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# Integrated Model of Product Design Methods

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## Abstract

A critical factor in product innovation creativity is the development of design methodologies in various fields. The design and manufacture of a product, whether new or existing, is a significant part of engineering activities. The ability to design, develop, and produce products that customers want efficiently is the key to success in today's dynamic global market. Among these capabilities is the ability to design products that are competitive, cost-effective, and ready to be marketed on time. One key factor for maintaining competitiveness in the market is the focus on product and innovation processes by using various integrated design methods that are implemented as a standard part of design activities. The innovative integrated method, which combines various product design methods precisely can solve the main contradictory problems in the process from product demand analysis, product design, to production.

**Keywords:** product design, integrated model, quality function deployment (QFD)

## 1. Introduction

In the actual market situation, manufacturing companies must develop products that can be accepted by the customer, and at the same time, this product must be able to give satisfaction to the customer. Product design must be optimized by considering the costs, design requirements, and customers' needs [1]. The economic success of a manufacturing company depends on the ability to identify customer needs, then create products that meet those needs at a low cost. The company strategy is strongly related to the design and production processes with the most optimum level of the product quality based on customers' needs [2].

Various priorities can be increased competition in the company: quality, the speed of delivery, cost, innovation, and product limitations [3]. The customers' satisfaction and optimizing the total value of the product design is an essential goal for product development time. After defining the design of the product, the production cost can be used to create a new alternative of product design.

Many companies have tried various new approaches in product design to stay competitive. With globalization, enterprises have to compete with both local and international companies. Many methods and techniques are used by some manufacturing companies to enhance product competitiveness by fulfilling customer desire and satisfaction by improving the quality of product design. Many researchers suggest a variety of design tools that were implemented early in the design process. Therefore, various design techniques have already been developed, generated,

and some of them are implemented as a design activity in some manufactures [4]. Various methods have been developed to help collect, organize, analyze, synthesize, and display the information used in the design process [5]. According to Sakao [4], various design guidelines have been developed, while a large number of individual design methods and tools have been generated, of which some were implemented as a standard part of design activities.

## 2. Design on engineering perspective

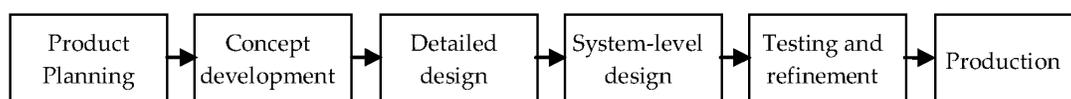
Design based on an engineering perspective is the application of scientific, mathematical, and creative concepts that are imagined into structures, machines, and systems that display the functions of an engineering perspective. In the process of designing consumer products in addition to the form and function of the product, engineering and industrial design are very important in the development of these products depends on the engineer and industrial designer, where the engineer functions as a determinant of the product function and the industrial designer functions to add aesthetic value in the design.

The company's ability to design, develop, and produce products that customers want efficiently is the key to success in today's dynamic global market. Among these capabilities is the ability to design products that meet the demands of competitive and cost-effective products and are ready to be marketed on time. So, companies need to develop strategic goals based on achievement, which creates a competitive advantage in the market. However, these efforts often have limitations in establishing a systematic and consistent set of methods.

## 3. Product design & development

Product design is the process of developing practical and effective ideas for producing new products, encompassing all the engineering and industrial design work used to develop products, from initial concept to production [6]. In this phase, important decisions are made that affect other activities. The general product development goal has not changed much over time: design a product that sale lots of the right margin. Another way to say this is: design the right product the first time, while designing the product right the first time. Product design has been widely studied in order to create methodologies that are generic enough to develop new products. The systematic method developed by Ulrich and Eppinger [7] structures the product development process according to four stages (see **Figure 1**).

This product-oriented approach defines the design process as a sequence of different phases. The transition from the task to the solution takes place in a succession of different stages. Many academic practitioners and researchers have proposed many design principles and methods to improve the quality of design, and some design methods are implemented as part of the design activities of some manufacturing companies. Each of these phases makes it possible to detail a result. Thus the



**Figure 1.**  
*Product development process [7].*

specifications of the design problem are determined when the issue is clarified and defined. These specifications are then used during the various stages of the development process. Then comes the definition of the structure of the functions, the principles of solution, the structural model, technical plans and then production documents.

