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Multi-Kansei Qualities Optimization Design of Products Combined with Refined Kano Model and QFD

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Abstract. Along with the rapid improvements in life quality, the customers' emotional needs for products are becoming increasingly complex and diverse. However, the traditional Kansei Engineering emphasizes more on the connection between single emotional quality and product design elements. The generated design scheme can't satisfy the characteristics of customers' composite perceptual attributes. Therefore, this study develops an optimized design model that satisfies customers' multi-Kansei qualities, and it is committed to continually improving and differentiating products to maintain a competitive advantage. First, before QFD transforms the customers' emotional qualities into engineering features, the refined Kano model distinguishes the attribute division, and the importance of the customer's multi-Kansei qualities. Then, the QFD's relationship matrix is filled with the contribution values between the customer's key emotional qualities and engineering features which are established by the quantitative theory type I. These data contain positive and negative effects. Finally, the weighted sum calculation obtains a prioritization of engineering features. The case study of the citrus juicer validates the effectiveness of the proposed model which significantly improved research efficiency and customer satisfaction.

Keywords: Kansei Engineering, Refined Kano model, QFD, Quantitative theory I
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1 INTRODUCTION

With the rapid development of the economy and the improvement of life quality, customers' pursuit of product functionality and usability gradually shift to emotional experience. Since human emotions are subjectively uncertain, when one customer wants to buy something, a series of feelings or images are naturally formed in the mind, for example: "I want to be more fashionable, lively and lovely...", "Wow! It's so novel and elegant...". If these feelings are met during human-computer interaction, customer satisfaction can be increased [1]. Desmet and Hekkert [2] believed that three levels of emotional feedback can be achieved from the users' interaction with the product, including the aesthetic level of sensory pleasure, the meaning level of the product symbol, and the emotional levels which are induced from products. This shows that emotional quality is an indispensable part of product design in the new era.

Most manufacturers advocate the highest quality, the lowest cost, and the shortest time-to-market successful product during the endeavor of new product development [3]. The survival of businesses in a competitive ambiance also requires innovation, consumer loyalty, and products that are easily identifiable by consumers [4]. The external appearance of the product is the first impression to a customer which contains rich artistic style and personality taste, which is the key factor to attract customers' attention and enhance the psychological value. Therefore, how to quickly obtain the multiple emotional preferences of most customers and translate them into design parameters become an important issue in the market competition. Kansei Engineering (KE) is a reliable technology that is widely used in a product or service design [5-6]. It applies mathematical models to establish a quantitative relationship between customer subjective emotional responses and physical elements. For example, Park et al. [7] adopted KE methodologies in international airline services to analyze the relationship between customers' feelings and service elements. Chang and Chen [8] used regression analysis to assess the performance of crucial adjectives (aesthetics, operational strength, modernity factors) with the constituent elements and the overall interactions in car steering wheel design. Shen and Wang [9] applied multiple linear regression and back-propagation neural network schemes to build the relationship between four final Kansei words and the design elements of a horn speaker. However, KE mostly studied the relationship between single Kansei image and product design elements in the past. The above paper can only guarantee a single sensible quantity, it fails to represent a satisfactory optimization design. It can't truly reflect the customers' all-round and comprehensive emotional thinking. Nowadays, customer needs are sophisticated and dynamic. How to satisfy the multi-dimensional Kansei quality of customers has become a concern of every enterprise. Therefore, we need a process to assist the designer in finding the composite perceptual value of the target product in the early stage of new product development and satisfying it in practice, expecting to create the maximum benefit with the least resources.

QFD is a successful strategy which shifts the customers' opinions into final product characteristics and demand-oriented engineering approach [10]. It provides basic and strategic guidance to achieve higher levels of customer satisfaction. Nearly 50 years of development of QFD, severe researchers [11-12] applied QFD to convert customer multi-Kansei attributes into specific design features. Yadav et al. [13] presented a QFD approach that converts the prioritization of aesthetic attributes (i.e., elegant, family-feeling, modern, and youthful) into usable design data of car profile. However, the traditional QFD relationship matrix calculation has two major defects: 1. The association strength symbol is determined by subjective and vague linguistic statements like "strong relationship", "medium relationship" and "weak relationship" (generally represented by interval values of 1, 3, 5 or 1, 5, 9). They can only identify positive information that affects customer demand and can't provide negative information that has a passive impact. 2. Relying on individual engineers to determine the relationship between "customer demand (Whats)" and "engineering characteristics (Hows)", which can't represent the voice of the majority of customers. Given this, this study applies statistical analysis methods to establish a mathematical model between "Whats" and "Hows". Based on a large collection of customer voices, cross-check the degree of the positive or negative impact of different "Hows" on "Whats". And fill in the relationship matrix, so that more valuable information can be provided to fully understand the customer's multiple feelings.

According to Herzberg's Two-Factor Theory, Kano et al. [14] proposed a two-dimensional quality model to improve the shortcomings of people's perception of one-dimensional quality. In the Kano model, a classification of attractive, one-dimensional, and must-be quality can clearly understand the relationship between product sensibility and customer satisfaction [15-16]. However, the traditional Kano model doesn't consider the importance of quality attributes. Therefore, Yang [17] proposed the refined Kano model to modify the classification of importance and quality elements. Researchers integrated the refined Kano model and QFD to improve service quality in healthy fast-food chain restaurants [18] and nursing homes [19]. Also, there is rarely refined Kano related literature which involves the product's multi-Kansei design.

The author combines with the refined Kano model and QFD to explore the design of the product's multi-Kansei qualities and make the nutritional healthy citrus juicer as the experimental object. The research is divided into three steps. First, the refined Kano model identifies the composite perceptual attributes and their importance of the citrus juicer. It screens the multi-Kansei qualities as customer needs on the left side of the QFD. Secondly, based on the known product morphology deconstruction table, the quantitative theory type I establishes the functional relationship between the multi-Kansei qualities and the morphological elements of the citrus juicer and introduces the relationship matrix of QFD. Finally, the QFD weighted total calculation yields a prioritized design specification. Base on the results of the survey data, I hope to design a product that meets the customer's complex perceptual, greatly improving research efficiency and satisfaction. The main contributions of this research include:

- It proposes a product innovation design model that satisfies customers' multi-Kansei qualities.
- The refined Kano model achieves more accurate quality decisions and higher customer satisfaction which base on quality importance.
- The relationship between "Whats" and "Hows" in QFD replaces the matrix symbols in the past by the positive and negative continuous values which are obtained by the quantitative theory, which narrows the cognitive generation gap between engineers and customers.

