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An Improved Algorithm for Product Conceptual Design based on Quality Function Deployment

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Abstract: Conceptual design is the key to product innovation and it will decide the success or failure of the products. Quality function deployment (QFD) provides an open framework and systematic analytical method for product design and Kano model contributes to make different highlight of marketing, so the combination of the two can optimize product design and improve customer satisfaction and loyalty. The author develops an improved algorithm for product conceptual design which is based on the framework of QFD and integrated rough analytic hierarchy process (RAHP) and Kano, through the expansion of typical house of quality. The simulation application in conceptual design of steering wheel illustrates that it can transfer the requirements and importance of customers into technical characteristics and importance of products. This will provide the basis of decision-making for enterprise on final product design and innovation.

Keywords: Quality Function Deployment, Kano Model, Rough Analytic Hierarchy Process, Product Conceptual Design

1 Introduction

Along with the intensive market competition and diversified requirements of the customers, the competitive advantages of enterprise increasingly rely on continuous product innovation [1], and the main stage of product innovation lies in conceptual design. Conceptual design is the process of forming conceptual products which is according to the customers' requirements and using the knowledge of design science, product manufacturing and commercial operation to make an overall planning of product function and structure [2,3]. Conceptual design is the key to product design, and the structure, performance, quality, cost, delivery time, manufacturability, maintainability of product are all set at this stage. Although the investment costs of conceptual design accounted for 7% of the cost of product life cycle, it can decide about 70% of the total cost of product life cycle. Therefore, the success of conceptual design determines the quality of final product and its market competition ability, and directly influences the profitability of enterprise. How to ensure the quality of product design during conceptual design has become the urgent affairs for the designer at present.

Quality Function Deployment (QFD) is a kind of tool for the planning of product design which directly facing the Voice of Customer (VOC), and House of Quality (HOQ) is its core tool. It transfers customer requirements (CRs) into technical characteristics (TCs) by the way of multi-level deductive during the product development design process and provides an open framework and systematic analytical method for product conceptual design [4]. At the same time, Kano model can get a systematic understanding of product requirements and provide some standards of functional trades-offs for product development stage so that it helps to make different highlight of marketing. Thus, the combination of QFD and Kano model has a good application prospect in the stage of product conceptual design, but there is no unified framework at present.

In view of the above situations, the author wants to explore the theory and methods for guiding the product innovation and practice of enterprise which is in order to enhance the core competitiveness by constructing the

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whole framework of product conceptual design under the framework of QFD combing with related methods.

2 Theoretical Backgrounds

2.1 QFD

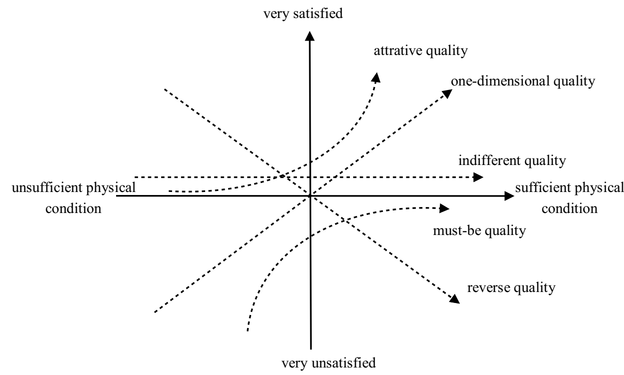
The concept of QFD was first proposed by Japanese scholar named Yoji Akao in 1966. As a customer-oriented product design and planning method, QFD can reasonably and effectively convert customer demands into technical target and operational control procedures in the phase of product development, which can make sure the design and manufacture of products indeed meet customer requirements [5]. Be different from the traditional passive or reactive product development mode "design-experiment-adjust", QFD has turned into a kind of active and preventive modern product design and development mode, and has become a methodology for product design and development driven by customer demands.

