. Then, based on the results of the QFD, improvements were made with VE, resulting in a type of water dispenser hose that was originally silicon that was substituted for polyethylene with a savings of 0.25 USD and a type of thermostat that initially reset KSD 301 that was substituted for a bakelite thermostat with a savings of 0.14 USD. The total cost savings is 0.38 USD or 26.54%.

**Keywords:** Quality function deployment; Value engineering; Water dispenser

## 1. Introduction

In an increasingly competitive market, companies are required to continue to develop products by identifying product functions as well as the needs or interests of consumers to achieve products that are competitive, of high quality, and still generate high profitability (Prasad et al., 2011). The success of product development lies in the company's ability to understand customer preferences and ensure customer satisfaction with the quality of the provided products. Additionally, it is crucial to focus on optimizing design and production processes while prioritizing customers (Ratlam et al., 2011).

Product development is the turning of market opportunities and different technological presumptions into goods that may be sold in the marketplace. Product development is the process of improving a product's design in order to increase its utility and customer satisfaction (Krishnan and Ulrich, 2001). Problem definition, customer needs analysis, conceptual design, embodiment design, and detailed design are the four fundamental stages into which activities during the design stage can be divided. Gathering and analyzing consumer demands is a crucial first step. Next, those

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needs are translated into features and functions of the product, and finally, concepts that meet the criteria are created and modeled (Ginting and Silalahi, 2023; Favi et al., 2018)

Water dispensers are household appliances that use electricity to heat the heating element and run the cooling machine (Easa et al., 2022). During the course of the use of these products, he raises various complaints. In order to design improvements to the water dispenser product, an external analysis was carried out, namely a preliminary questionnaire to find out complaints or dissatisfaction with users of the water dispenser product. The water dispenser hose frequently leaked, the indicator light was turned off, hot water could not be produced, and the water pump was damaged. However, it was found that the price of the water dispenser product was said to be expensive by users because these complaints were often found, so the value obtained was not in accordance with the costs incurred by consumers.

The objective of this study is to demonstrate how the integration of QFD and VE methodologies is used in the development of a product. The Water Dispenser is the case study object raised in this paper. The development that is expected in this research is to develop product attributes of water dispensers that are tailored to the wishes of consumers to find out the best alternative and make cost savings. According to research by (Liang et al., 2024) the QFD approach is an effective tool for developing products based on customer needs. QFD can assess customer big data information as a foundation for product development (Shen et al., 2022). However, most of the parameters in QFD have uncertainty potential in the process of increasing value. Until the need for a mixture or integration of additional ideas or procedures arises. Therefore, in this paper, the QFD method will be integrated with the VE method to solve the problem. In research conducted by (Youssef, AlDeep, & Olwan, 2023), value engineering was used as an approach to improve quality and reduce costs at oil company plants. The goal of value engineering is to lower product costs without degrading quality or performance (Gunnam and Eneyo, 2016). This aligns with the findings of a study conducted by (Wibisana and Budiyanto, 2021). VE has the goal to increase value by adjusting both cost and function (Value=Function/Cost). Usually, cutting expenses while maintaining or improving the necessary project functions results in an increase in value (Chen et al., 2022). In a related research, the integration of these two methods resulted in cost reduction and enhanced product performance based on consumer complaints (Ginting and Satrio, 2020).

## 2. Introduction

### *2.1. Quality Function Deployment*

Customer opinions are planned and transformed into quantifiable engineering specifications using the Quality Function Deployment (QFD) tool (Erdil and Arani, 2018). This implies that client demands are transformed into quantitative goals. With its focus on the needs of the client, QFD serves as a direct instrument for gathering customer requirements that will be incorporated into product features (Rampal et al., 2022).

Since the QFD approach uses a matrix format that looks like a house, it is sometimes known as a "House of Quality" (HoQ). HoQ is a matrix-style chart that correlates Whats with Hows, consisting of six submatrices (Karasu et al., 2024). Making a deliberate choice concerning the customer's voice is made easier with the help of this strategy. The purpose of the QFD method is to transform objective quality requirements – even subjective ones – into criteria that can be assessed and quantified. It is a complementary step for outlining how and where priorities in product development should be determined. There are three primary steps for implementing QFD; Prioritize the customer needs or wants, both spoken and unspoken; Translate the identified customer needs into technical characteristics and specifications; Build and provide high-quality goods or services while remaining focused on customer satisfaction (Kiran, 2017).