The rest of this paper is organized as follows. Section 2 showed the literature review of the relative methodology. The hybrid research framework is provided in Section 3 and the case study of citrus juicer design is presented in Section 4. Section 5 presented the analysis and discussion of the results. Finally, the major conclusions achieved in this work are given in Section 6.

2 LITERATURE REVIEW

2.1 Citrus Juicer Design

The surge in social pressure leads to an increase in working hours of people, a cup of freshly-squeezed orange juice helps relieve fatigue and nervousness. Due to the low barriers to entry of citrus juicer, many benchmark brands such as Alessi, Braun, OXO, etc. have entered the industry. Philippe Starck's Juicy Salif has a simple and purely sleek look that has been a classic of Alessi since its inception in 1990. Even if it doesn't work well, it doesn't affect its popularity in sales (Fig. 1). Therefore, with the maturity of manufacturing technology, the performance differences between major manufacturers are getting smaller and smaller. Consumers' buying motives will no longer mainly consider functional requirements, and attractive appearances become particularly important.

Besides, most scholars focus on the energy costs [20], ecodesign [21], modular redesign [22], visual image structure analysis and description [23] of the citrus juicer, but the Kansei quality design of the citrus juicer is seldom discussed. Besides, consumers frequently contact the citrus juicer in their daily life, which is easy to form a deep cognition and impression to facilitate the implementation of the questionnaire. Therefore, this paper selects the citrus juicer as the experimental object, trying to find the shape design that favors the customer's emotional quality to enhance the added value of the product.

2.2 The Kano Model and Refined Kano Model

Kano et al. [14] summarized the customer's satisfaction with the product design quality in terms of function and dysfunctional situation into five aspects: Attractive quality, one-dimensional quality, must-be quality, indifferent quality and reverse quality. The customer's perception of the same quality demand will change due to a different time, that is, a certain quality is analyzed as indifferent quality at this stage, but it may be changed to attractive quality in the future. Therefore, the possibility of any quality can't be ignored. The result of the two-way questionnaire is the most commonly used method for Kano quality attribute partitioning [24]. Base on the application of the Kano model, the customers' ambiguous needs can be translated into clear and usable quality categories, helping to understand the real needs of customers and the reference for design

decisions. Ma et al. [25] employed Kano model to analyze consumers' perceived satisfaction concerning different service quality elements of future vehicle-driving. Madzik [26] used Kano model to significantly improve the accuracy of requirement categorization for after-services in the car industry.

Figure 1: Juicy Salif.

However, Yang [17] pointed out that customers provide high importance evaluation on certain quality attributes, which will directly affect customer satisfaction. Therefore, the refined Kano model is developed in combination with the importance index of customer evaluation to make up for the lack of judgment of Kano's two-dimensional quality classification. Yang [17] subdivided the four categories into eight categories (Fig. 2), that is, the high-importance attractive quality is named as highly attractive quality attributes, and the low-importance is named as less attractive quality attributes; The one-dimensional quality can be divided into high value-added quality attributes and the one-dimensional quality with low importance can be divided into low value-added quality attributes; the must-be quality with high importance is classified as critical quality attributes, and the must-be quality with low importance classified as negative quality attributes; classify high importance indifferent quality as potential quality attributes and low importance indifferent quality into care-free quality attributes (Table. 1). Refined Kano model can accurately classify quality attribute types and develop a high-competition strategy to increase market share. Lin et al. [27] applied a refined Kano model to offer a better understanding of a customer's viewpoint for product functions development. Pai et al. [28] classified restaurant service quality attributes by using a refined Kano model. However, the refined Kano model hasn't been used in the affective quality management of products, so this study uses this method to measure the multi-Kansei quality requirements of customers and their importance.

2.3 QFD

QFD is an overall concept that provides a means of translating customer requirements into the appropriate technical requirements for each stage of product development and production [29]. It is a well-known customer-driven product design methodology to help decision-making. Japan first applied QFD to shipyards in 1972 and then subsequently used it in areas such as consumer electronics, household goods, and apparel to improve product or service quality. House of Quality (HoQ) is the first set of matrices of QFD and plays a central role (Fig. 3) in a successful QFD team. It looks like a house that can go through inter-functional planning and communication to define the link relationship between customer desires and product capabilities. Chen et al. [30] adopted a refined Kano model to extract service-quality factors and establish a department-store HoQ for innovative service. Li et al. [31] provided a practical product improvement of the turbine engine to achieve higher customer satisfaction in QFD. However, the characteristics of human thinking have complex, subjective and uncertain preferences, that is, it is difficult for the subject to

completely using a single scale or value to provide the strong and weak relationship of the relation matrix. Therefore, many artificial intelligence methods, such as fuzzy theory [32-33], rough set theory [34-35], and gray relational analysis [36-37] combine QFD to achieve more objective and accurate solutions. Also, there are rarely articles that introduce statistical analysis methods like quantitative theory type I into QFD's relationship matrix, they express the interaction between "Whats" and "Hows" with continuous values of positive and negative influence degrees. Therefore, this study hopes to make some breakthroughs in this aspect.

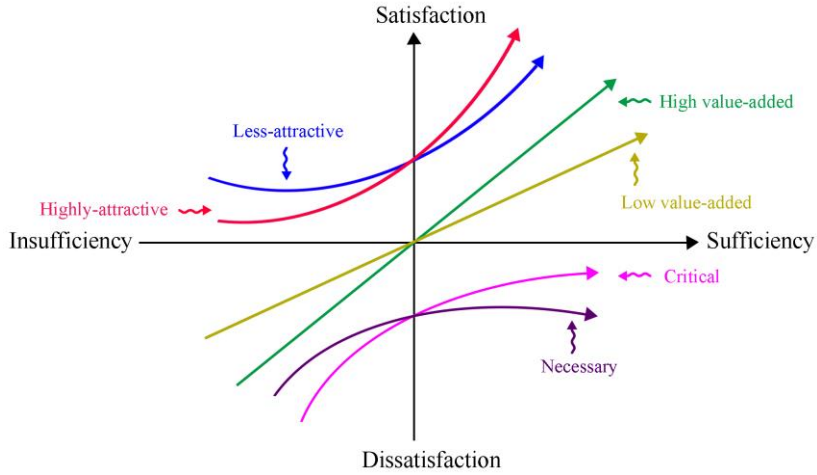

Figure 2: The refined Kano model.