Many scholars and experts have extensively focused on the method research and practical application of QFD theory in product planning and design [6,7,8]. Some scholars integrated relevant research methods into QFD, such as Taguchi Method, TRIZ, D-FMEA, Fuzzy Set, etc., in order to discuss the problem existing in the product planning and design, and has got some important theoretical results [9,10,11,12]. However, these studies mostly focus on one part of HOQ (such as "the left wall") for improving certain step of product design (e.g., customer requirements analysis), whereas the systematic perspective of conceptual design does not yet exist. The expression and transformation of uncertainty and fuzzy customer demand information in conceptual design is still the difficulty and hotspot in these studies, and needs to be further discussed in order to support product R&D and innovation activities of enterprise.

2.2 Kano Model

Kano model, also called attractive quality theory, is proposed by doctor Kano in 1984, which explains how the relationship between the sufficiency of a given quality attribute and its resultant customer satisfaction can be distinguished in five perceived quality dimensions as shown in figure 1.

According to the theory [13], quality can be classified into following five categories. (1) Attractive quality. When the products have attractive quality attributes, customers will be very satisfied. But it will not lead to dissatisfaction when it is not present. These quality attributes are not usually expected and often difficult to express by customers, which sometimes refer to the quality attributes bringing about "surprise" for customers.



Source: Kano et al. (1984)

Fig. 1: Kano Model.

(2) One-dimensional quality. When present, customer will be satisfied. When it is not present, it will be dissatisfied. Thus, it can also be called "the more-the better" attributes, that is the more this attributes, the more customers like the product, which refer to the quality attribute which will not give rise to unsatisfied if not satisfied [14]. (3) Must-be quality. Customers expect the must-be attributes, which are considered to be the most basic quality requirements in product design. Under this circumstance, they generally will not tell the company exactly what they want when they are asked about [15]. (4) Indifferent quality. This quality attributes are neither good nor bad, and will not lead to satisfied and unsatisfied whether the quality is present. (5) Reverse quality. It refers to the product quality attribute which is not the customer expected to appear. The higher the degree of implementation of this kind of quality attributes, the more unsatisfied of customer.

Understanding the category of the quality elements is beneficial in improving the quality management of enterprise. One can select different strategies for different quality demands in order to enhance customer satisfaction and loyalty through minimizing dissatisfaction [16]. Related researches on Kano model mainly involved classification of quality type [17,18,19,20], correction of Kano scale [14,21,22] and the application in relevant industries, etc.

2.3 Integration of QFD and Kano Model

The integration of QFD and Kano Model has attracted the attention of many scholars, mostly concentrate on empirical research and mainly focus on its application into different industries and verification of its rationality. Berger et al. [21] put forward the coefficient of customer satisfaction which is an important water-shed. According to Berger et al. [21], combining with Kano model, when considering the quality attribute of products, we should taking both the improvement of satisfied and the damage of unsatisfied about the quality attribute in customer satisfaction into account. This thought has important contribution and influence on the follow-up study. Matzler and Hinterhuber [23] introduced the coefficient of customer satisfaction in the use of QFD, and believed that product development should satisfied the must-be quality requirements of customer, and to be competitive in one-dimensional quality and to surpass competitors in attractive quality. But the study didn't specify how to integrate Kano model into the application of QFD. Tan and Shen [24] proposed to integrate Kano model into QFD framework in order to provide attractive product and give promotion to product R&D. Tan and Pawitra [25] integrated Kano model and SERVQUAL into QFD, and calculated the importance degree of customer requirements through assignment of different quality attributes. Tontini [26] introduced the adjustment factor as a row of the importance degree of customer requirements in QFD. Thus, it is not hard to see, the combination of QFD and Kano model has important application value in practice, but has not yet to form a unified framework.

3 Product Conceptual Design Framework

Based on the existing research [27,28,29], the author constructs the whole framework of product conceptual design by the expansion of typical HOQ under the basic framework of QFD combing with RAHP and Kano model, as shown in figure 2.

