

AN INTEGRATED OF AHP–QFD METHODOLOGY FOR PRODUCT DESIGN: A REVIEW

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ABSTRACT

Many methods, rules, and techniques are used by some manufacturing companies to enhance product competitiveness by fulfilling customer needs and satisfaction possible by improving product design quality. Many researchers suggest a variety of design tools that were implemented early in the design process. Quality function deployment and Analytical hierarchy process methods are one of them. Some researchers have studied in-depth incorporating these two design techniques in product design and development by focusing on translating the consumers' desire into product design. This paper presents the review, investigates analysis, and discussion of some literature on the QFD combined AHP, which is used for product design, either re-designing existing products or designing new products. Several international journal articles have been selected, collected, and analyzed through several relevant scientific publications published in 2010-2016. An in-depth analysis has been carried out on this paper on the benefit, and drawbacks of the integration method on previous research. This paper provides suggestions based on the analysis of the development of the integration method. Hope this paper could be a reference for researchers and other manufacturing companies to implement QFD-AHP integration method in designing product.

Keywords: QFD, AHP's Model, Product Design, Integrated method

ABSTRAK

Banyak metode, aturan, dan teknik yang digunakan oleh beberapa perusahaan manufaktur untuk meningkatkan daya saing produk dengan memenuhi kebutuhan dan kepuasan pelanggan dengan meningkatkan kualitas desain produk. Banyak peneliti menyarankan berbagai alat desain yang diimplementasikan pada awal proses desain, di antaranya adalah penggunaan Metode Quality Function Deployment (QFD) dan Analytical hierarchy process (AHP). Dalam melakukan desain dan pengembangan produk, beberapa peneliti telah mempelajari secara mendalam menggabungkan kedua metode ini dengan melakukan identifikasi kebutuhan konsumen dalam mendesain suatu produk. Dalam penelitian ini menyajikan tinjauan, menyelidiki analisis, dan diskusi beberapa literatur tentang AHP dan QFD, yang digunakan untuk desain produk, baik mendesain ulang produk yang sudah ada atau merancang produk baru. Beberapa artikel jurnal internasional telah dipilih, dikumpulkan, dan dianalisis melalui beberapa publikasi ilmiah yang relevan yang diterbitkan pada 2010-2016. Analisis mendalam telah dilakukan pada makalah ini tentang manfaat, dan kelemahan dari metode integrasi pada penelitian sebelumnya. Makalah ini memberikan saran berdasarkan analisis pengembangan metode integrasi. Semoga tulisan ini dapat menjadi referensi bagi para peneliti dan perusahaan manufaktur lainnya untuk menerapkan metode integrasi QFD-AHP dalam mendesain produk.

Kata kunci: QFD, Model AHP, Desain Produk, Metode Terintegrasi.

INTRODUCTION

Products are the main parts of the production and business activities of manufacturing enterprises. However, product development is the source of this activity, which is a process of continuously meeting user needs. The purpose of grasping every stage of product design and manufacturing is to make sure that the products meet user needs [1]. The general product development goal has not changed over time: design a product that you can sell lots of at a good margin. Another way to say this is: Design the right product the first time while designing the product right the first time. To meet this need, several design guidelines have been actually already developed, while a large number of design methods and tools have been generated and some of them are implemented as a part of design activities in some manufactures [2].

Various techniques have been developed to help, organize, analyze, synthesize, and display the information in the design process [3].

Quality Function Deployment (QFD) is a systematic approach that determines consumer demands or requests and then translates these demands accurately into technical, manufacturing, and proper production planning. Revelle [4] argued that QFD was created to help an organization improve their ability to understand their customer's needs as well as to effectively respond to those needs. It means that QFD is created to help organizations improve the ability to understand customer's needs, and respond effectively. QFD method is used because it can identify the customer's needs and provide the 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.

Unfortunately, many problems faced in implementing conventional QFD, and have been widely reported in various studies. The conventional QFD methodology framework was unsuitable for product design and development. Customer's voices are still qualitative, no measurable, and misleading, not systematic while product requirements are too complex, difficult to defined [5].

Many product design principles that have advantages in implementation, especially when integrated with QFD. Integration conducted to improve the ability to analyze the QFD process on customer satisfaction and desires. One of them is the Analytical Hierarchy Process (AHP) method. AHP method is used to find the priority sequences of various alternatives in solving problems. In complex situations, decision-making is not influenced by only one factor but is multifactorial and covers various levels.