Kano quality attributes	Refined Kano quality attributes	
	High important degree	Less important degree
Attractive	Highly attractive	Less attractive
One-dimensional	High value-added	Low value-added
Must be	Critical	Necessary
Indifferent	Potential	Care-free

Table 1. The refined Kano model.

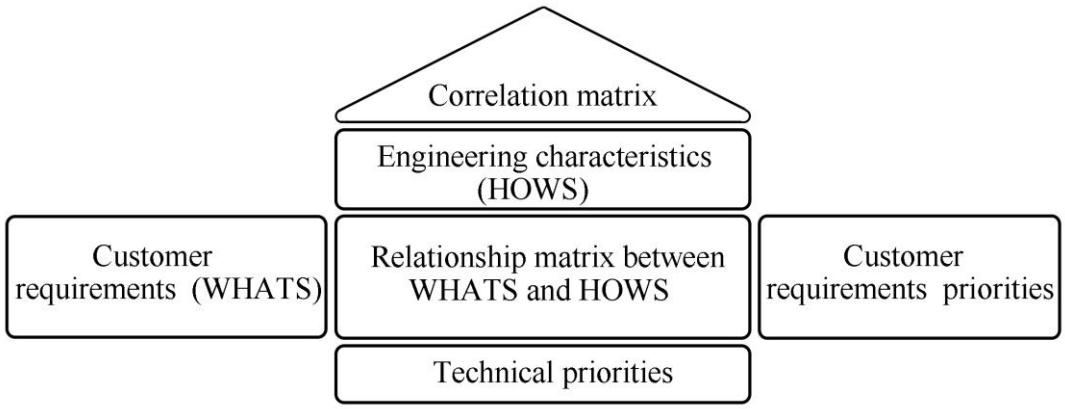

Figure 3: The house of quality.

3 THE PROPOSED METHOD

The main purpose of this study is to discuss the optimal design of product Kansei quality combining with the refined Kano model and QFD. Taking the citrus juicer as an example, this paper explores the strong degree of customer's different inner feelings which are caused by such products, and establish the corresponding relationship between multi-Kansei qualities and product design elements. The research framework which is shown in Fig. 4 can be divided into three steps:

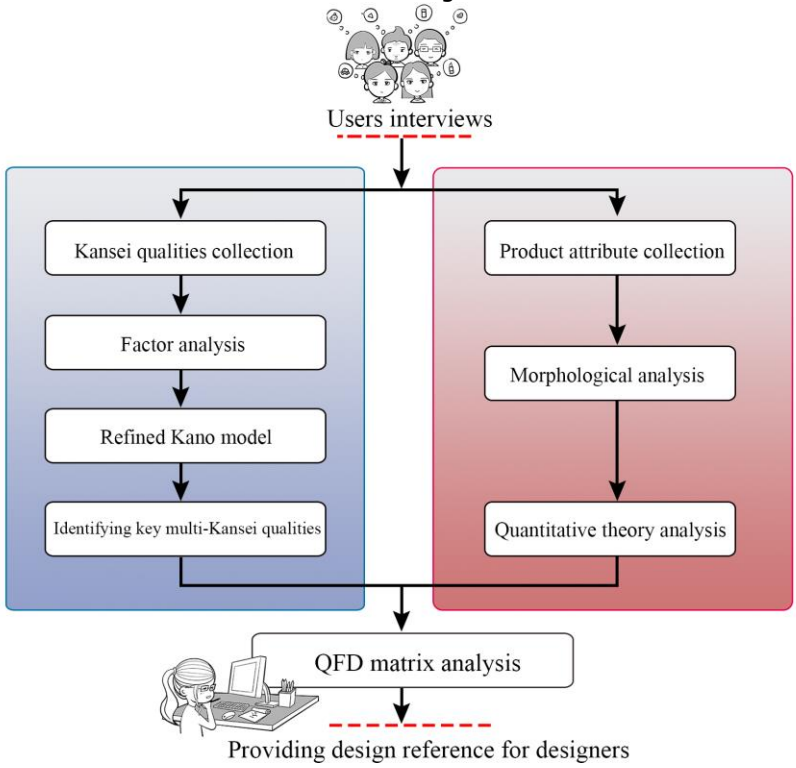

Figure 4: The proposed research framework.

- Refined Kano model determines the quality attributes of key multi-Kansei and its importance based on the representative semantic meaning of the screening.
- Quantitative Theory type I constructs a mapping model between multi-Kansei qualities and product engineering characteristics. The data results illustrate the form elements should be applied or avoided.
- The QFD's relationship matrix is filled by the contribution of positive or negative impact levels. Several multi-Kansei qualities are considered as composite perceptual needs that are imported to the left of the QFD. The final weighted total calculation determines the priority of the optimized product design (The best solution of modeling features).

4 CASE STUDY

4.1 Stage One: Refined Kano Model Determines Key Multi-Kansei Quality

4.1.1 Collection and Production of Product Images

Since there are no conditions for making experiments by the entity citrus juicer, this study mainly displays network pictures. According to the Amazon website, I select 50 models of the citrus juicer which are listed in 2010-2018. Since if the number of samples is too large, it is easy to increase the burdens on the subject, which is not conducive to the stability of the results.

Therefore, I select five industry experts (two product managers and three industrial designers) with the experience to construct a focus group to group similar styles based on subjective feelings and select one of the most representative images in each group. A total of 12 representative citrus juicers are obtained as the final interview objects. To remove the influence of picture background, logo, and color, the author applies the computer software Adobe Photoshop to convert the color picture into black and white form, as it is shown in Fig. 5.

Figure 5: Twelve citrus juicers samples.