#### **4. Integrated of product design methodology**

The ability to quickly identify the required method is an essential priority in product achievement and design process [8]. Any company that meets the specifications and requirements of the customer will usually be more competitive than the others [9]. The ability of a company to efficiently design, develop, and manufacture customers' favorite products is key to its success in today's dynamic global marketplace. Among these capabilities is the ability to design products that meet customer needs at a competitive cost and are ready to be marketed promptly [10]. So, companies need to develop strategic goals based on achievements that create a competitive advantage in the market [11]. However, these efforts often have limitations in establishing a systematic and consistent set of methods.

There are many cases where it is difficult to find a product by merely relying on today's technology, such as technical innovation, and the identification of available technological collections in other sectors or areas will be a crucial factor. Therefore, a company must be able to innovate to meet customer needs [12]. A key factor in product innovation creativity methods is the development of design methodology methodologies that have been developed for product development [10, 13–15].

Lance and Bonollo [16] argued that the design method was about procedures, engineering, and design process. The development of design methodology includes research on design principles, practices, and procedures. The main focus on developing a product requires a deep and practical understanding of the design process and how it can be modified to be more productive.

Many academic researchers have proposed various principles of design ethics to improve the quality of design, some of which have been implemented as part of design activities in some manufacturing companies [4]. As a paradigm for simultaneous engineering design processes, it is possible to adopt various design theories and methodologies commonly used in designing a product [17].

##### **4.1 Quality function deployment method**

QFD has been recognized as an effective method for integrated products. QFD is a structured approach for integrating customer voice into product design and development [18]. The introduction of the QFD into the Americas and the European Region began in 1983 and today, and QFD continues to provide strong inspiration worldwide in the academic and manufacturing world. It is widely used in many industries such as the automotive, electronics, construction, and services sectors [19]. QFD is a multifaceted process, offering the greatest potential for significant benefits [20]. QFD is recognized as an effective method for the development of integrated processes and products [21]. The QFD aims to increase customer satisfaction based on their needs and also to enhance the profitability of the company [22]. In other words, QFD is a way of transforming the customers' desire into product design [23]. Further, Lai et al. [24], stated that QFD is a general concept that provides a means for translating customer requirements into technical requirements.

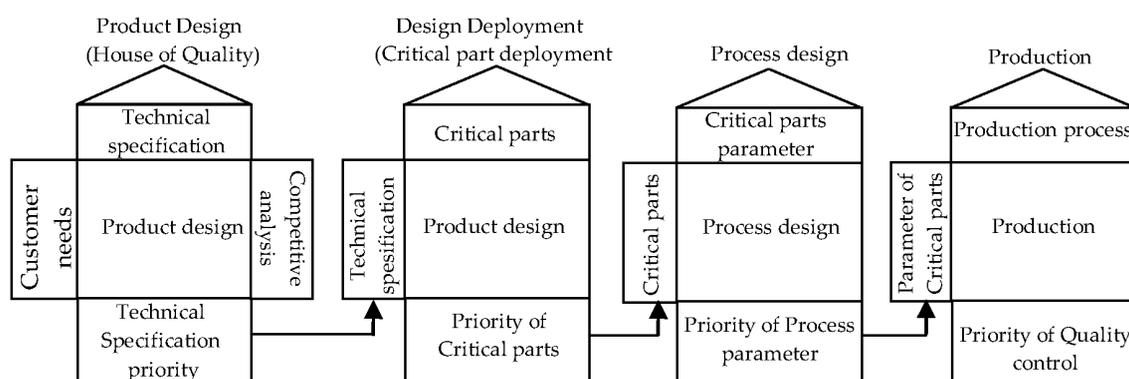
QFD is a systematic approach that determines consumer demands or requests and then translates these demands accurately into technical, manufacturing, and appropriate production planning. Revelle [25] argued that QFD was created to help an organization improve its ability to understand its customers' needs as well as to respond to those needs effectively. It means that QFD is created to help organizations improve the organizational capacity to understand customer needs, and respond effectively. QFD method is used because it can identify the customer needs and provide solutions to the existing problems. QFD described by house of quality contributes to the company about the attributes that need to be prioritized, improved and meet the customer needs.

Bouchereau and Rowlands [26], argued that the starting point of the QFD is customer preference, though often cited but measurable. These requirements will then be converted to technical specifications. Each phase of the QFD matrix represents a more specific aspect. However, only one of the essential aspects is moved into the next matrix.

Various names know the QFD matrix; the most common is the quality house (HoQ). HoQ introduces cross-linking between customer needs and design change and between the design variants themselves. Each customers' requirement is converted into one or more technical specification at all levels of the structured project with interrelated matrix [24, 27, 28] (see **Figure 2**).