Felice and Petrillo [6] claimed that QFD-AHP is a suitable approach to enhance the definition of customer needs at the planning stage of the QFD phase, as well as to define the hierarchy of interests comparable to functions for the customer needs. Also, [6] argued that the QFD - AHP method is very flexible to analyze and identify customer needs effectively by focusing on the technical activities on outputs that are much more desirable.

This study provides a brief introduction about the QFD method, along with its advantages and drawbacks. Then the AHP approach is reviewed on how this method can help the QFD process. Then it is considered along with what role AHP can play in helping the limitations of the QFD process.

This study was conducted to investigate and examine the advantages and the limitations of the use or application of QFD methods in terms of product design, including analyzing the inadequacies of previous studies in applying AHP integration models into the QFD process both in terms of designing existing products, or new products. Therefore, from the analysis, hope this study can help researchers, designers, manufacturing companies and decision-makers in applying the QFD-AHP integration model more effectively, a more realistic and promising decision on its application in product design.

METHOD

The literature of QFD combined AHP was collected through a classification of the international journal articles from 2010 to 2016. Based on that, 8 journals were selected on product design issues. The main purpose of this paper is to review, investigates and depth analysis the QFD combined AHP with important cases into consideration. This paper describes the integration of QFD with the AHP and its applications. This paper is organized as follows: in section 2, 3, and 4, an introduction of the literature of QFD together with its benefits and drawbacks are reviewed. Section 5 gives an overview of the AHP methodology is introduced. A QFD combined AHP and the model integration applied are discussed briefly in section 6. While the discussion and the direction is carried out in the last section.

CONCEPT

Quality Function of Deployment

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 [7]. QFD continues to offer strong inspiration in the academic and manufacturing worlds [8].

QFD is recognized as an effective guide to the development of the integrated processes and product [9]. QFD aims to increase customer satisfaction of product fulfillment requirements and to increase the company's profit [9]. In other words, QFD is the rule to change the customers' needs in product design [10]. Furthermore, [11] argued that QFD is a general concept that provides rules for translating customer needs into technical specifications. QFD is implemented as a multi-phase process, offering the greatest potential to realize significant benefits [12].

Polak and Bunkowska [13] also argued that the starting point of QFD is the customer's wishes, although often referred to but measurable. These needs will then be changed to the technical specification.

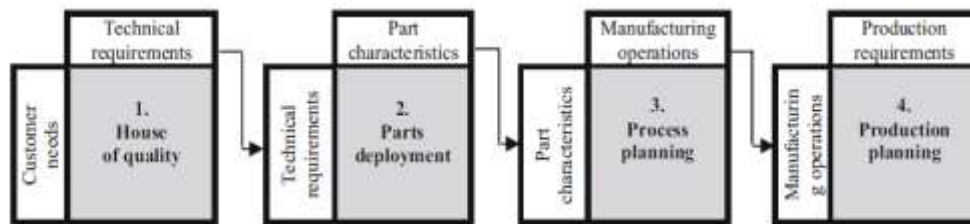


Figure 1. The QFD matrix phases

Each QFD matrix phase represents a more specific aspects, however, only one of the most important aspect is deployed into the next matrix, as shown in figure 1.

The QFD matrix is known by several names, the most common is the quality house (HoQ). HoQ introduces cross-linking between customer needs and design change and between the design variants themselves. By using HoQ, each customer's need is converted into one or more technical specifications at all levels of the structured project with an interrelated matrix [11,14].

The Benefits of QFD Method

Generally, QFD facilitates an organization in 1) understanding the needs, 2) prioritizing customer needs, 3) communicating between team experts to make sure decision-making and reducing data loss, 4) designing a product that meets or exceeding customer requirements, and 5) strategic product. Hales and Staley [15] stated that using QFD can produce better product development at a cost paid by the customer. Besides, based on its customer in a different companies, the benefits and the advantages of some of the research done, such as customer satisfaction, reduced product production time [16], improved communication through teamwork [17], and better design [18]. Also, Bicknell in Wu et al [19] 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.

Table 1 shows some of the advantages of applying the QFD method in the design that was investigated through some previous research.