4.1.2 Screening for Representative Images

To select the Kansei images of the citrus juicer, firstly, we obtain 50 emotional vocabularies that are related to the design image from the research of related journals, magazines and TV commercials. The repeated vocabularies add the total times. Since the higher the number of vocabularies is, the higher the correlation they have, we first select 15 Kansei adjectives that are highly correlated with the perceptual cognition of the citrus juicer (Table 2).

simple	unique	practical	compact	plain
exquisite	bionic	convenient	novel	nostalgic
handy	beautiful	natural	stylish	fashionable

Table 2. Fifteen Kansei adjectives for re-selected.

Then, 100 graduate students with design professional backgrounds are selected as the interview targets. For the 12 samples of the citrus juicer which are screened, the 15 perceptual semantics are scored by the 7-point Likert scale. If you think that the perceptual semantics is very consistent with the shape of the citrus juicer, then you can score 7 points, the average degree of consistency will be 4 points, and if you don't agree, you will score 1 point, and finally form 12×20 matrix data.

Finally, the factor analysis program in SPSS software is applied to perform reduction and calculation on the matrix table. The 15 images semantics are concentrated without loss of explanatory power. KMO sampling appropriateness test and Bartlett spherical test are used to determine whether the perceptual semantics is suitable for factor analysis, the test results find that the correlation coefficient from the KMO and Bartlett's test achieved a significance level of 0.843 (KMO>0.5 means the sampling is reasonable), the chi-square value is 976.492, the df is 451, sig= 0.000 is less than 0.05 with a significant difference (Table 3). The results of the verification indicate that each variable conforms to the conditions of the factor analysis. Then, each factor is orthogonally rotated by the maximum variance method in the principal component analysis method to form the following rotation component matrix table (Table 4).

Kaiser-Meyer-Olkin Measure of Sampling Adequacy	0.843
Bartlett's Test of Sphericity Approx. Chi-Square	976.492
df	451
sig	0.000

Table 3. KMO and Bartlett's test.

Factors	Kansei words	Factor 1	Factor 2	Factor 3	Factor 4	Eigenvalue	Contribution	Accumulated
modern	unique	0.831	0.402	0.070	-0.228	10.447	50.435	50.435
	exquisite	0.870	0.248	0.144	-0.130			
	novel	0.907	0.198	0.194	-0.023			
	beautiful	0.884	0.259	0.352	0.025			
	fashionable	0.961	0.094	-0.046	0.164			
	stylish	0.876	0.417	-0.040	-0.002			
Small	compact	0.125	0.842	0.128	0.414	4.017	16.945	67.380
	convenient	0.283	0.832	0.188	-0.149			
	handy	0.409	0.774	0.422	-0.117			
	bionic	0.391	0.706	-0.043	0.363			
Simple	practical	0.306	0.067	0.733	-0.289	2.117	9.939	77.319
	simple	0.345	0.419	0.739	0.232			
	plain	-0.250	0.122	0.831	0.203			
Nostalgic	natural	-0.019	0.385	0.449	0.664	1.322	7.821	85.140
	nostalgic	0.017	-0.013	0.058	-0.889			

Table 4. Factor analysis results.

Four factors are extracted from the principle that the initial eigenvalue is greater than 1: Factor facet 1 consists of six factors, which are named as "modern factor" according to the characteristics of modern trend. Factor facet 2 consists of four factors, they are named as "small factor" which are based on its compact and lightweight features. Factor facet 3 consists of three factors and can be named as "simple factors". Factor facet 4 is named as "nostalgic factor".

4.1.3 Identify the Key Multi-Kansei Quality Attributes

The quality attribute classification of the refined Kano model is based on the Kano questionnaire, which adds importance to the 5-point Likert scale to measure the quality attributes. The positive and negative questionnaires are used to obtain the degree of consumer satisfaction in the case of sufficient quality and insufficient situations, and the connection of the two answers in the Kano evaluation form (see Table 5) [13-14] can be used to judge the classification of product attributes: Attractive, one-dimensional, must-be, indifference, reverses, and doubts. The average value of overall quality importance is called the cut-off point for classification. If the importance of the attractive quality is higher than the average value, it is called high attractive quality, and vice versa is low attractive quality. The study introduces the Kansei quality of 15 citrus juicers into the refined Kano model questionnaire, and then it obtains the classification results which is as shown in Table 6.

Criteria/attributes		Insufficiency				
		Satisfied	It must be that way	It is Indifferent	I can live with it	Dissatisfied
Sufficiency	Satisfied	Q	A	A	A	O
	It must be that way	R	I	I	I	M
	It is Indifferent	R	I	I	I	M
	I can live with it	R	I	I	I	M
	Dissatisfied	R	R	R	R	Q

A-attractive,O-one-dimensional,M-muse-be,I-indifference,R-reversal,Q-questionable

Table 5. Kano evaluation table.

Factor	Kansei word	Importance Average (4.14)	Kano attribute	Refined Kano attribute
modern	unique	4.32	Attractive	High attractive
	exquisite	4.68	One-dimensional	High value-added
	novel	4.51	Indifferent	Potential
	beautiful	4.37	One-dimensional	High value-added
	fashionable	3.94	Attractive	Low attractive
	stylish	4.47	Indifferent	Potential
Small	compact	4.31	One-dimensional	High value-added
	convenient	3.56	Must-be	Necessary
	handy	4.38	Must-be	Critical
	bionic	4.27	Attractive	High attractive
Simple	practical	3.80	Must-be	Necessary
	simple	3.95	Attractive	Low attractive
	plain	3.77	Indifferent	Care-free
Nostalgic	natural	4.39	Indifferent	Potential
	nostalgic	3.41	Indifferent	Care-free

Table 6. Kansei quality attribute classification.

Yang [17] believed that high-attractive quality can greatly enhance customer satisfaction, and potential quality will gradually become an attractive attribute, and these two qualities should be considered in the future. Therefore, this study identifies the five critical multi-Kansei qualities: "Unique", "bionic", "novel", "stylish" and "natural".

4.2 Stage Two: Quantitative Theory Type I Construct the Relationship Between Key Multi-Kansei Quality and Product Design Features

4.2.1 Establish the Morphological Analysis Matrix

The product design features and hierarchical analysis are carried out according to the samples which are collected from the citrus juicer. The appearance components of the citrus juicer are deconstructed by the morphological analysis method, the design features and corresponding level form elements are established. The author again invites the above five experts to characterize the 12 representative images of the citrus juicer and extract four relatively important design features, namely the lid, body, base, and handle. Then, the designer's subjective experience and aesthetic feeling are used to decompose the important design features, and the design details from level 1 to level 4 are obtained. Finally, the corresponding modeling projects are dismantled and a total of 16 design types are obtained, as it is shown in Fig. 6.