QFD is a method for developing design quality that aims at customer satisfaction and then translates these needs into design goals and quality assurance points to be used at all stages of production. QFD has been recognized as an effective method for integrated products. QFD is a structured approach to integrate customer voices into product design and development [18]. QFD continues to provide strong inspiration in the academic and manufacturing worlds [19]. QFD is recognized as an effective guide to the development of integrated processes and products [21]. The objective of QFD is to increase customer satisfaction of product fulfillment requirements and to increase the company's profit [22].

In other words, QFD is the method to change the customers' needs in product design [23]. Furthermore, Lai et al. [24] argued that QFD is a general concept that provides methods for translating customer needs into technical specifications. QFD is implemented as a multi-phase process, offering the greatest potential to realize significant benefits [20]. Bouchereau and Rowlands [26], also argued that the starting point of QFD is the customers' wishes, although often referred to but measurable. These needs will then be changed to the technical specification. Each QFD matrix phase represents a more specific aspect. However, only one of the essential aspect is deployed into the next matrix.



**Figure 2.**  
QFD Matrix [29].

## 4.2 QFD: its advantages and drawbacks

Generally, QFD facilitates the organization in (1) understanding the needs, (2) prioritizing customer needs, (3) communicating between team experts to ensure decision making and reducing data loss, (4) designing a product that meets or exceeding customer requirements, and (5) strategic product. Hales and Staley [30] stated that using QFD can produce better product development at a cost paid by the customer. Also, based on its customer in different company, the benefits and the advantages of some of the research done, such as customer satisfaction and reduced product production time [31], improved communication through teamwork [32] and better design [33]. Also, Bicknell in Chan and Wu [34] reported that significant benefits when QFD were used a 30–50% reduction in engineering change, a 30–50% shorter design cycle, 20–60% lower startup cost, and a security claim 20–50% less.

Lai et al. [24] recognized that QFD has great benefits that can help companies provide a better product, enhance their competitiveness in the market, and increase customer satisfaction. Poel [35] showed that the main objective of QFD is to translate customers' wishes as a goal for product specification. However, QFD is not always easy to implement, and some companies have problems using it, especially in large numbers, as well as complex systems. The problem is conventional QFD is not optimal because it's every stage of the process is subjective and qualitative during data collection to meet customer desires and to obtain technical specifications and critical parts when conducting analysis.

On the other hand, the various problems faced at various stages of QFD implementation have been widely reported in the study, in particular the traditional QFD method [36, 37]. First, the methodological framework of the conventional QFD method is no longer suitable to meet the design and product development requirements [4, 34, 38, 39]. Second, The QFD matrix is too large, and Third, the time required for the matrix sequence deployment is too long, and the product time to be marketed is not acceptable [8]. Then fourth, QFD is difficult to meet the needs of different customer groups or segments [40]. Fifth, the customers' voice is still qualitative, cannot be measured, and often misleading, it is not systematic, and the terms of product function too complicated (in this case, engineering process) are not easily determined [36]. Sixth, the customers' requirement translated into engineering terms (technical specifications) obtained from the company is still vague, too subjective, difficult to verify, and expressed in the linguistic form [40, 41]. These problems or drawbacks prompted the need for other approaches to be added when applying the QFD method. There are many different methods for generating new ideas and selecting the ideas to create a new design or to improve existing ones. Combining QFD with other techniques helps to address these drawbacks and can form the basis of future research. The integrated innovation method, which combines QFD with another technique tool, can precisely solve main contradictory problems in the process from the product demand analysis to the product design, production, and application.

## 4.3 An integrated model of QFD and TRIZ for product design

Although QFD has many advantages, there are still some general implementation problems in QFD. Many investigators have shown that the first phase and the second phase of QFD have many specific limitations and need to be combined with other technical norms. Kazemzadeh and Behzadian [42], have analyzed 650 articles about QFD and grouped them into four broad categories, namely general introduction, functional areas, refinery applications, and literature development.

Their findings show that some of the limitations of QFD, which need to be combined with particular applications to break QFD restraints.

QFD not only deals with product functions but also quality specifications. QFD can be accomplished by considering the adverse effects and evaluating the repair options. The TRIZ methodology can support better designers to find improvement solutions. Therefore, it is used in conjunction with QFD, because TRIZ methods, based on integrated innovation methods, can be organized in many ways. An essential element of TRIZ is conflict [43]. The essential aspects of TRIZ are discrepancies, 40 principles of creation, matrices, and scientific implications [21]. Also, the design of discrepancy matrices is useful for detecting the adverse effects of technical specifications under other improvements [44].