Table 1. Some of The Identified QFD Objectives

References	Objectives
[20]	QFD Provides a way to translate customer requirements into technical requirements at every phase.
[21]	Describe a structured method to bridge the gap between marketing, manufacturing, and strategy design..
[12]	QFD provides insight into the entire design and manufacturing process and can improve efficiency as production issues are completed at the beginning of the design stage.
[22]	Enables the project team to give detailed specifications of customer specifications and expectations by referring them to technical solutions
[23]	Ensuring customer satisfaction, eliminating mistakes made during service provision and reducing service costs
[24]	Maintain the right focus of the specifications and minimizes misinterpretation of customer specifications, and the HoQ matrix enables organizations to prioritize customer specifications, identify their place in the market, and identify their place against other competitors (benchmarking).
[25]	The matrix series to make sure every customer needs is handled by at least one element in the design, and thus help designers understand the most important design elements.
[26]	QFD promotes group decision-making, where discussion is continued until all available and relevant information is analyzed, and an alternative consensus option that is most likely to achieve the organization's customary goals are achieved.

The Drawbacks of QFD Methodology

Lai et al. [11] recognized that QFD has great benefits that can help companies provide a better products, enhance their competitiveness in the market, and increase customer satisfaction.

Prasad and Chakraborty [26] showed that the main goal of QFD is to translate customer's wishes as a goal for product specification. However, QFD is not always easy to carry out, and some companies have the problem of using them, especially in large numbers, as well as a complex system.

Jaiswal [27] argued that QFD was not merely a design rule but should also be a way of management. Detection of change records and craft expert knowledge in QFD development is necessary.

Farsijani and Torabandeh [28], claimed that the QFD rules could improve the technical specification of the product based on the customer's wishes. Due to the dissemination complexity, various approaches or quantitative design have been proposed to enhance QFD's reliability by objective..

Claudio et al [29] stated that there is a need to be human resource ability to develop the matrix of technical specification and the relationship between the matrices. Some researchers have incorporated QFD method with some other techniques that tend to focus only on one aspect of the design process.

Some restrictions and identities are based on the results of some research relating to the QFD applied canbe seen in Table 2, as follows.

Table 2. Some Identified Drawbacks of QFD Applied

Year	References	Drawbacks
2013	Bouchereau and Rowldans;	Manual response from customer surveys to the house of quality is time-consuming.
2013	Somadatta and Karanjekar, et al.	QFD relies heavily on research results. If the investigation is designed or constructed poorly, the QFD implementation will not meet its aim.
2016	Goderstad and Haskins	For complex products, QFD shows weaknesses that must be addressed to support effective decisions.
2016	Kumaran and Vigneshwar.	Problems in maintaining the commitment to inappropriate organizational and organizational culture are also highlighted. Other aspects such as time-consuming and complexity of the method are often mentioned.
2016	Kecek and Akinci	QFD is not a tool to handle or analyze problems, but a design process.
2016	Sharma and Khdanait	The critical nature of QFD and involves subjectivity actions as weak links that can be solved by blurring integration with QFD.
2016	Olewnik and Lewis	There is a serious limitation for HoQ that has the potential to influence the very early decision in the design process, which subsequently fails in the design or the success of the product market.

AHP Methodology

Analytic Hierarchy Process (AHP) is one of the techniques that can be used in deciding a functional hierarchy with its main input is human perception. The Analytic Hierarchy Process (AHP) was developed by Thomas L. Saaty, who can solve many complex issues, as well as due to the unclear structure of the problem, the uncertainty of decision-makers' perception, and the uncertainty of accurate or even non-existent statistical data at all. The AHP is a flexible model that provides the opportunity for the individuals or groups to build ideas and determine the problem by making their assumptions and getting the desired solution. Analytical Hierarchy Process (AHP) can solve complex multicriteria problems into a hierarchy. Complex problems can be interpreted that the criteria of a problem are so many (multicriteria), the structure of the problem is unclear, the uncertainty of the opinion of the decision-maker.

AHP is a decision-making system using mathematical models. AHP helps in prioritizing several criteria by conducting a pairwise comparison analysis of each criterion [30]. Saaty argued again that AHP is defined as a representation of complex problems in a multi-level structure where the first level is a destination, followed by the factor level, criteria, sub-criteria and the last level of alternatives. With AHP, complex problems can be described in its group that is then set to a hierarchical form so that problems become more structured and systematic in Figure 2.