4.2.2 Quantitative Theory Type I Analysis

The quantitative theory that began in the 1950s was a branch of multivariate analysis. The five key multi-Kansei qualities which are reduced by the refined Kano model are considered as the criterion variables, and the combination of the modeling elements of the 12 representative samples are regarded as the explanatory variables. After evaluating the relationship between the multi-Kansei qualities and the citrus juicer through the 7-point Likert scale (Table 7), the regression equation 1 is used to establish the relationship between the two variables (Table 8).

$$\hat{y} = \sum_{i=1}^{m} \sum_{j=1}^{n} \beta_{ij} x_{ij} + \varepsilon \tag{1}$$

Where $\hat{y}$ is the affective response, x_{ij} is the level of design variable, β_{ij} is the weight for the level, m is the number of design variables, n is the number of levels, and ε is the random variable.

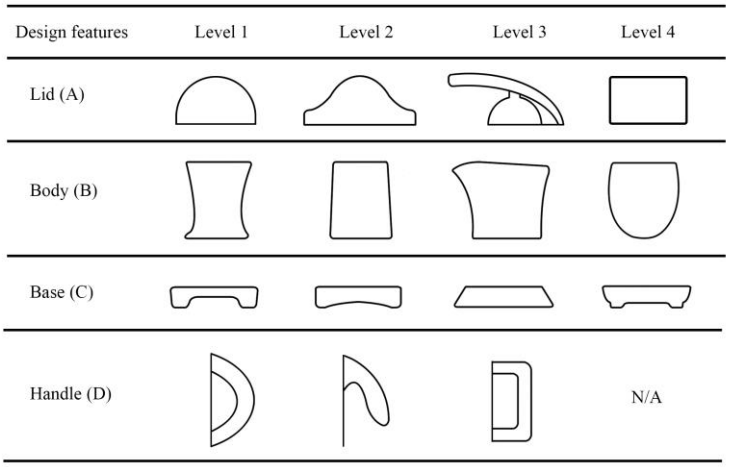

Figure 6: Citrus juicer morphology analysis matrix.

No.	A Lid				B Body				C Base				D Handle				Multi-Kansei qualities				
	A_1	A_2	A_3	A_4	B_1	B_2	B_3	B_4	C_1	C_2	C_3	C_4	D_1	D_2	D_3	D_4	unique	novel	stylish	bionic	natural
1	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	1	4.77	4.69	4.14	3.40	4.20
2	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	5.11	4.49	4.26	4.03	4.17
3	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	1	4.94	4.83	4.43	3.74	4.31
4	0	1	0	0	0	0	1	0	0	0	1	0	0	1	0	0	3.97	3.80	3.46	3.23	3.51
5	0	1	0	0	0	0	1	0	0	0	1	0	0	1	0	0	4.31	3.94	3.94	3.43	3.89
6	0	0	1	0	1	0	0	0	0	1	0	0	0	0	0	1	5.54	5.17	4.91	3.80	4.54
7	0	1	0	0	1	0	0	0	0	0	1	0	0	0	1	0	3.74	3.94	3.46	3.23	3.89
8	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	1	5.23	4.74	4.80	3.51	4.23
9	0	1	0	0	0	0	1	0	0	0	1	0	1	0	0	0	3.49	3.91	3.77	3.31	3.97
10	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	1	4.60	3.97	4.06	3.49	4.06
11	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	4.63	4.40	4.63	4.40	4.23
12	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	1	4.46	4.26	4.14	3.71	4.26

Table 7. Relationship table.

Item		unique		novel		stylish		bionic		natural	
		PCC	CS	PCC	CS	PCC	CS	PCC	CS	PCC	CS
A Lid	A1	0.680	0.023	0.439	0.015	0.707	-0.022	0.877	-0.008	0.575	0.012
	A2		0.235		0.330		-0.170		-0.005		0.065
	A3		0.450		0.140		0.030		0.070		0.110
	A4		0.000		0.000		0.000		0.000		0.000
B Body	B1	0.656	0.250	0.706	0.030	0.627	-0.310	0.864	-0.080	0.727	-0.080
	B2		-0.188		-0.475		-0.910		-0.108		-0.158
	B3		0.041		0.063		-0.025		0.015		0.032
	B4		0.000		0.000		0.000		0.000		0.000
C Base	C1	0.561	-0.480	0.612	-0.090	0.598	0.370	0.968	0.370	0.694	0.060
	C2		-0.463		0.245		0.790		-0.213		0.248
	C3		-0.580		0.080		0.820		-0.510		0.030
	C4		0.000		0.000		0.000		0.000		0.000
D Handle	D1	0.872	0.009	0.744	0.018	0.808	-0.011	0.652	0.003	0.855	-0.005
	D2		0.650		-0.040		-0.070		0.020		-0.270
	D3		0.000		0.000		0.000		0.000		0.000
	D4		1.275		0.990		1.140		0.205		0.295
Constant		3.835		3.500		3.120		3.825		3.875	
R		0.975		0.931		0.960		0.992		0.928	
R^2		0.951		0.867		0.922		0.984		0.861	

Notes: CS: Category scores; PCC: Partial correlation coefficients; R: Multiple correlation; R^2: Determination coefficient

Table 8. Weight coefficient scores in statistical analysis.

4.3 Stage Three: QFD Determines the Optimal Product Design

The five key multi-Kansei qualities are first regarded as a composite emotion, and the customer demand facet on the left side of HoQ is introduced. Then, the category scores which are obtained in the previous stage are imported into the HoQ's relationship matrix (Table 9). Since each engineering feature must correspond to at least one customer's requirement correlation, the non-corresponding engineering features A4, B4, C4, and D3 will be eliminated. That is, these features don't affect multi-Kansei qualities. Then, apply the weighted sum calculation to get the impact of each engineering feature.