The synergy achieved between the four phases of QFD and TRIZ is a powerful tool for enabling product development in improvement as it emphasizes error prevention practices [10]. The synergies achieved can detect issues such as characteristic conflicts in goal specification as well as negative interactions between product structure, materials, manufacturing processes, and production control specifications.

Many researchers have worked on QFD and TRIZ combination and deployed TRIZ to address QFD problems and shortcomings. For example, Wang et al. [44] identified contradictions within TRIZ by defining methods based on HOQ (House of Quality) in QFD. Various main parameters can be extracted and used to resolve conflicts and contradictions in QFD [45]. Regazzoni et al. [46] pointed out that taking an innovative, active, and prospective approach is much more effective than showing passive reactions in preventing product collapse during its initial designation stages. TRIZ instrument was implemented to resolve these conflicts by translating the technical requirements into 39 designation parameters.

In the contradiction matrix, ameliorating parameters in rows and deteriorating parameters are arranged in columns. As QFD reveals the “what’s” of required operations, the TRIZ instrument determines the “how’s” of the required procedures [5]. Sakao [4] presented TRIZ as a set of technology trends related more to quality control. The purpose is to help designers to become more efficient in making improvements changes to their designs. The designers need only to focus on more

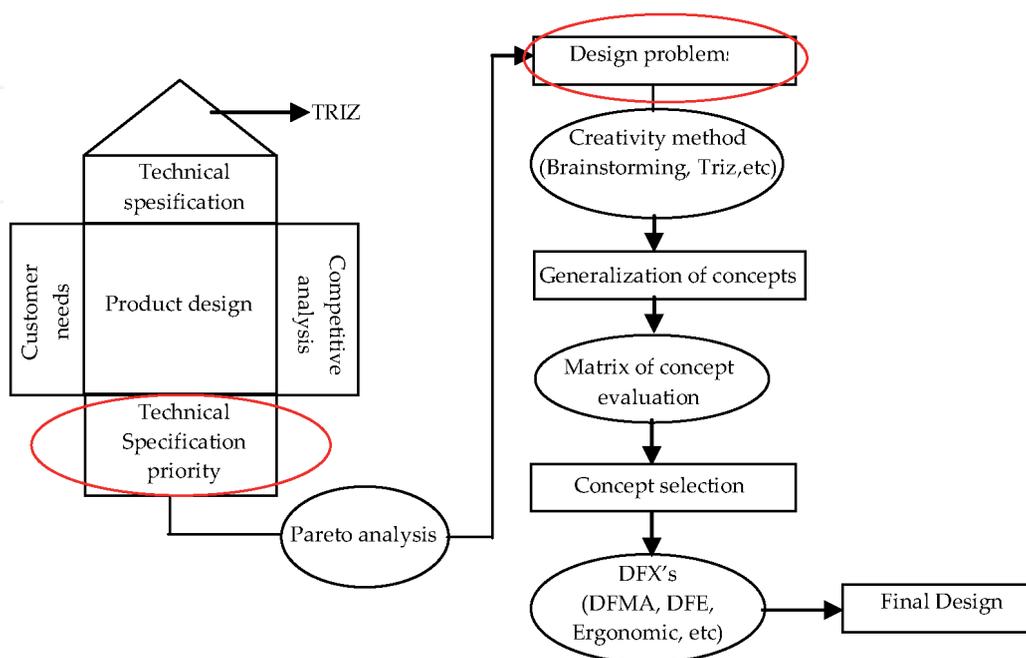


Figure 3. QFD and its application [5].

influential components to improve the quality aspect of a product. This is because QFD reveals “what” of the required operations, while TRIZ instrument determines “how” of the required operations. Farsijani et al. [5] addressed the combination of QFD and TRIZ as in **Figure 3**.

The TRIZ method focuses on solving problems and constraints inherent in QFD. For example, Wang et al. [44] identified contradictions in TRIZ by defining quality-based home methods in QFD. Regazzoni et al. [46] showed that innovative approaches, more active and prospective. The correlation matrix at the top of the quality house is the key QFD integrated with TRIZ [47]. **Table 1** shows a list of some relevant literature on sectors and areas related to TRIZ integration with QFD [27–33].

As shown in **Table 1**, various previous studies have integrated the TRIZ model into the QFD process, mainly in defining the optimum technical specification priority in product design. Numerous previous studies have systematically integrated QFD with TRIZ and enabled effective and systematic technical innovation for new products. TRIZ was developed to help engineers find innovative solutions during the technical product development process. Some case studies show that the proposed model enables designers to find solutions that are simple, innovative, and customer-centric. Therefore, researchers conclude that TRIZ can help QFD quantitatively identify technical requirements and critical section with inventive principles 40 and 39 parameters.