QFD consists of four phases, but in this study, it will only be employed up to phase 2 since the intended use of QFD focuses on product design improvements. The Planning Product Phase, also known as Home Quality, involves translating customer needs into technical product requirements.

On the other hand, the Product Design Phase focuses on translating technical requirements into key characteristics or main system components (Childs, 2019; Jaiswal, 2012). During the design phase, the Phase 1 QFD Matrix aids in identifying and organizing customer needs. Phase 1 is a methodical process for converting consumer demands (or product qualities) into technical demands. A methodical process for converting engineering requirements (or product functions) into product parts is represented by the Phase 2 QFD Matrix. It explains how functions and product components relate to one another.

### *2.2. Identification of functional requirements and analysis of the importance of each functional requirement*

This is the voice of consumers, who have their own needs for products in terms of service quality, expectations, and requirements. Customer requirements can be obtained through technical investigations, data analysis, literature reviews, analyzing the technical data, understanding of industry guidelines, questioning of relevant parties, etc. In this study, customer needs were identified through literature, brainstorming with experts, and distributing questionnaires to customers (Zulkarnain et al., 2023).

(Larger, 2017) argue that performance appraisal must be based on a strict priority process, level of importance, and level of difficulty. For analysis of the importance of each functional requirement, QFD usually uses two approaches, namely the opinion questionnaire and the AHP. In this study, determining the level of importance of each customer's need was carried out by distributing closed questionnaires. By examining the mode values on the closed questionnaire, or the frequency of responses of the majority of respondents to each attribute, the relative importance of these characteristics can be determined.

### *2.3. Analysis of technical requirements*

Key in defining the final design is the technical requirements. Technical requirements are stated in accordance with customer requirements. Technical requirements are ways to meet customer needs (Sugiono et al., 2022). Technical requirements are obtained through literature and brainstorming with experts.

After determining the technical requirements, the level of relationship between TRs is determined. In terms of product design, a change in the expected value of a particular technical requirements of a new product can affect the value of the other technical requirements, which in turn may have an impact on customer expectations. Drawing a correlation between technical requirements was so crucial. In order to do that, component-technical requirement were also examined (Rianmora and Werawatganon, 2021). Describe the level of relationship between each TR using the roof ranking method with the existing symbols (e.g., V = strong positive, v = moderate positive, x = moderate negative, X = strong negative, – = no relationship).

Then determine the relationship between CR and TR as input for the main space in the HoQ matrix using the body ranking scale. It is represented in the form of a symbol or number (e.g., 0 = none relationship, 1 = weak relationship, 3 = moderate relationship, 9 = strong relationship) (Yan et al., 2022; Murugan and Marisamynathan, 2022; Dikmen et al., 2005).

So that the final ranking of TR is carried out. This is used to determine the priority of improvements to the product. TR ranking is done by looking at difficulty rating, then the degree of importance, and estimated costs.

The difficulty rating is specified by the relationship of TR. The tally is done by changing all relationship weight values and dividing the weight of each TR by the total weight. Furthermore, the difficulty level (scale 1–5) is given based on the percentage range: 0-5% (scale 1), 6–11% (scale 2), 12–17% (scale 3), 18–23% (scale 4), and >24% (scale 5). TR's difficulty level can be calculated using the formula (1). The degree of importance can be specified by accounting for the total weight of each relationship between customer requirements and technical requirements. TR's degree of importance can be calculated using formula (2). The calculation of cost estimation is based on the difficulty level. The more difficult it is to meet a technical requirement, the more expensive the cost allocation will be. Calculation of estimated costs using formula (3).

$$\text{Difficulty Rating TR-i} = \frac{\text{Weight of TRi}}{\text{Total of weight TR}} \times 100\% \quad (1)$$

$$\text{Degree of Importance TR-i} = \frac{\text{Weight of TR-i with Attributes}}{\text{Total of weight TR with Attributes}} \times 100\% \quad (2)$$

$$\text{Cost Estimation TR-i} = \frac{\text{Difficulty Rating TRi}}{\text{Total of Difficulty Rating TR}} \times 100\% \quad (3)$$