The criteria and the procedure of the QFD are built on quantitative analysis. The degree of influence of the engineering features, AI_j , can be obtained using the evaluation method, which is to multiply the customer demands weight by the category scores, and then sum these results through equation (2):

$$AI_j = \sum_{i=1}^{n} W_i \otimes R_{ij} \tag{2}$$

Where AI_j is the influence degree of the jth HOW, W_i is the weight of the ith WHAT, and R_{ij} is the category scores between the ith WHAT and the jth HOW, $i = 1,2,...,n$, n is the total number of customer demands, $j = 1,2,...,m$, m is the total number of engineering features.

The importance of different product characteristics is affected by the weight of customer expectations. Therefore, the higher the importance of customer demand and category scores, the greater the impact of results on customer Kansei, and the more time and resources designers need to invest.

The design features with the largest scores under each project are combined to obtain the optimized citrus juicer design that satisfies the customer's complex sensibility.

	A Lid			B Body			C Base			D Handle				
Multi-Kansei Qualities	A1	A2	A3	B1	B2	B3	C1	C2	C3	D1	D2	D4	Importance	Rank
unique	0.023	0.235	0.450	0.250	-0.188	0.041	-0.480	-0.463	-0.580	0.009	0.650	1.275	4.32	4
novel	0.015	0.330	0.140	0.030	-0.475	0.063	-0.090	0.245	0.080	0.018	-0.040	0.990	4.51	1
stylish	-0.022	-0.170	0.030	-0.310	-0.910	-0.025	0.370	0.790	0.820	-0.011	-0.070	1.140	4.47	2
bionic	-0.008	-0.005	0.070	-0.080	-0.108	0.015	0.370	-0.213	-0.510	0.003	0.020	0.205	4.27	5
natural	0.012	0.065	0.110	-0.080	-0.158	0.032	0.060	0.248	0.030	-0.005	-0.270	0.295	4.39	3
Degree of influence	0.087	2.008	3.491	-0.863	-8.177	0.554	1.018	2.815	-0.525	0.062	1.215	17.24		
Rank	9	4	2	10	12	8	6	3	11	7	5	1		

Table 9. Relationship matrix analysis of QFD.

4.4 3D Model Verification

The visualization establishment of the solid model is based on the optimal combination of design features that trigger the maximum customer emotion, that is, A3+B3+C2+D4. It is the combination of product features in Table 9 that maximize the impact. This result can trigger the complex multi-Kansei of customers. Based on the reference of the optimal product design combination, I visualize the results by using the 3D software Rhino, as it is shown in Fig. 7. The 7-point Likert scale is used to ask 50 customers about the five multi-Kansei qualities of the design and the overall satisfaction degree. According to the statistics of the questionnaire data, the overall satisfaction of this citrus juicer is 6.35, which is significantly higher than the average of 3.5 points. The mean values of the five multi-Kansei qualities are shown in Fig. 8. It can be seen from the results of the innovative model which is proposed in this study that a composite perceptual expectation that satisfies most customers can be obtained.

Figure 7: The final new designed product-based research result.

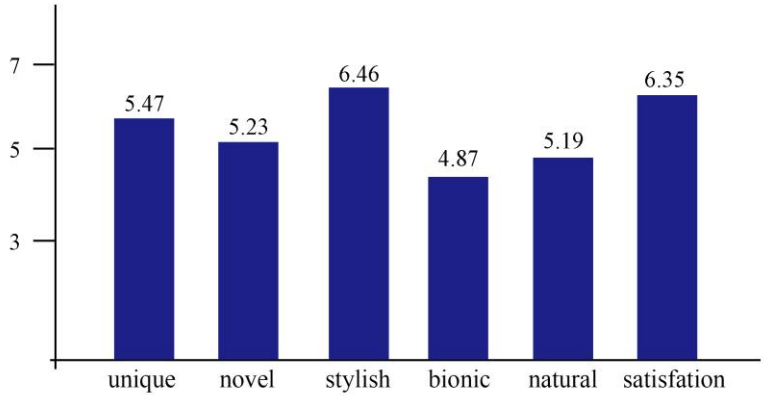

Figure 8: Five multi-Kansei qualities and satisfaction scores.

5 ANALYSIS AND DISCUSSION OF THE RESULTS

The critical multi-Kansei qualities of a competitive edge are evaluated by the refined Kano model. Afterward, the quantitative theory type I determined the positive and negative influence degree between the customer's composite perceptual qualities and the design features of the citrus juicer, and introduce it into the HoQ's relationship matrix. In the first stage, customer importance is added to the Kano model. Applying the refined Kano model, 15 perceptual quality attributes are classified and found:

- High attractive quality has "unique" and "bionic" items, indicating that customers are very appreciative of products that are unique in appearance and imitate natural or biological shapes. Companies must pay full attention to the high-attractive qualities which appeal to customers to create higher benefits.

• Low attractive quality has two items: "Fashionable" and "simple". It is recommended that companies can reduce the cost of this quality with limited resources.

• High value-added quality includes "exquisite", "beautiful" and "compact" these 3 items. It shows that the small and delicate visual beauty of the citrus juicer contributes a lot to customers' satisfaction. Enterprises should strive to provide these qualities to users, as an opportunity to expand market share and maintain customer loyalty.

• Critical quality only has one "handy" item. This quality is the utmost importance and the company must provide sufficient quality to the customer.

• Necessary quality has "convenient" and "practical" these 2 items, and companies need to provide quality attributes for these two basic usage functional requirements to avoid customer dissatisfaction.

• Potential quality contains "novel", "stylish" and "natural" these 3 items. These qualities will gradually become attractive attributes. Companies can consider setting those qualities as a strategic weapon to attract future customers.

• Care-free quality contains "plain" and "nostalgic" these 2 items, indicating that customers don't care about these qualities, and companies don't need to spend energy.

Since high-attractive quality and potential quality are easy to maximize customer satisfaction, it then determines that "unique", "bionic", "novel", "stylish" and "natural" as key multi-Kansei qualities. In the second stage, I use the quantitative theory type I to establish the relationship between the five key composite perceptual qualities and the design elements of the citrus juicer. From the numerical value of the partial correlation coefficient, in addition to the "bionic" quality, the importance of the base is considered to be the highest, and the other four qualities all believe that the style changes of the handle have the greatest influence on the user's emotion, indicating that the designer should give priority to the shape design of the handle. From the category scores, it can be found that the customers think that the citrus juicer without the handle has the highest impact on each perceptual quality, so we can consider removing it in the future design.