Year	References	Variables	Applied in
2002	Yamashina et al. [14]	Customer requirements and technical specifications	Design of washer
2004	Marsot and Claudon [48]	Customer requirements and technical specifications	Knife design
2009	Rau and Fang [49]	Technical specifications and product changes	Computer packaging design
2010	David et al. [50]	Customer requirements and technical specifications	Design a message change tool
2010	Butdee [51]	Customer requirements and technical specifications	Design of high-performance machines
2011	Yeh et al. [10]	Customer requirements and technical specifications	Design a laptop computer
2012	Yihong et al. [6]	Product details	Material design/construction
2013	Melgoza et al. [52]	Customer requirements and technical specifications	Design of biomedical equipment (stent tracheal)
2013	Shihdan Chen [53]	Product specifications, product details and costs	Design of mobile health tools
2013	Farsijani and Torabdaneh [5]	Customer requirements and technical specifications	Design of power transformers
2016	Patel and Deshpande [54]	Customer requirements and technical specifications	Total performance excellence design
2016	Dos Santos et al. [55]	Customer requirements and technical specifications	Design of lego foam toys
2016	Suzianti et al. [56]	Customer requirements and technical specifications	Laptop computer design

**Table 1.**  
 TRIZ method of solving technical conflicts.

#### 4.4 A novel of QFD combined TRIZ methodology

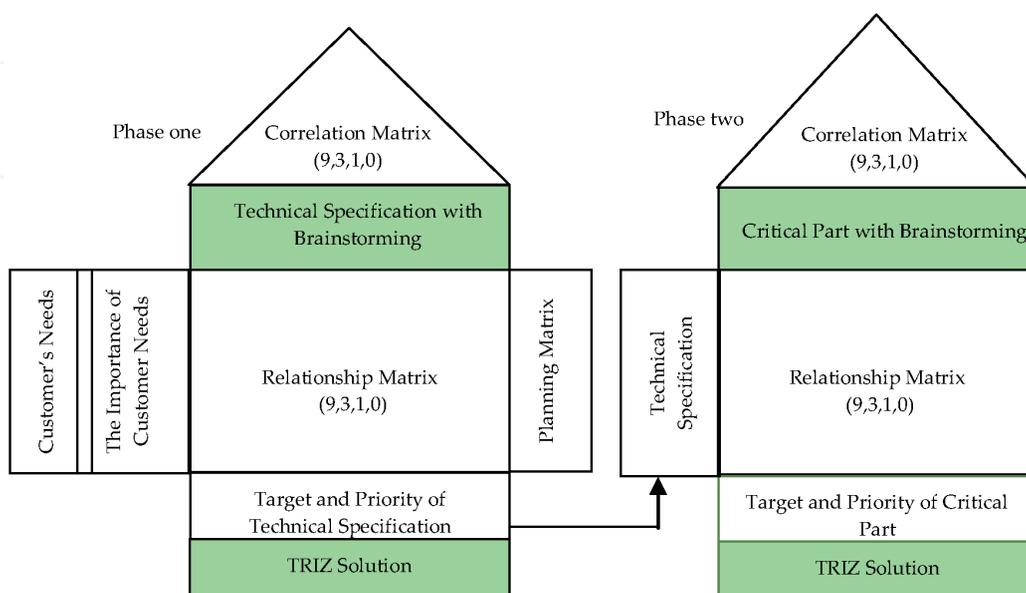
At this phase, the identification of technical specifications and important parts objectively uses the technique of Brainstorming. The next step is to design the proposed concept of an appropriate integration method in dealing with the times that occur in the QFD process of the first and second phases, especially in addressing the contradiction between the technical specification variable (phase one of QFD) and the critical part variable (phase two QFD). This integration built through a combination of the QFD framework with the TRIZ method in a systematic and more integrated manner. Stages of the proposed Integrated QFD (IQFD)-TRIZ methodology framework can be seen in **Figure 4**.

The proposed QFD-TRIZ integration methodology in **Figure 5** which is used to develop the QFD model combined with a more integrated TRIZ can be described in fourteen stages in the followings:

1. To determine and establish research objects.
2. To identify product variables that will be used as question items for the questionnaire.
3. To identify customers' complaints through a questionnaire survey to obtain information related to what customers complained.
4. To identify customers' desires by distributing open questionnaires based on information obtained from customers' complaint questionnaires and to identify customers' needs.

In this phase, customers need to identify product variables uses a questionnaire with a Likert scale.

5. Test the content validity and reliability of the questionnaire through the criterion related validity test, and test reliability with Alpha Cronbachs' coefficient test technique.