### *2.4. Identification of critical parts and analysis of their importance*

The stages of determining CP are an analysis of the parts that are important or critical to the product produced. Critical parts (CP) are the most important characteristics of parts or materials in the water dispenser design repair process (Ishak et al., 2024). Product critical parts were identified through interviews and discussions with experts (Zadry et al., 2019). Then, determine the relationship between the phase 1 TR and the CP themselves, as well as the relationship among the critical parts themselves. The degree of relationship between each critical part is described using the roof ranking method. While the relationship between CP and TR uses a body ranking scale.

Then, similar to QFD Phase 1, priority determination of critical parts is performed. The ranking of critical parts is done by looking at the difficulty level, degree of importance, and cost estimation using equations (4), (5), and (6).

$$\text{Difficulty Rating CP-i} = \frac{\text{Weight of CPi}}{\text{Total of weight CP}} \times 100\% \quad (4)$$

$$\text{Degree of Importance CP-i} = \frac{\text{Weight of CP-i with TR}}{\text{Total of weight CP with TR}} \times 100\% \quad (5)$$

$$\text{Cost Estimation CP-i} = \frac{\text{Difficulty Rating CP-i}}{\text{Total of Diffuculty Rating CP}} \times 100\% \quad (6)$$

### *2.5. Value Engineering*

Value engineering is a technique that seeks to reduce and control key costs through methodical analysis to ensure that a particular product or component is designed and manufactured to serve all the desired functions at the lowest cost while maintaining quality, reliability, performance, and appearance (Kiran, 2022). There are five steps taken in the application of value engineering in cost design management, namely:

- Information Phase: The information collected will determine the function of the initial design and proposal and will affect the value of the benefits provided.
- Creative Phase: In this phase, the idea is explored for all possible alternatives to achieve the required function. Therefore, alternatives must be developed to perform the function at a lower cost while maintaining the required performance.
- Evaluation/Assessment Phase, Ideas that have been found during the creative phase will be assessed. A value score is calculated at this stage. The ideas that show the greatest potential in cost savings and product development will be selected.
- Recommendation Phase, this phase presents the best alternatives as well as improvements produced. This phase also presents a description, design, and cost comparison.

Implementation Phase, this phase provides recommendations to companies for implementing the results of improvements with VE (Sahu et al., 2023; Sharma and Belokar, 2012a; 2012b).

### 2.6. *Conceptual of Integration QFD and VE*

QFD and VE have different orientations. QFD aims to improve product design based on customer needs to increase customer satisfaction. While VE aims to reduce operational product costs without lowering the product's quality. The concept of the relationship between QFD and VE has been described by Alain Leblanc, which can be seen in Figure 2.

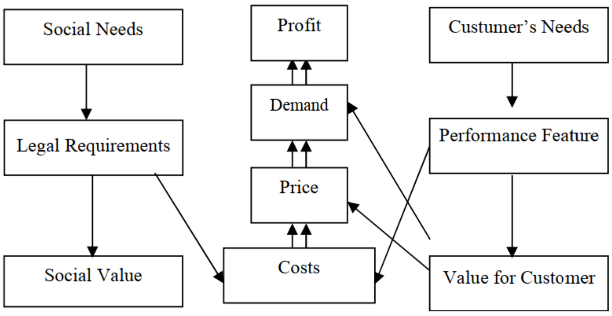


**Figure 1** Relationship between QFD and Value Engineering

The main objective of combining these two methods is to choose alternative improvement designs to increase product value without increasing product operating costs. The product improvement design process begins by identifying customer needs and requirements, determining the characteristics of the product, and identifying solutions or alternatives to meet consumer needs. Then use the VE Technique by choosing solutions that can provide higher value for consumers. According to (Woodhead and Berawi, 2022) research, function analysis is critical in producing product improvement suggestions. It became an important factor in the success of design development. As a result, in this article, functional analysis is aided by integration with the QFD method. The conceptual integration of QFD and VE can be seen in Figure 3.