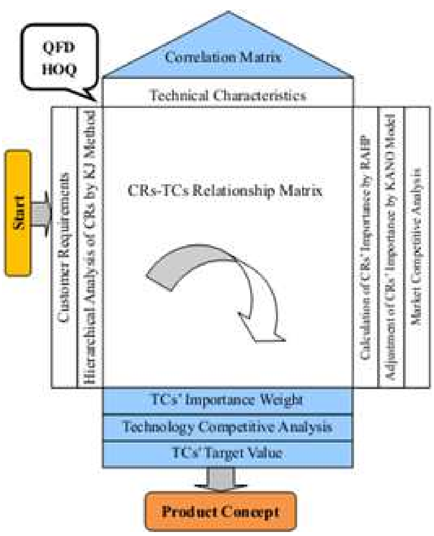


Fig. 2: Framework of Product Conceptual Design.

3.1 Acquisition of Customer Requirements

To deeply dig and accurately grasp the customer requirements is the foundation of the success of product and service, and it is also the guarantee of successful implementation of QFD. The information of customer requirements can be obtained by means of scenario analysis, market investigation, expert interviews, historical data and etc., and analyzed by means of 5W1H (Who, Why, When, What, Where, How) in order to form more comprehensive understanding, which is the key input of follow-up QFD analysis.

3.2 Hierarchical Analysis of CRs by KJ

The information of customer requirements is often diversified in expressing, including advice, complaint, evaluation, want, etc. Therefore, the original data collected not only have multifarious content, but also have different concepts. Customer requirements information is of complexity and polysemy, and in order to cluster and simplify such condition, KJ method is used to construct the hierarchical structures of customer requirements information. The specific steps of KJ is omitted here for its not the focus of the study, which can be consulted from related literature and books.

3.3 Calculation of CRs' Importance by RAHP

According to [28], calculate the CRs' importance by RAHP, with the steps as following.

3.3.1 Build hierarchical structure of CRs

Based on the questionnaire survey of AHP, unfold customer requirements from the first level to the second level, from the second to the third, and so on. Meanwhile, the number of sub-items of previous level must be less than nine to ensure the maneuverability and effectiveness of AHP evaluation.

3.3.2 Conduct AHP questionnaire survey and consistency inspection

Collect and invite customers to participate in AHP questionnaire survey and obtain AHP judgment matrix. Suppose that there are l customers participating in AHP questionnaire survey, so the AHP judgment matrix can be expressed as:

$$P_k = \begin{bmatrix} 1 & P_{12}^K & \cdots & P_{1m}^k \\ P_{21}^k & 1 & \cdots & P_{2m}^k \\ \vdots & \vdots & \ddots & \vdots \\ P_{m1}^k & P_{m2}^k & \cdots & P_{mm}^k \end{bmatrix}$$

in which, $k = 1, 2, \cdots, l$.

Make consistency inspection of AHP judgment matrix by calculating consistency ratio CR. If $CR > 0.1$, judgment matrix gets adjusted; if $CR \leq 0.1$, it shows that evaluation information of surveyed customers is of consistent.

3.3.3 Seek rough pairwise comparison matrix

Build rough group decision matrix of CRs' judgment information to get the rough number of each element in the matrix. Take l AHP judgment matrixes which have passed the consistency inspection and construct rough group decision matrix as follows:

$$P^* = \begin{bmatrix} 1 & P^*_{12} & \cdots & P^*_{1m} \\ P^*_{21} & 1 & \cdots & P^*_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ P^*_{m1} & P^*_{m2} & \cdots & P^*_{mm} \end{bmatrix}$$

in which, $P^*_{ef} = \left\{P^1_{ef}, P^2_{ef}, \cdots, P^l_{ef}\right\}$.

Based on the algorithm of rough number, get rough number P^k_{ef} of each element included in P^*_{ef} by: $RN\left(P^k_{ef}\right) = \left[P^{k-}_{ef}, P^{k+}_{ef}\right]$.