**Figure 4.**  
Novel Integration model of QFD-TRIZ.

6. Establish relationships among technical specifications (correlation matrix) uses a questionnaire with weight 9,3,1,0
7. Determine the phase of the relationship between customer requirements and technical specifications, uses the survey, submitted to the company, weighing 9,3,1,0
8. Define and define the planning matrix
9. Define technical specification priority and targets
10. Design improvements to phase one QFD uses TRIZ methods
11. Determination of critical parts is done with the Alerting method
12. Establishing relationships among critical sections (correlation matrix) by analyzing weights 9,3,1,0
13. Determine the phase of the relationship between the Critical Divisions in phase two. The calculation is done by analyzing 9,3,1,0 weight
14. Design improvements to QFD phase two use TRIZ methods
15. Product design.

Meanwhile, the existing integration methodology of QFD-TRIZ model by Melgoza et al. [52], was used as the development of a Novel integration model developed in the study (see **Figure 5**). The QFD integration methodology steps with the TRIZ model have been selected to be compared with the Novel IQFD-TRIZ. The stages of the existing model as follows:

1. Identification of customer requirements matrix

In this phase, customer voice recognition to know what customers want in terms of product design is done through the product survey. The data are qualitative data.

2. Engineer's voice matrix identification

In this phase, defining the technical specifications of the existing IQFD – TRIZ method is done uses Interviews.

3. Identification of the interest phase of the customer change

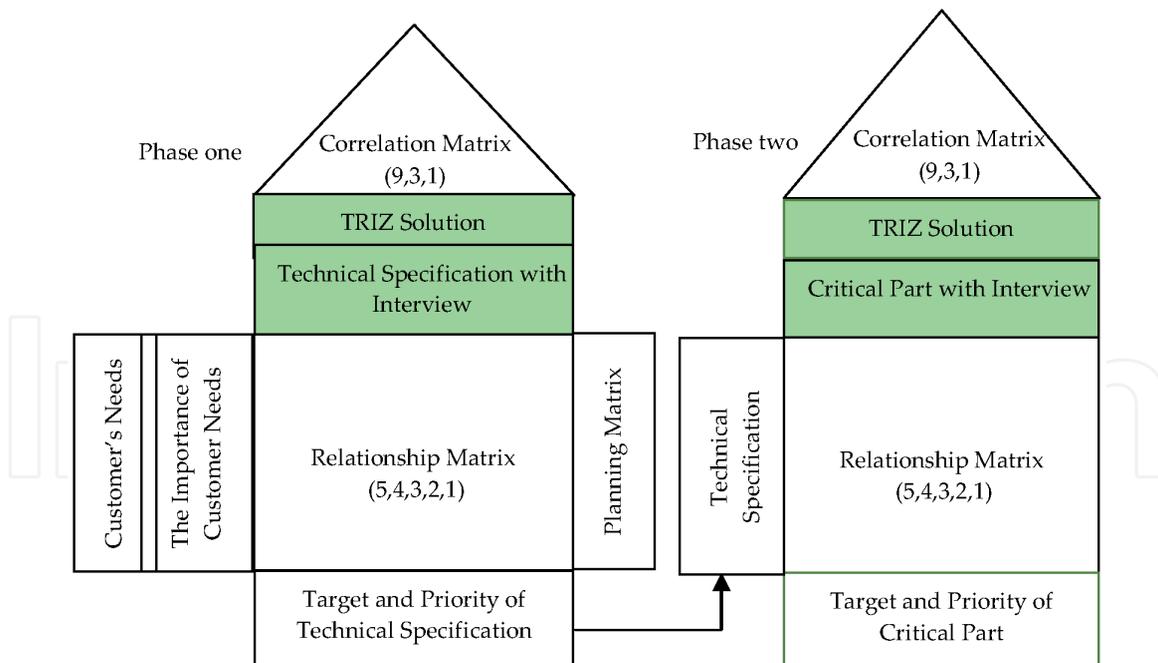
This phase uses a questionnaire with the Likert scale.

4. Determine the phase relationship matrix

In this phase, the relationship between customer requirements and technical specifications uses the 5,4,3,2,1 scale.

5. Determine the phase correlation matrix

6. In this phase, the relationship between each technical specification uses the 9,3,1 scale.



**Figure 5.** Matrix of QFD-TRIZ model by Melgoza et al. [52].

#### 4.4.1 Discussion of how to use the novel QFD framework compared to existing QFD

The main focus of this research is to optimize the performance of the QFD process integrated with quantitative design techniques, namely comparing novel QFD integration components (novel IQFD) with existing QFD integration (IQFD). The combination built into this research is compared to the existing one developed by previous research. The components of the novel IQFD methodology framework developed in this research maximize product design models efficiently, structurally, quantitatively, systematically, and propose new solutions in designing new products and company products maximizes the functionality of the TRIZ model into the QFD process.