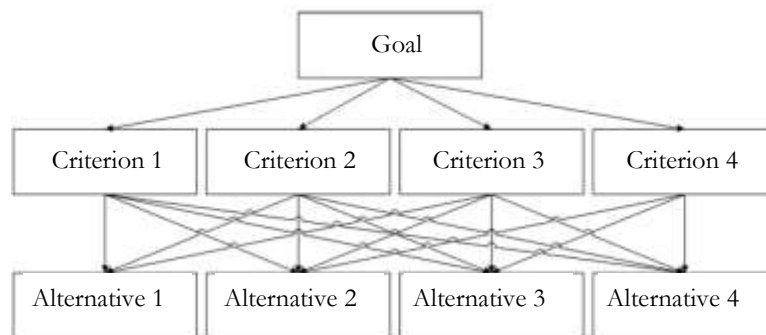


Figure 2. Analytical Hierarchy Process – Problem Decompositions

Complex systems can be easily understood if we break them down into various elements which are the main elements, arranging these elements hierarchically. Then compile or synthesize our considerations on the relative importance of these elements at each level of the hierarchy into a comprehensive set of priorities. Hierarchy is a fundamental tool of the human mind. They involve identifying the elements of a problem, grouping into several homogeneous collections, and then arranging collections at different levels. The simplest hierarchy is linear, which rises or falls from one level to another.

In principle, AHP provides a priority score for each of the criteria. It can be done by using paired comparison questionnaires and a priority scale, which will compare and determine between the priority one item to the other one. The AHP framework has been widely accepted as a realistic, flexible, simple, but highly mathematical modeling technique in a variety of decision-making criteria areas. The AHP framework can be considered as a powerful tool and is needed to make strategic decisions because of its ability to consider the various dimensions of information from several groups, both qualitative and quantitative, into an analysis [31].

COMBINATION OF QFD AND AHP

As widely known, the difficulty in understanding and defining customer needs is one of the common problems of implementing QFD throughout the company. As reported by

the study conducted by [33], about 70 percent of NPD failure cases, customer needs are not carefully considered and properly identified by development teams.

Hundal & Kant [32] presented the QFD planning as a multi-criteria decision and has proposed a new Fuzzy approach to give priority to design needs known in QFD.

In general, QFD facilitates companies in (1) understanding the needs of customers, (2) prioritizing customer needs in terms of interest from the customer point of view, (3) communicating between team experts to ensure decision making and data loss, (4) products that meet or exceed customer needs, (5) designing or selecting product design strategically [34].

Meanwhile, AHP is a rule that can be used in deciding a functional hierarchy with its primary input being human perception. AHP has been developed to address complex problems with multiple criteria. The use of AHP solving complex problems can be described in the groups which then turn to the hierarchical form so that problems become more organized and systematic.

Farsijani and Torabandeh [28] presented the QFD designers as multi-criteria decision problems and have proposed a new fuzzy approach to QFD. By combining QFD-AHP, it can elaborate unstructured problems into a systematic hierarchical decision form. QFD uses quantitative means of pairing benchmarking to define the weight of priorities as well as alternative estimates.

By combining QFD and AHP, then in a qualitative sense, QFD describes unstructured problems into the hierarchy. QFD uses quantitative means to hire paired comparisons to determine the weight of the priorities and alternatives. AHP methodology quantifies the factors with a scale which is called "*the nine points Saaty*" [6]. QFD uses direct performance values, but should not consider multi-level criteria unless some QFDs have been compiled, where it is very complicated to organize it.

Mayyas et al [35] demonstrated AHP and QFD to improve the efficiency of design procedures and the reduction of inconsistencies. Likewise, the system provides a better interpretation of the results using graphical representations, as well as the possibility of detecting the validation of the final manufacturing process selected according to customer requirements.

Erkarslan et al [21] suggested QFD-AHP translate the customer expectations into technical features, and then transformed into numerical values within a measurement system. This study showed that customers' expectations, technical features, and interrelated planning barriers are placed in the matrix for more accurate results. The results of this study prove that when the QFD method is used early in the design process, it can be more effective in product improvement.

Kumar and Garnaik [36] proposed QFD-AHP to design a chair at Lakshmi Enterprises, Odisha, India. They conclude that concludes that the most important technical attribute that must be considered to meet the customer's optimum requirements are "Design". It was preceded by "Stiffness of Cushion for example Seat" and "Volume". It is also concluded that the most important customer needs among all 7 are "Seat Width", followed by, "Support Handles" and "Good Appearance". Therefore, throughout their research, it has been found that to meet the most important customer requirements, the "Seat Width" optimally "Design" must be perfect and must be maintained with the highest priority.