In the third stage of the study, the five key perceptual images are regarded as a whole multi-Kansei quality which is introduced into the left side of HoQ. The obtained statistical analysis data is imported into HoQ's relationship matrix. Cross-comparison results show that if you want to fully satisfy customers' expectations of five multi-Kansei quality attributes, the top four A3, B3, C2, and D4 with the highest degree of influence should be combined. This is the top priority of matrix expansion that is the optimal design of the citrus juicer. Also, in the new product development process, try to avoid A1, B2, C3, D1, and other modeling elements, otherwise, it will greatly reduce the semantic expression of the composite perceptual qualities.

In recent years, influenced by social and economic changes, people's quality of life has gradually improved, and different people have different functions or emotional needs for a citrus juicer. In the development of new products, we need to consider the specific needs of various target groups. For example, the elderly needs a practical and stable citrus juicer, while children like a cute and small citrus juicer. This kind of personalized demand will be directly reflected in the form of products. At the same time, to get representative questionnaire results, the evaluation data of the target population should be as well-spread and reasonable as possible. Therefore, carefully selecting the target group for evaluation is a very important step.

6 CONCLUSION

The main purpose of this study is to develop an innovative design model that satisfies the customer's multi-Kansei qualities combining with the refined Kano model and QFD, it successfully predicts the customer preference and the future trends of the target products. Due to the rapid improvements in manufacturing technology, it is difficult to achieve differentiated competition in terms of product function, price, and availability. For manufacturers, meeting the emotional needs of customers becomes increasingly important and complex, and products that have multi-Kansei qualities help customers make purchasing decisions and help designers improve new products. In the experimental results of the citrus juicer, the refined Kano model is more specific to

the traditional Kano model because it considers the importance of the attribute, and it divides the properties of 15 Kansei qualities into two high attractive quality, two low attractive quality, three high value-added quality, one critical quality, two necessary quality, three potential quality, and two care-free quality, means that designers need to concentrate more energies to promote these high attractive and potential qualities for the company to make decisions with the more accurate information. The relationship matrix of QFD analyzes the contribution value of each engineering feature based on the positive and negative data which are obtained from the quantitative theory type I and determines the optimal design element combination that satisfies the customer's multiple sensibilities.

The proposed method still has some limitations to be solved: 1. The customer's emotional needs are generally extracted from the literature review and the expert panels. This method is very likely to force the product design to start from the expert's thinking, but not from the customers' perspective. It is recommended to use text mining to obtain real-time and first-hand customer sentimental quality information in online reviews of online shopping platforms (ie. Amazon, eBay). 2. The quantitative theory is a linear regression analysis method. It may not be able to accurately measure customer non-linear and non-normal thinking habits. It is recommended to replace neural networks and genetic algorithms in artificial intelligence methods. 3. The Refined Kano model doesn't take the subjective uncertainty of the subject into account. In the future, the fuzzy refined Kano model can be used to obtain more objective attribute classification. 4. The introduced case study of the development of a citrus juicer represents a relatively simple product. It would be interesting to discuss the introduced approach in view of its capability to develop more complex products.

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REFERENCES

[1] Nagamachi, M.: Kansei engineering as a powerful consumer-oriented technology for product development, Applied Ergonomics, 33, 2002, 289-294. https://doi.org/10.1016/S0003-6870(02)00019-4

[2] Desmet, P.; Hekkert, P.: Framework of Product Experience, International Journal of Design, 1(1), 2007, 57-66.

[3] Huang, Y.; Chen, C-H.; Khoo, L. P.: Kansei clustering for emotional design using a combined design structure matrix, International Journal of Industrial Ergonomics, 42, 2012, 416-427. https://doi.org/10.1016/j.ergon.2012.05.003

[4] Lokman, A. M.; Awang, A. A.; Omar, A. R.; Abdullah, N. A. S.: The integration of quality function deployment and Kansei Engineering: An overview of application, AIP Conference Proceedings, 2016, 1-8. https://doi.org/10.1063/1.4940252

[5] Nagamachi, M.: Kansei engineering: a new ergonomic consumer-oriented technology for product development, International Journal of Industrial Ergonomics, 15(1), 1995, 3-11. https://doi.org/10.1016/0169-8141(94)00052-5

[6] Hartono, M.; Raharjo, H.: Exploring the mediating role of affective and cognitive satisfaction on the effect of service quality on loyalty, Total Quality Management & Business Excellence, 26(9), 2015, 971-985. https://doi.org/10.1080/14783363.2015.1068595