Meanwhile, the weights and scales used in the novel IQFD use the 9,3,1.0 scale much better than the existing IQFD uses the + 2, +1, 0 -1, -2, 4, 3, 2, 1 scale, 0 and scale 5, 4, 3, 2, 1.0. Besides, to identify customer requirements, technical specifications and critical parts of the novel QFD component use the “Brainstorming” method, and the resulting changes are more relevant than the existing QFD use “Interview” method that performed by only one person in the company. The contribution is used to stimulate open discussion of product creative ideas and improvements made to various sources of information, namely, research, specialist, marketing, sales, production, and management.

#### 4.4.2 Discussion the difference of novel QFD framework compared to existing QFD

Some previous studies have discussed QFD integration with various quantitative design techniques models to overcome the constraints of the QFD process in each of its phases. However, there are still limitations in its implementation. This section will discuss in stages how to use the novel IQFD framework component in comparison to the existing IQFD conducted by previous research.

How to use the novel IQFD-TRIZ framework built in this research in comparison to the existing IQFD-TRIZ developed by Melgoza et al. [52], can be seen in **Tables 2** and **3**, as follows.

Item	Novel IQFD-TRIZ	Existing IQFD-TRIZ
Customer requirements	Conventional QFD	Conventional QFD
Technical specifications	The burden of suffering	Interview method
Relationship matrix	Weight 9,3,1,0	Weight 5,4,3,2,1
Correlation matrix	Weight 9,3,1,0	Weight 9,3,1
Triz solution	Emphasized after analysis of target matrix and technical specification priority	Emphasized after correlation matrix analysis
Extra space/matrix	1. Technical specification contribution 2. Triz solution	Triz solution

**Table 2.**  
 The differences in the novel IQFD-Triz analysis vs the existing IQFD-Triz (Phase One).

**Table 2** above can be described as follows:

1. Identifying customer requirements of the Novel IQFD-TRIZ and IQFD-TRIZ models uses questionnaires to determine product design changes. After identifying the customers' needs, it defines the importance of the customers' requirements. Novel IQFD-TRIZ built on this research, and the existing IQFD-TRIZ developed by Melgoza et al. [52] uses a Likert scale
2. Identification of technical specifications (phase one), and weighting of interests.

After identifying customer requirements, technical specification is implemented with Brainstorming method used in the proposed IQFD-TRIZ, while the existing IQFD-TRIZ uses the interview method.

As discussed earlier, it is found that customers' voice is still qualitative, that is, measurable and often misleading, systematic. At the same time, the product function requirements are too complex and, therefore, not easy to determine. Changing customer requirements translated into technical specifications obtained from companies is still unclear, too subjective, difficult to verify and only expressed in linguistic form, so the study emphasized that the problem is solved mainly in phase one and phase two, then the novel IQFD framework component built in this research uses Brainstorming method, compared to the existing IQFD that uses the interview method.

Brainstorming methods focus on companies, from top management to middle management, are involved in defining technical specifications and critical areas, making these changes more objective than those of the incorporation rules. Existing QFDs, where technical specifications and critical parts are made to one person from the company, the production manager, make the changes more subjective. Through the use of Brainstorming, it is possible to obtain more specific technical and critical properties than just one person, the production division manager. The focus of Brainstorming in defining technical specifications and critical parts of the novel QFD framework components is to analyze the translation of customer requirements into technical specifications in phase one and also technical specifications into critical parts in phase two objectively, efficient and accurate translation. Also, the identification of technical specifications and critical parts with Brainstorming can identify product changes that are in line with customer requirements.

3. Define the relationship (relationship matrix) between customer requirements and technical specifications (phase one).

Subsequently, defining the relationship between customer requirements and technical specifications, in phase one, and technical specification relationships with critical parts in phase two were performed on the Novel IQFD-TRIZ uses 9,3,1.0. Meanwhile, the existing IQFD-TRIZ model developed by Melgoza et al. [52] uses a scale of 5,4,3,2,1.

4. Define the correlation matrix between technical specifications (phase one).

Correlations between technical specifications in phase one of the novel IQFD-TRIZ model were performed uses the 9,3,1.0 scale, whereas the existing IQFD-TRIZ model uses the 9,3,1 scale.