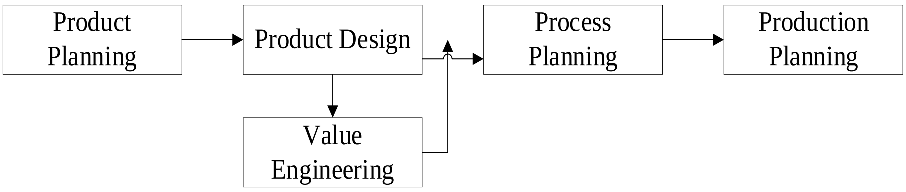


**Figure 2** Conceptual Framework for QFD and VE Integration

The use of VE is in QFD Phase 2. Output data from QFD Phase 2 will be input data for VE Phase 2. The data includes technical product requirements and critical parts of the product. In other words, the first stage of VE has been implemented in the early stages of QFD, so that stage is omitted in the integration concept.

The merger of QFD and VE begins with the identification of customer needs and requirements, as well as technical features. Then, in the needs table, these are reviewed along with the questions of who, how, why, where, and what. So, the first HOQ matrix has been formed. Through this matrix, an analysis of the relationship between customer needs and technical requirements is generated, which then becomes input in the second HOQ matrix. This matrix analyzes the relationship between the solution (which is the critical component in this study) and product characteristics. After these stages, followed by the VE process, The VE will identify a list of design solutions based on the results of the second HOQ. The design improvement process in the form of a solution is determined according to its impact on the product's technical features (Ishak et al., 2020; Ginting et al., 2020; Yegenegi et al., 2011).

Based on the explanation above, this paper is carried out according to the process flow diagram shown in Figure 1, where work begins with an understanding of the terminology and principles of the QFD and Value Engineering methodologies that will be used in improving product design.

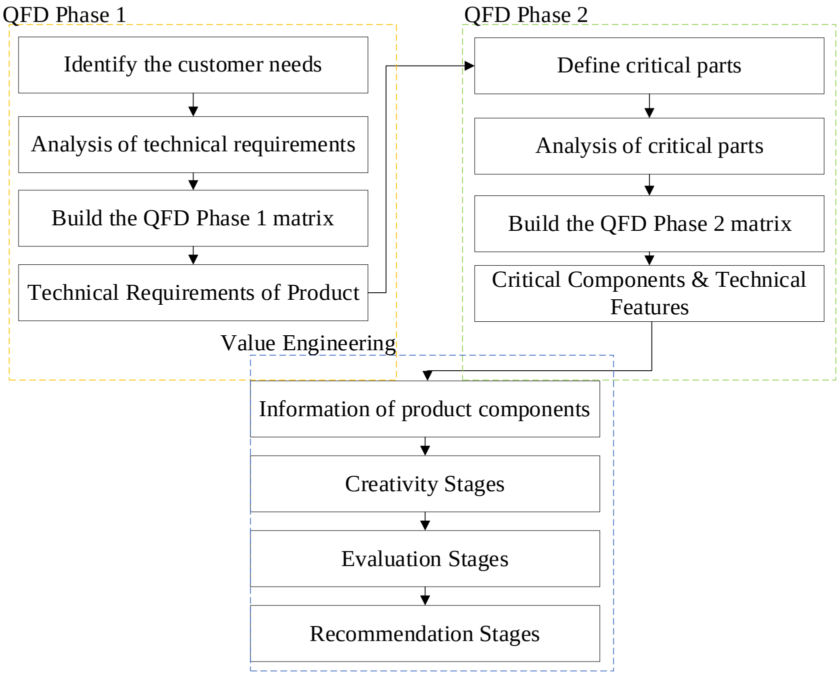


**Figure 3** Flow Chart of Study Methodology

## 3. Results and Discussion

### *3.1. Conceptual of Integration QFD and VE*

QFD and VE have different orientations is made by distributing open questionnaires. Open questionnaires were distributed to 30 respondents using water dispensers. Then a closed questionnaire was prepared to determine the level of interest (consumer perception) and the level of satisfaction (consumer expectations) of the product. To determine the level of importance, the mode values from the closed questionnaire or the frequency of responses from the majority of respondents for each attribute were examined. Table 1 shows details of the attributes that are relevant to customer needs.