And rough set P^*_{ef} is:

$$RN\left(P^*_{ef}\right) = \left\{\left[P^{1-}_{ef}, P^{1+}_{ef}\right], \left[P^{2-}_{ef}, P^{2+}_{ef}\right], \cdots, \left[P^{l-}_{ef}, P^{l+}_{ef}\right]\right\}$$

Based on the algorithm of rough number, seek average rough interval of P^*_{ij} by:

$$RN\left(P_{ef}\right) = \left[P^-_{ef}, P^+_{ef}\right]$$

Then get the rough pairwise comparison matrix:

$$P = \begin{bmatrix} [1,1] & [P^-_{12}, P^+_{12}] & \cdots & [P^-_{1m}, P^+_{1m}] \\ [P^-_{21}, P^+_{21}] & [1,1] & \cdots & [P^-_{2m}, P^+_{2m}] \\ \vdots & \vdots & \ddots & \vdots \\ [P^-_{m1}, P^+_{m1}] & [P^-_{m2}, P^+_{m2}] & \cdots & [1,1] \end{bmatrix}$$

in which, $\left[P^-_{ef}, P^+_{ef}\right]$ is a rough number, P^-_{ef} is the lower limit and P^+_{ef} is the upper limit.

3.3.4 Calculate the importance of CRs at all levels

$$RN(q_e) = \left[\sqrt[m]{\prod_{j=1}^{m} P^-_{ef}}, \sqrt[m]{\prod_{j=1}^{m} P^+_{ef}}\right]$$

3.3.5 Get the fundamental importance of CRs

Multiply the importance of CRs at all levels by its corresponding importance of sub-level to get the fundamental importance of CRs.

3.4 Adjustment of CRs' Importance by Kano Model

According to [24,28], the relationship between customer satisfaction and the performance of product or service can be approximately expressed as a function in Kano model, that is

$$s = f(k, p)$$

with s representing customer satisfaction, p representing product or service performance, and k is the adjustment index of Kano classification.

Obviously, good product or service performance can bring high customer satisfaction. When compared with must-be quality, attractive quality can easily increase customer satisfaction. Moreover, attractive attribute can increase customer satisfaction quickly with the improvement of product performance. Therefore, there is condition as:

$$\Delta s/s > \Delta p/p$$

in which, s and p represent customers' satisfaction and product performance respectively, Δs and Δp represent increment of customers' satisfaction and increment of product performance respectively for attractive attribute.

In a similar way, there is condition as:

$$\Delta s/s = \Delta p/p$$

$$\Delta s/s < \Delta p/p$$

for one-dimensional attribute and must-be attribute respectively.

According to the research of Tan and Shen [24], the three relations above can be expressed with the equation by using an index k.

$$\Delta s/s < k(\Delta p/p)$$

in which, $k > 1$ for attractive attribute, $k = 1$ for one-dimensional attribute and $0 < k < 1$ or must-be attribute [10,24].

Therefore, the equation can be further transformed into:

$$s = cp^k$$

in which c is constant.

Suppose that s_0 and p_0 respectively represent customer satisfaction and product performance at present, s_1 and p_1 represent the target value of customer satisfaction and the ideal level of product performance respectively, therefore:

$$s_0 = cp_0^k$$

$$s_1 = cp_1^k$$

$$\frac{s_1}{s_0} = \frac{cp_1^k}{cp_0^k} = (\frac{p_1}{p_0})^k$$

Thus, we can get

$$R_{adj} = (IR_0)^{1/k}$$

where IR_{adj} represents the increasing rate of level after adjustment, IR_0 represents the original increasing rate of level in the quality planning matrix of QFD, and k is the classification index of Kano model. For must-be attribute, one-dimensional attribute and attractive attribute, the value of k can be 1/2, 1 and 2 respectively.