5. Resolving conflicting differences between technical specifications.

In this phase, the TRIZ method was applied to resolve conflicting issues that occur in phase one QFD. Conflict resolution was performed in various stages, namely (1) defining specific problems, (2) defining common problems uses a  $39 \times 39$  matrix conflict table, (3) identifying joint solving uses 40 TRIZ rules.

6. Define planning matrix (phase one).

After resolving the conflicts in the correlation matrix, then the novel QFD-TRIZ and the existing perform an analysis of customer requirements and the technical specification to prevent design changes in the next phase. In phase two of the QFD, by completing the calculation and determination of the matrix planning, which defines the planned weight loss, calculates the ratio of improvement value to ratio, absolute weight, and relative weight.

7. Define target and technical specification priority (phase one).

The goals and priorities of the critical sections of the novel IQFD-TRIZ and the existing IQFD-TRIZ are both defined to assess the importance of which critical parts are of the highest weight, the difficulty level in designing the smallest product, and the lowest design cost.

Meanwhile, for the differences between the novel IQFD-TRIZ compared to the two-phase IQFD-TRIZ can be seen in **Table 3** as follows:

Item	Novel IQFD-TRIZ	Existing IQFD-TRIZ
Critical part	Brainstorming method	Interview method
Relationship matrix	Weight 9,3,1,0	Weight 5,4,3,2,1
Correlation matrix	Weight 9,3,1,0	Weight 9,3,1
Triz solution	Emphasized after the target matrix and critical section priority	Emphasized after correlation matrix
Extra space/matrix	1. Brainstorming on critical part	Triz solution on correlation matrix

**Table 3.**  
*The differences analysis of novel IQFD-Triz vs the existing IQFD-Triz (Phase Two).*

**Table 3** above can be described as follows:

1. Identification of critical parts (phase two), and weighting of interests.

The identification of the critical part in phase two of the novel IQFD-TRIZ was made uses the Brainstorming method. In contrast, in the existing IQFD-TRIZ model developed by Melgoza et al. [52] uses the interview method. Meanwhile, the novel IQFD-TRIZ uses the Likert scale.

2. Define the relationship (relationship matrix) between technical specification and critical part (phase two).

Defining the correlation matrix in phase two of the novel IQFD-TRIZ model uses the 9,3,1,0 scale, and the 5,4,3,2,1 scale built on the existing IQFD-TRIZ, is similar to the scale used in phase one.

3. Define correlation (correlation matrix) between critical parts (phase two).

After obtaining the variables that are in line with the customers' needs, the next step is to perform a correlation analysis between the variables of the qualitative components defined uses the 9,3,1.0 scale in the model developed in this research. Meanwhile, in the model developed by Melgoza et al. [52] used a scale of 5,4,3,2,1.

4. Define planning matrix (phase two).

Subsequent to defines the correlation matrix further performs customer requirements analysis and technical specifications to prevent any product design changes in the next phase, in phase two or phase three and phase four, which is done by calculating and determining the design matrix, which defines weight planned interest, calculating the ratio of the value of the improvement ratio, absolute weight, and relative weight.

5. Define the target and priority of the critical parts (phase two).

The target matrix and the critical phase priority in phase two are defined just as they were in phase one of the novel IQFD-TRIZ or the existing IQFD-TRIZ.

#### *4.4.3 The contribution for knowledge*

Discussions on the contribution of new knowledge have been discussed through the comprehensive and phases of the QFD matrix. The proof of the contribution of this new knowledge is described as follows:

1. The design of an integrated QFD integration development framework that is oriented to customer emotional satisfaction, technical specifications, and critical parts.
2. QFD phases become more objective by facilitating the calculation of subjective matters.
3. Brainstorming method allow the idea to fill technical specifications in phase one QFD and critical phase in phase two QFD.

4. The methodology combined with QFD is the same for both phases and facilitates learning and application (the same data can be used for QFD phase one and phase two (seamless transfer)).
5. House of QFD model more integrated between phase one and phase two than existing models for each type of QFD combination.
6. House of QFD on phase one and phase two are different for each type of QFD combination where the focus aspects of product design will follow the combined technique.

## 5. Conclusion

QFD flexibility has facilitated integration with other engineering design tools. This research developed a framework of phase one and phase two of QFD combined Triz, in which the concept developed in this research based on previous studies. The framework components of novel QFD-Triz can effectively overcome the drawbacks while increasing QFD analysis in every phase, and also, there is a new procedure in product design. A novel of QFD framework developed in this study has the potential to be the best technique for designing quality from the customers' point of view. It is believed that this study will provide some research opportunities, for example, emphasizing on improving QFD capabilities and raising problems related to the product design.

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