**Table 1** CR and Importance Rating of CR

| No | Customer Requirements | Importance Rating |
|---|---|---|
| 1 | The durability of water dispenser products is 5 years. | 3 |
| 2 | The material for the main tube of the water dispenser is plastic. | 4 |
| 3 | The color of the main tube of the water dispenser is blue. | 3 |
| 4 | The water dispenser product has dimensions of 30 by 40 cm. | 4 |
| 5 | An additional function of the product is to add a cup ring. | 3 |

Technical requirements are design requirements or product manufacturing techniques that affect product attributes. Product technical requirements are collected through brainstorming with experts and literature studies. The technical requirements needed to meet consumer needs are maintainable design, standardization of product specifications, durability, product dimensions, product weight, component sizes, and component costs.

The next step is to identify the relevant relationship between each technical characteristic and the relationship between product attributes and technical requirements. The relationship matrix was carried out by a panel of experts. To help experts comprehend the technique, the authors previously discussed the aim of this study and the QFD approach to them. Experts use the roof ranking method to evaluate the relationship between TR and the QFD body ranking scale to evaluate the relationship between CR and TR. This can be seen in Figure 4 (a).

Furthermore, the difficulty level, degree of importance, and cost estimation of the TR are estimated using the equation. (1), (3), and equations. (2), and the results are provided in Table 2.

**Table 2** Difficulty Rating, Degree of Importance, and Estimated Cost of QFD Phase I.

| Factor | TR1 | TR2 | TR3 | TR4 | TR5 | TR6 | TR7 |
|---|---|---|---|---|---|---|---|
| Difficulty Rating | 3 | 3 | 4 | 3 | 3 | 3 | 4 |
| Degree of Importance (%) | 18 | 11 | 20 | 12 | 7 | 11 | 20 |
| Cost Estimation (%) | 14 | 14 | 17 | 14 | 14 | 14 | 17 |

Based on data that has been collected from consumers and experts. HOQ Phase 1 is formulated in Figure 4 (a).

### *3.2. Constructing the HOQ Phase 2 Matrix*

The most significant features of elements or parts in a product are known as critical parts. The critical parts obtained through literature study and brainstorming with experts are the hose of the water dispenser, the accuracy of tying the hose, the Water Path Against Faucet Direction, and the temperature on the thermostat.

The preparation of the design deployment matrix is to determine the relationship among each critical part. The preparation is done using the roof ranking method. The relationship between critical parts and technical requirements is determined by a body ranking scale. The relevant relationship between each critical part and the relationship between the technical requirements and the critical part is resolved by experts. This can be seen in Figure 4 (b).

Then, to determine the priority of critical parts, the level of difficulty, degree of importance, and estimated cost of TR is calculated using the equation. (4), (5), and equations (6), and the results are shown in Table 3.

**Table 3** Difficulty Rating, Degree of Importance, and Estimated Cost of QFD Phase II

| Factor | CP1 | CP2 | CP3 | CP4 |
|---|---|---|---|---|
| Difficulty Rating | 5 | 5 | 5 | 4 |
| Degree of Importance (%) | 35 | 26 | 19 | 19 |
| Cost Estimation (%) | 26 | 26 | 26 | 21 |

### *3.3. Increasing the Value of Water Dispenser Products Using Value Engineering Methods*

The information and data needed to carry out engineering on water dispenser products include data on product constituents, material prices, and material quantities.

The product design improvement process starts with QFD Phase 1, namely identifying customer wants and changing them into technical requirements. The QFD Phase 2 will be based on technical requirements in QFD Phase 1. QFD Phase 2 will generate priority critical parts and will be used as input in value engineering.