Parvez et al [37] proposed AHD integrated QFD to evaluate the performance of the bathtub, and the rankings of the four renowned bathtub companies are determined according to their results. This study presented that from a safety perspective, the guide bar is recommended so that the user can reach his feet down. QFD gives project managers a

systematic method for compiling and analyzing customer requirements. Subject to further downsizing and optimize it as best you can to improve the design of the bathtub.

Meanwhile, Haroglu et al [38] proposed QFD combined AHP to better understand market demand in terms of performance sensors for automotive heavyweight sensors, as part of the QFD house of quality (HOQ) analysis. They applied the integration model of QFD-AHP to develop textile-based optical fiber sensors for automotive seat occupants. The most important features for the performance of the sensors identified in this study: repeatability, and accuracy, were based on the experimental design of their previous publications.

Parvez et al [39] argued that AHP-QFD integration is used in phase one of QFD. Gagreet Singh Hundal and Dr.Suman Kant (2014), integrated QFD with AHP and fuzzy logic to obtain product design decision-makers based on customers' needs.

Table 3. Some Identified of QFD Combined AHP

References	Parameter	Method Applications
[35]	Technical requirements	Material selection for vehicle structure
[21]	Customer needs, Technical requirements	Design of washbasin ceramics
[36]	Customer needs, product attributes	Chair design
[37]	Customer needs, Technical requirements, Product attributes	Bathtub
[38]	Customer needs, Technical requirements, Product attributes	Automotive Weight Sensor
[39]	Technical requirements, Product attributes	Blender

Table 3 above shows that the QFD integration model with AHP is used to identify and define design parameters and variables. AHP is useful for weighing choices against effective consumer needs. Meanwhile, AHP can overcome multi-objective problems and various criteria based on the priorities of each element in the hierarchy. Therefore, this model is a comprehensive decision-making method. It is concluded that AHP can help translate QFD as well as identify the highest priority of customer needs, technical needs, and critical parts quantitatively and objectively.

ANALYSIS ON DRAWBACKS OF QFD COMBINED AHP

AHP-QFD integration also has limitations and constraints. Particularly constructed by Partovi (2006,2007), that only discussed the relationship and the correlation matrix. Brochner and Mazur (1999), used HoQ more optimally for mobile chair designs.

Table 4. Some Identified Inadequacy on QFD-AHP Integration

References	Drawbacks
[35]	This research does not involve companies at the beginning of the research, such as information on development processes, market analysis, cost, concept research, or prototype research are not included in the scope of research.
[21]	The integration of AHP and QFD does not seem to be clearly defined as detailed of the data processing stage.
[36]	There is no description of the matrix part in which AHP is incorporated in the QFD process. Also, the model integration step is not detailed describes.
[37]	The advanced model of integration is more focused on topical rules than AHP models, and the integrated model is only decided to the first phase of QFD, disconnect to the second phase.
[38]	Customer input data and technical specifications are not explained, as well as the results of the advanced integration model are not reflected in QFD matrices, so the results of the integration were unknown.
[39]	The integrated model developed is more focused on the AHP model, and the integration into the QFD process only stops in the QFD first phase. Meanwhile, integration measures are not discussed in detail.

Table 4 above shows that the combined application of AHP that is integrated into the QFD rules is not optimal enough and the discussion is only to the extent that the development of rules and the joint development stages of the two rules unclearly (yet the AHP rules have not been integrated into the QFD). Besides, although QFD and AHP can

define problems in design proposals, none of them can provide concrete solutions on the way they are required to alter technical specifications.

CONCLUSION

The aim of this paper is hopefully achieved as expected which is contained important result such as success to improve the design of the product case study by applying the selected methods and develop products that has maximize value, convenience, suitable, and easy to use by the consumer. Customers' needs, design requirements, products' characteristics, technical operation and producing requirements become important design procedures. These procedures are organically linked through HoQ, so they can support the product's innovation design processes effectively. The application system of integrating AHP into the QFD process can implement QFD effectively in the process of the development of a new product. Analytic Hierarchy Process (AHP) can solve multi-objective and multi-criteria issues based on the comparison of the priorities of each element in the hierarchy.

This model is a comprehensive decision-making technique. AHP combined QFD could be a very powerful tool for any manufacturing organization in developing new products or optimizing existing products. Manufacturing organizations today need to be able to apply new technology to their products and processes to be successful in the highly competitive global marketplace, and the usage of QFD-AHP integrated can help them meet this objective.

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