3.5 Construction of CRs-TCs Relationship Matrix

It is similar to customer requirements acquisition that product technical information can also be obtained by scenario analysis, market investigation, and expert interviews, and etc., and then make hierarchical analysis by KJ method. After that, the two-dimensional HOQ matrix of CRs and TCs can be constructed. The evaluation of their relationship of each group between CRs and TCs should be completed by some experts who have a deep understanding about the company's product. Usually, "strong, medium and weak" are used to represent the degree of relationship between each pair of CRs and TCs. Every cell of the matrix will be scored. Then the CRs are connected with the TCs.

3.6 Transformation of TCs' Importance

From the above steps, the CRs have been prioritized by RAHP. Each requirement has an importance weight to indicate its order among all of the CRs. With the relationship matrix above and the methods of proportional allocation and independent distribution, the CRs' importance weight can be transformed into the TCs' importance weight. The importance weight of the TCs provides a guideline for designers. Then, the relatively important items can be pinpointed according to the TCs' importance weight. The designers can put forward some product design solutions of product design according to the TCs' priority and the technical feasibility.

4 Simulation Study

Verification of the effectiveness of the product conceptual design framework mentioned above is studied by simulation, which is built on the existing team research results of [28,29,30,31], but with further development.

4.1 Background

The steering wheel is an important component of the car, which plays an important role in the control with the forward direction of the vehicle. In order to reduce later changes and shorten the development cycle, we try to apply QFD, RAHP, and Kano integrated to the design of steering wheel and transfer the importance of customer requirements into the importance of technical characteristics with HOQ. Based on the evaluation of technical characteristics' importance, the designers can determine which aspect should be emphasized on and take more resources. Through the new attempt above, it can improve the conceptual design quality of the steering wheel, and verify the feasibility and effectiveness of the method.

Because of the specialism of steering wheel knowledge, in order to make sure to get the correct data and reliable results, we pay close attention to the following work. First, we finished a lot of information collecting and literature studying at first. At the same time, we conducted some interviews with car users, especially with some steering wheel designers. Besides, we consulted with some design experts to confirm the CRs and TCs. As for the prioritizing of CRs, we investigated nearly eighty four steering wheel designers to fill the AHP questionnaires. And when construct the HOQ matrix of CRs and TCs, we discuss the relationship of CRs and TCs and mark every cell of the matrix in a meeting.

4.2 Hierarchical Analysis of CRs and Determination of Importance Degree

After repeated discussion and by use of KJ clustering method, customer requirements of steering wheel can be divided into the following three levels as shown in table 1, such as the first level "customer satisfaction", the second level "safety, controllability, comfort, reliability and durability, beautiful", and the third level which contains twenty-four items like "non-slip, steering convenient, combination switch is easy to operate", etc.

According to the step 3.3, we can get the importance degree of customer requirements, as shown in table 2. Here we just presented the results, and similarly hereinafter. Rather than regurgitating, the calculating details is omitted which can be seen from the previous step.

In the synthesis of the contents above, we can get the HOQ of the steering wheel as shown in table 3. It is worth noting that the HOQ diagram has no ceiling. The ceiling in HOQ is mainly used to represent the relationship between technical characteristics, which is not the focus of this study. Therefore, the ceiling is omitted in the HOQ, just customer requirements and its relative technical characteristics are represented.

4.3 Expand of TCs and Transformation of Importance Degree

From table 3, following the step 3.5 and 3.6, we can get the sequence of TCs' importance, as shown in table 4.

Table 1: Hierarchical structure of CRs

First-level	Second-level	Third-level
customer satisfaction	safety	[1] material fireproof [2] steering wheel don't block the combination instrument [3] damage light when collision
	good controllability	[4] non-slip [5] steering convenient [6] combination switch is easy to operate [7] steering wheel don't run into other parts [8] operation of function key is comfortable and convenient [9] honk the horn any position are ringing [10] honk the horn feel even
	good comfort	[11] good material tactility [12] grip comfortably [13] no abnormal noise in use [14] steering wheel can absorb sweat
	reliability and durability	[15] wear resistance [16] corrosion preventive [17] components don't loose [18] function key not failure [19] steering wheel don't drop epidermal [20] surface material do not fade
	beautiful	[21] color coordinate with interior [22] good fit between parts [23] good-looking surface material [24] attractive appearance