The QFD Phase I and Phase II data are used to decide the design for repairing water dispenser items, with the difficulty level, importance level, and cost estimation receiving the most weight. These results indicate that the improvements that must be implemented are in the sections related to; Hose durability and Thermostat durability.

| *Customer Requirement* | *Customer Importance* | TR 1 | TR 2 | TR 3 | TR 4 | TR 5 | TR 6 | TR 7 |
|---|---|---|---|---|---|---|---|---|
| The durability of water dispenser products is 5 years | 3 | 9 | 9 | 3 | 1 | 3 | 1 | 9 |
| The material for the main tube of the water dispenser product is plastic. | 4 | 9 | 3 | 3 | 1 | 0 | 0 | 9 |
| The color of the main tube of the water dispenser is blue | 3 | 0 | 0 | 1 | 1 | 1 | 1 | 3 |
| The water dispenser product has dimensions of 30 by 40 cm | 4 | 3 | 1 | 9 | 9 | 3 | 9 | 1 |
| An additional function of the water dispenser product is to add a cup ring | 3 | 1 | 1 | 9 | 3 | 1 | 3 | 3 |
| Difficulty Rating | | 3 | 3 | 4 | 3 | 3 | 3 | 4 |
| Degree of Importance (%) | | 18 | 11 | 20 | 12 | 7 | 11 | 20 |
| Cost Estimation (%) | | 14 | 14 | 17 | 14 | 14 | 14 | 17 |

(a)

| Technical Requirements | *Customer Importance* | CP - 1 | CP 2 | CP 3 | CP 4 |
|---|---|---|---|---|---|
| Durability | 4 | 9 | 3 | 3 | 3 |
| Component Cost | 4 | 3 | 1 | 3 | 3 |
| *Maintanable Design* | 3 | 3 | 1 | 1 | 1 |
| Standardization of product specifications | 3 | 1 | 3 | 1 | 1 |
| *Product Dimensions* | 3 | 3 | 3 | 3 | 3 |
| Component Sizes | 3 | 1 | 3 | 0 | 0 |
| Product Weight | 3 | 0 | 1 | 0 | 0 |
| Difficulty Rating | | 5 | 5 | 5 | 4 |
| Degree of Importance (%) | | 35 | 26 | 19 | 19 |
| Cost Estimation (%) | | 26 | 26 | 26 | 21 |

(b)

**Figure 4** Quality Function Deployment Phase 1 and Phase 2.

VE seeks to provide the required function of a particular facility at the lowest possible cost, according to (Chhabra, Tripathi, 2014). By doing this, VE shouldn't work to lower the quality, reliability, performance, and maintainability of the product. The creative stage provides several alternatives to the ingredients of the water dispenser product, which will provide cost savings. To facilitate the selection of the best alternative, specific criteria for evaluating the ingredients of the product are established.

**Table 4** List of Alternative Materials

| Component | Alternative Materials | Price |
|---|---|---|
| Hose | Silicone | 1.17 USD |
| | Polyethylene | 0.92 USD |
| | Acrylonitrile-Butadiene-Styrene | 1.14 USD |
| Thermostat | Phenolic | 1.11 USD |
| | KSD 301 Reset Thermostat | 0.45 USD |
| | Bakelite Thermostat | 0.32 USD |

Furthermore, in the evaluation stage, the best alternative is selected from all the alternatives generated in the previous stage. The existing alternatives are analyzed for their advantages and disadvantages based on some assessment criteria. Then experts give weighting and ranking to the criteria.

The known weights will be analyzed for all criteria by showing preferences as important and less important references for each alternative by giving a number of 1 for the alternative that is better than the other alternatives and 0 for the alternative that is less good than the other alternatives. The results of the calculation of the criteria weight will be recapitulated. For example, in Alternative A, the criterion-I water dispenser hose has an index of 0/6, so the weight is 0/6 multiplied by the criterion weight, which is 45, which equals 0. And so on until the third criterion. Matrix analysis can be seen in Table 5.

Based on the matrix analysis results, it can be concluded that the selected alternative is a combination of alternatives B and F. The selected alternative for the water dispenser hose material is polyethylene because it has the largest weight index value compared to other alternative water dispenser hose materials. The chosen alternative for the water dispenser thermostat is the Bakelite Thermostat because it has the largest weight index value compared to other alternative thermostats.

A comparison of the total cost of materials in the initial plan and the selected water dispenser product proposals is shown in Table 6.