[7] Park, M-J.; Park, J. W.; Yoo, H.: Application of affective engineering to service industries: feelings from airlines' in-flight service elements, Total Quality Management & Business Excellence, 29, 2018, 9-10. https://doi.org/10.1080/14783363.2018.1486548
[8] Chang, Y-M.; Chen, C-W.: Kansei assessment of the constituent elements and the overall interrelations in car steering wheel design, International Journal of Industrial Ergonomics, 56, 2016, 97-105. https://doi.org/10.1016/j.ergon.2016.09.010
[9] Shen, H. C.; Wang, K. C.: Affective product form design using fuzzy Kansei engineering and creativity, Journal of Ambient Intelligence and Humanized Computing, 7(6), 2016, 875-888. https://doi.org/10.1007/s12652-016-0402-3
[10] Akao, Y.: History of Quality Function Deployment in Japan, Hanser Publishers, 1990.
[11] Kang, X.; Yang, M.; Wu, Y.; Ni, B.: Integrating Evaluation Grid Method and Fuzzy Quality Function Deployment to New Product Development, Mathematical Problems in Engineering, 2451470, 2018, 1-15. https://doi.org/10.1155/2018/2451470
[12] Park, J.; Kim, S.; Kim, K.: A Study on Affection and Design Elements Affecting the User Satisfaction of Physical Keyboard, Journal of the Korean Institute of Industrial Engineers, 44(3), 2018, 237-248. https://doi.org/10.7232/JKIIE.2018.44.3.237
[13] Yadav, H. C.; Jain, R.; Shukla, S.; Avikal, S.; Mishra, P. K.: Prioritization of aesthetic attributes of car profile, International Journal of Industrial Ergonomics, 43(4), 2013, 296-303. https://doi.org/10.1016/j.ergon.2013.04.008
[14] Kano, N.; Seraku, N.; Takahashi, F.; Tsuji, S.: Attractive quality and must-be quality, Journal of The Japanese Society for Quality Control, 14(2), 1984, 147-156.
[15] Llinares, C.; Page, A. F.: Kano's model in Kansei Engineering to evaluate subjective real estate consumer preferences, International Journal of Industrial Ergonomics, 41(3), 2011, 233-246. https://doi.org/10.1016/j.ergon.2011.01.011
[16] Chen, C. C.; Chuang, M. C.: Integrating the Kano model into a robust design approach to enhance customer satisfaction with product design, International Journal of Production Economics, 114(2), 2008, 667-681. https://doi.org/10.1016/j.ijpe.2008.02.015
[17] Yang, C-C.: The refined Kano's model and its application, Total Quality Management and Business Excellence, 16(10), 2005, 1127-1137. https://doi.org/10.1080/14783360500235850
[18] Chen, K-J.; Yeh, T-M.; Pai, F-Y.; Chen, D-F.: Integrating Refined Kano Model and QFD for Service Quality Improvement in Healthy Fast-Food Chain Restaurants, International Journal of Environmental Research and Public Health, 15(7), 2018, 1310. https://doi.org/10.3390/ijerph15071310
[19] Yeh, T. M.; Chen, S. H.: Integrating refined Kano model, quality function deployment, and grey relational analysis to improve service quality of nursing homes, Human Factors and Ergonomics in Manufacturing & Service Industries, 24(2), 2014, 172-191. https://doi.org/10.1002/hfm.20358
[20] Sandhu, P.: Reduction in energy costs of doing selected household work by using efficient gadgets and applying ergonomics in homes, Journal of Human Ecology, 14(5), 2003, 323-327. https://doi.org/10.1080/09709274.2003.11905632
[21] Bereketli, I.; Genevois, M. E.: An integrated QFDE approach for identifying improvement strategies in sustainable product development, Journal of Cleaner Production, 54, 2013, 188-198. https://doi.org/10.1016/j.jclepro.2013.03.053
[22] Sebastián, L. M.; Álvaro, G. G.; Rubio, O.; Eder, W. E.: Modular redesign methodology for improving plant layout, Journal of Engineering Design, 27(1-3), 2016, 50-74. https://doi.org/10.1080/09544828.2015.1103843
[23] Cho, S-K.: Analysis and description of the Visual Image Structure of Lemon Juice Squeezer, designed for Italy ALESSI company by Philippe Starck, Archives of Design Research, 16(2), 2003, 39-414.
[24] Matzler, K.; Hinterhuber, H. H.: How to make product development projects more successful by integrating Kano's model of customer satisfaction into quality function

deployment, Technovation, 18(1), 1998, 25-38. https://doi.org/10.1016/S0166-4972(97)00072-2
[25] Ma, M-Y.; Chen, C-W.; Chang, Y-M.: Using Kano model to differentiate between future vehicle-driving services, International Journal of Industrial Ergonomics, 69, 2019, 142-152. https://doi.org/10.1016/j.ergon.2018.11.003
[26] Madzik, P.: Increasing accuracy of the Kano model-a case study, Total Quality Management & Business Excellence, 29(3-4), 2018, 387-409. https://doi.org/10.1080/14783363.2016.1194197
[27] Lin, C-S.; Chen, L-S.; Hsu, C-C.: An innovative approach for RFID product functions development, Expert Systems with Applications, 38(12), 2011, 15523-15533. https://doi.org/10.1016/j.eswa.2011.06.007
[28] Pai, F-Y.; Yeh, T-M.; Tang, C-Y.: Classifying restaurant service quality attributes by using Kano model and IPA approach, Total Quality Management & Business Excellence, 29(3-4), 2018, 301-328. https://doi.org/10.1080/14783363.2016.1184082
[29] Sullivan, L. P.: Quality function deployment, Quality Press, 19(6), 1986, 39-50.
[30] Chen, M-K.; Lin, Y-L.; Chen, I-W.: Constructing innovative service quality for department stores, Total Quality Management & Business Excellence, 26(5-6), 2015, 482-496. https://doi.org/10.1080/14783363.2013.844913
[31] Li, Y-L.; Du, Y-F.; Chin, K-S.: Determining the importance ratings of customer requirements in quality function deployment based on interval linguistic information, International Journal of Production Research, 56(14), 2018, 4692-4708. https://doi.org/10.1080/00207543.2017.1417650
[32] Zhai, L. Y.; Khoo, L. P.; Zhong, Z. W.: Towards a QFD-based expert system: A novel extension to fuzzy QFD methodology using rough set theory, Expert Systems with Applications, 37(12), 2010, 8888-8896. https://doi.org/10.1016/j.eswa.2010.06.007
[33] Kang, X.; Porter, C.S.; Erik, B.: Using the fuzzy weighted association rule mining approach to develop a customer satisfaction product form, Journal of Intelligent & Fuzzy Systems, 38(4), 2020, 4343-4357. https://doi.org/10.3233/JIFS-190957
[34] Li, Y.; Tang, J.; Luo, X.; Yao, J.; Xu, J.: A quantitative methodology for acquiring engineering characteristics in PPHOQ, Expert Systems with Applications, 37(1), 2010, 187-193. https://doi.org/10.1016/j.eswa.2009.05.006
[35] Kang, X.: Aesthetic Product Design Combining with Rough Set Theory and Fuzzy Quality Function Deployment, Journal of Intelligent & Fuzzy Systems, 39(1), 2020. 1131-1146. https://doi.org/10.3233/JIFS-192032
[36] Kang, X.: Combined Grey Relationship Analysis and Neural Network to Develop Attractive Automobile Booth Design. Computational Intelligence & Neuroscience, 2020, 2020, 8863727. https://doi.org/10.1155/2020/8863727
[37] Yazdani, M.; Kahraman, C.; Zarate, P.; Onar, S. C.: A fuzzy multi attribute decision framework with integration of QFD and grey relational analysis, Expert Systems with Applications, 115, 2019, 474-485. https://doi.org/10.1016/j.eswa.2018.08.017