Table 2: Importance degree of CRs

Customer requirements	Fundamental importance of CRs	Kano classification	Rate increase of level after adjustment	Product characteristic point	Importance degree of CRs
[1]	$[0.18, 0.36]$	M	1.11	1.20	$[0.09, 0.18]$
[2]	$[0.52, 0.98]$	M	1.00	1.00	$[0.27, 0.52]$
[3]	$[0.22, 0.25]$	A	1.27	1.50	$[0.21, 0.24]$
[4]	$[0.04, 0.15]$	M	1.00	1.00	$[0.02, 0.08]$
[5]	$[0.63, 0.99]$	M	1.52	1.20	$[0.53, 0.98]$
[6]	$[0.24, 0.49]$	A	1.28	1.00	$[0.16, 0.33]$
[7]	$[0.30, 0.54]$	M	1.00	1.00	$[0.15, 0.29]$
[8]	$[0.06, 0.33]$	O	1.26	1.20	$[0.05, 0.26]$
[9]	$[0.15, 0.61]$	M	1.76	1.20	$[0.14, 0.57]$
[10]	$[0.05, 0.13]$	I	1.32	1.00	$[0.03, 0.09]$
[11]	$[0.17, 0.37]$	A	1.15	1.00	$[0.12, 0.26]$
[12]	$[0.12, 0.40]$	A	1.26	1.00	$[0.08, 0.27]$
[13]	$[0.31, 0.57]$	O	1.31	1.20	$[0.21, 0.40]$
[14]	$[0.05, 0.17]$	I	1.58	1.00	$[0.04, 0.14]$
[15]	$[0.06, 0.30]$	O	1.00	1.50	$[0.05, 0.24]$
[16]	$[0.02, 0.11]$	A	1.21	1.20	$[0.01, 0.08]$
[17]	$[0.40, 0.98]$	M	1.12	1.00	$[0.25, 0.61]$
[18]	$[0.16, 0.77]$	M	1.59	1.20	$[0.13, 0.63]$
[19]	$[0.05, 0.15]$	M	1.00	1.00	$[0.03, 0.08]$
[20]	$[0.04, 0.12]$	O	1.24	1.00	$[0.03, 0.08]$
[21]	$[0.09, 0.33]$	M	1.00	1.20	$[0.05, 0.17]$
[22]	$[0.18, 0.38]$	O	1.35	1.00	$[0.13, 0.27]$
[23]	$[0.04, 0.26]$	A	1.26	1.20	$[0.02, 0.17]$
[24]	$[0.08, 0.32]$	A	1.15	1.00	$[0.07, 0.23]$

Table 3: HOQ diagram of steering wheel (partial)

TCs CRs	Exterior	Dimensions	Mating dimensions	Moment of inertia	Vibration noise	General arrangement	Operating force of speaker	Operational direction of speaker	Button itinerary	Surface hardness
Steering convenient		3		3						
Combination switch is easy to operate	1	5								
Steering wheel don't run into other parts		3				5				
Operation of function key is comfortable and convenient	1	3							3	
Honk the horn any position are ringing	1	3	3				3	5	3	
Honk the horn feel even			3				3	5	3	
Good material tactility										3
No abnormal noise in use			5		5		1		1	
...										