**Table 5** Ranking for Alternatives Proposed

| Material | Alternative | Criteria Index | | | Total |
|---|---|---|---|---|---|
| | | I | II | III | |
| | | 45 | 40 | 15 | |
| Hose | Alternative A | 0/6 | 1/6 | 1/6 | 9.17 |
| | Alternative B | 3/6 | 3/6 | 3/6 | 47.50 |
| | Alternative C | 1/6 | 2/6 | 2/6 | 25.83 |
| | Alternative D | 2/6 | 0/6 | 0/6 | 15.00 |
| Thermostat | Alternative E | 0/1 | 0/1 | 1/1 | 15.00 |
| | Alternative F | 1/1 | 1/1 | 0/1 | 85.00 |

**Table 6** Comparison of the Total Cost of Materials in Initial and Proposed Designs

| Initial Design | | Proposed Design | | Savings Cost |
|---|---|---|---|---|
| Material Type | Cost (USD) | Material Type | Cost (USD) | |
| Silicone | 1.17 | Polyethylene | 0.92 | 0.25 |
| Reset KSD 301 Thermostat | 0.45 | Bakelite Thermostat | 0.32 | 0.13 |
| Total | 1.62 | | 1.24 | 0.38 |

The total cost savings for the water dispenser product improvement design is 0.38 USD, or 26.54%. This means that the proposed design can save costs by 26.54%. Based on this, the recommendations given are material replacements for hose and thermostat components. Detailed improvement suggestions can be seen in Table 7.

**Table 7** Designs Improvement Suggestions

| Initial Design | Suggestion Design | Information |
|---|---|---|
|  |  | Changing the material of the dispenser hose from silicone to polyethylene |
|  |  | Changing the KSD 301 reset thermostat to a bakelite thermostat |

The water dispenser was repaired in two parts, as illustrated in Table 7. The two components were repaired by changing their materials. Polyethylene replaces silicone for the dispenser hose, which has a high cost and a limited shelf life of 3-6 months. Meanwhile, the KSD 301 thermostat, which did not have a working temperature limit, was replaced with a bakelite thermostat that did. The two materials that are changed are less expensive and can solve the difficulties identified by the QFD approach.

## 4. Conclusions

The importance of technical requirements is determined using the value of the difficulty rating and the degree of importance. The technical requirements of durability and component costs are the technical requirements of the dispenser product, with the highest difficulty rating of 4 and the highest degree of importance of 17. While in QFD Phase II. Hoses and thermostats are priority critical parts, with a difficulty rating of 5 and a degree of importance of 35 and 26.

This implies that priority elements such as hoses and dispenser thermostats are a top concern when it comes to redesign dispenser. The thermostat temperature is critical for immediate repair since it impacts the use of the product dispenser. The hose's and thermostat's durability is related to its ability to endure external effects, which impacts the dispenser product's durability. QFD result to the dispenser hose and thermostat will be used as input to Value Engineering.

The repairs that must be carried out are in part related to the dispenser hose and thermostat. Savings on the cost of repairing dispenser products using the value engineering method include the type of silicone dispenser hose substituted with polyethylene with a savings of 0.25 USD, and the KSD 301 reset type thermostat was substituted with a bakelite thermostat with a savings of 0.13 USD.

The use of the QFD and VE methodologies in research can identify priority improvements in a product and result in cost savings of 0.38 USD or 26.54%. This figure is quite large in terms of saving money by simply replacing two components, yet replacing these components does not impair product quality and even answers consumer complaints too. In the future, this method could be integrated into product design development to improve manufacturing or assembly processes, even lower production costs, which can be done by combining it with other approaches such as DFX, where the "X" in DFX refers to things which will be the focus of improvement. So that QFD will function to identify consumer desires, while DFX can be used to support the creative phase at the VE stage, according to the problems found.

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## Author Contributions

Rosnani Ginting: Conceptualization, formal analysis, data validation, writing – review & editing, visualization, supervision. Rinaldi Silalahi: Conceptualization, literature review, methodology, investigation, writing – original draft, writing – review & editing. M. Alwi Marunduri: Writing – original draft, software, data collection, data analysis & interpretation. All authors have read and agreed to the published version of the manuscript

## Conflict of Interest

The authors declare no conflicts of interest.

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