Table 4: Importance order of TCs (top 15)

Importance Order	Technical Characteristics	$RN(wj)$
1	Dimensions	[0.43, 0.92]
2	Skeleton structure	[0.34, 0.56]
3	Exterior	[0.18, 0.50]
4	Skeleton weight	[0.22, 0.46]
5	General arrangement	[0.19, 0.49]
6	Button damping	[0.12, 0.44]
7	Contact structure of horn	[0.08, 0.36]
8	Vibration noise	[0.12, 0.33]
9	Surface quality	[0.09, 0.28]
10	Mating dimensions	[0.10, 0.27]
11	Moment of inertia	[0.13, 0.25]
12	Operational direction of speaker	[0.05, 0.23]
13	Button itinerary	[0.01, 0.21]
14	Operating force of speaker	[0.07, 0.17]
15	Weather-ability	[0.05, 0.16]

According to the importance sequence of technical characteristics, we can determine the conceptual design scheme of one kind of steering wheel. The designer should be focus on the design index which has a high importance weight and put time and energy into them. For example, in this example, the top 10 TCs (dimensions, skeleton structure, exterior, skeleton weight, general arrangement, button damping, contact structure of horn, vibration noise, surface quality, mating dimensions) should be satisfied firstly in the process of steering wheel designing.

Obviously, the designers can put forward a new product design solution according to the data from Table 4. And the new product design can fully meet the customer requirements, which was acknowledged by the very experienced designers and experts in the company and market.

5 Conclusions and Suggestions

This research constructs the framework of product conceptual design, being based on QFD and integrating with RAHP and Kano model. The application of product conceptual design in steering wheel illustrates that it can reasonably and effectively transfer customer requirements and its importance into product technical characteristics and its importance, and help the designer determine the scheme of product design. The framework of product conceptual design can help to stimulate the creativity of product concept, build the marketing highlight of products, and improve the development level of product concept. Moreover, it can improve the adaptability of the product, reduce the later design change, and shorten the period of research and development. Meanwhile, it is inspirational to the management practice of enterprise. Conceptual design is the key decision linking with the enterprise and market. On the one hand, the decision-making of conceptual design tightly coupling with market development strategy through the target orientation, which can not only avoid the product development with unclear target orientation, but also can effectively support the achievement of the strategic target of enterprise. On the other hand, through evaluation of conceptual design scheme, it can connect with the decision-making of detailed design, assembly design and manufacturing, and try to resolve the problem in the conceptual design phase.

However, the model of product conceptual design has not been widely used in the practice of product development because of some restrictions. Its practical value has been affected certainly, and it still needs to be further expansion. In the future, we can further expand the house of quality, transfer the technical characteristics into process requirements, and finally converted it into the requirements of manufacturing stage. Thereby, the basis for decision-making can be provided in production. Nevertheless, the decision-making of conceptual design is not only a technical decision problem, but also an economic decision problem. Therefore, it needs the support of systematic analytical method combining with technical and economic measures. In the future, it should also consider the economic feasibility of the conceptual design scheme. Only then can we find the best solutions to product conceptual design.

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References

[1] B.K. Jr. Simpson, D. Schaefer, Systematic design method for large-scale manufacturing of fabricated polymers. San Diego, United states: American Society of Mechanical Engineers, 541-552 (2010).

[2] S. Aungst, R. Barton, D. Wilson, The virtual integrated design method: institute for study of business markets. Pennsylvania State University, Pennsylvania State, (2001).

[3] M.J. French (1985) Conceptual design for engineers. London, UK: The Design **Council** (1-97).

[4] J.J. Cristiano, J.K. Liker, C.C. White, Customer-driven product development through quality function deployment in the U.S. and Japan, Journal of Product Innovation Management, **17**, 286-308 (2000).

[5] L.P. Sullivan, Quality function deployment. Quality Progress, **19**, 39-50 (1986).

[6] K. Bergquist, J. Abeysekera, Quality function deployment (QFD)-A means for developing usable products. International Journal of Industrial Ergonomics, **18**, 269-275 (1996).

[7] M. Benner, A.R. Linnemann, W.M. F. Jongen, P. Folstar, Quality Function Deployment (QFD)-can it be used to develop food products?. Food Quality and Preference, **14**, 327-339 (2003).

[8] M. Bevilacqua, F.E. Ciarapica, G. Giacchetta, A fuzzy-QFD approach to supplier selection. Journal of Purchasing and Supply Management, **12**, 14-27 (2006).

[9] N. Leon, I.H. Aguayo, A new model of the conceptual design process using QFD/FA/TRIZ. TRIZ Journal, 3-15 (1998).

[10] K.C. Tan, M. Xie, X.X. Shen, Development of innovative products using Kano's model quality function deployment. International Journal of Innovation Management, **3**, 271-286 (1999).

[11] E. Domb, QFD and TIPS/TRIZ. TRIZ Journal, **11**, 34-50 (2001).

[12] L. Chen, W. Ko, A fuzzy nonlinear model for quality function deployment considering Kano's concept. Mathematical and Computer Modelling, **48**, 581-593 (2008).

[13] N. Kano, N. Seraku, F. Takahashi, Attractive quality and must-be quality. Journal of the Japanese Society for Quality Control, **14**, 39-48 (1984).

[14] M.C. Lee, J.F. Newcomb, Applying the Kano methodology to meet customer requirements: NASA's Microgravity science program. Quality Management Journal, **4**, 95-110 (1997).

[15] G.H. Watson, "Customer focus and competitiveness", in Stephens, K.S, (Ed.), Six Sigmaand Related Studies in the Quality Disciplines. ASQ Quality Press, Milwaukee, WI (2003).

[16] Y. Kuo, Integrating Kano's Model into Web-community Service Quality, Total Quality Management, **15**, 925-939 (2004).

[17] P. Moura e Sa, P. Saraiva, The development of an ideal kindergarten through concept engineering/quality function deployment. Total Quality Management, **12**, 365-372 (2001).

[18] T.A. Pawitra, K.C. Tan, Tourist satisfaction in Singapore-a perspective from Indonesian tourists. Managing Service Quality, **13**, 399-411 (2003).

[19] C.C. Yang, Establishment and applications of the integrated model of service quality measurement. Managing Service Quality, **13**, 310-324 (2003).

[20] L. Witell, M. Lofgren, Classification of quality attributes. Managing Service Quality, **17**, 54-73 (2007).

[21] C. Berger, R. Blauth, D. Boger, C. Bolster, G. Burchill, W. DuMouchel, F. Pouliot, R. Richter, A. Rubinoff, D. Shen, M. Timko, D. Walden, Kano's methods for understanding customer-defined quality. The Center for Quality Management Journal, **2**, 1-37 (1993).

[22] M. Lofgren, L. Witell, Kano's theory of attractive quality and packaging. Quality Management Journal, **12**, 7-20 (2005).

[23] K. Matzler, H.H. Hinterhuber, How to make product development projects more successful by integrating Kano's model of customer satisfaction into quality function deployment. Technovation, **18**, 25-38 (1998).

[24] K.C. Tan, X.X. Shen, Integrating Kano's model in the planning matrix of quality function deployment. Total Quality Management, **11**, 1141-1151 (2000).

[25] K.C. Tan, T.A. Pawitra, Integrating SERVQUAL and Kano's model into QFD for service excellence development. Managing Service Quality, **11**, 418-430 (2001).

[26] G. Tontini, Integrating the Kano Model and QFD for Designing New Products. Total Quality Management & Business Excellence, **18**, 599-612 (2007).

[27] X.T. Wang, W. Xiong, Rough AHP approach for determining the importance ratings of customer requirements in QFD. Computer Integrated Manufacturing Systems, **16**, 763-771 (2010).

[28] J.L. Wang, Methodological research of conceptual design based on quality function deployment. Zhejiang University Hangzhou China, (2011).
[29] J.L. Wang, Product concept generation and evaluation based on QFD and Rough Set Theory. International Conference on Industrial and Intelligent Information Yunnan China, (2010).
[30] W. Xiong, Quality Function Deployment. Chemical Industry Press Beijing China, (2005).
[31] W. Xiong, Quality Function Deployment-from theory to practice. Science Press Beijing China, (2009).

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