An analytical Kano model for customer need analysis

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In an effort to address the inherent deficiencies of traditional Kano method, this paper proposes an analytical Kano (A-Kano) model with focus on customer need analysis. Kano indices in accordance with the Kano principles are proposed to incorporate quantitative measures into customer satisfaction. Accordingly, two alternative mechanisms are proposed to provide decision support to product design, (1) the Kano classifiers are used as tangible criteria for categorizing customer needs, and (2) the configuration index is introduced as a decision factor of product configuration design. The merit of product configurations is justified using a Kano evaluator, which leverages upon both the customer's satisfaction and the producer's capacity. A case study of dashboard in automotive design is also presented. It is demonstrated that the A-Kano model can effectively incorporate customer preferences in product design, while leading to an optimal tradeoff between customer's satisfaction and producer's capacity.

Keywords: product design, automotive design, perception, evaluation, Kano

Manufacturing enterprises are increasingly focusing on satisfying individual customer needs (CNs) in a highly competitive global market. A constant challenge for manufacturers is how to deal with the customer satisfaction, which in turn largely determines the customers' willingness to buy the products. Understanding and fulfilling CNs have been well recognized as one of the principle factors for product design and development to succeed in the market place (McKay et al., 2001).

Analysis of customer need information is an important task with focus on the interpretation of the voice of customers and subsequently derivation of explicit requirements that can be understood by marketing and engineering (Jiao and Chen, 2006). In general, it involves three major issues, namely (1) understanding of customer preferences, (2) requirement prioritization,

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and (3) requirement classification. Among many approaches that address customer need analysis, the Kano model has been widely practiced in industries as an effective tool of understanding customer preferences owing to its convenience in classifying CNs based on survey data (Kano et al., 1984). Nevertheless, traditional Kano methods are not equipped with quantitative assessment. And, Kano classification provides limited decision support in engineering design. Moreover, it inherently emphasizes the customer and market perspectives only, with limited consideration of the producer's capacity to fulfill the CNs.

To enhance the above aspects in relation to customer need analysis, this paper scrutinizes the theoretical foundation of the original Kano model and proposes an analytical Kano (A-Kano) model. The A-Kano model extends traditional Kano model (Kano et al., 1984; Berger et al., 1993) by introducing (1) *Kano indices*, which are quantitative measurements of customer satisfaction derived from Kano questionnaires and surveys; (2) *Kano classifiers*, which consist of a set of criteria to classify CNs based on the Kano indices; (3) *Configuration index*, which provides a decision factor for selecting the functional requirements (FRs) that contribute to product configurations; and (4) *Kano evaluator*, which is a shared surplus-based performance indicator leveraging upon both the customer's satisfaction and the producer's capacity. A comprehensive process model is proposed to integrate these techniques for customer need analysis.

The subsequent sections proceed as follows. A critical review of the Kano model is presented in Section 1. The fundamental issues of A-Kano are scrutinized in Section 2. The A-Kano process model is proposed in Section 3 by implementing the proposed techniques that address the fundamental issues. In Section 4, the A-Kano model is applied to car dashboard design. The results are compared with those derived from the traditional Kano model. Discussions and conclusions are presented in Sections 5 and 6, respectively.

1 Critical review of Kano model

The Kano model of customer satisfaction is a useful tool to classify and prioritize customer needs based on how they affect customer's satisfaction (Kano et al., 1984). It captures the nonlinear relationship between product performance and customer satisfaction. In practice, four types of product attributes are identified: (1) *must-be* attributes are expected by the customers and they lead to extreme customer dissatisfaction if they are absent or poorly satisfied, (2) *one-dimensional* attributes are those for which better fulfillment leads to linear increment of customer satisfaction, (3) *attractive* attributes are usually unexpected by the customers and can result in great satisfaction if they are available, and (4) *indifferent* attributes are those that the customer is not interested in the level of their performance.

The Kano model is constructed through customer surveys, where a customer questionnaire contains a set of question pairs for each and every product attribute. The question pair includes a functional form question, which captures the customers' response if a product has a certain attribute, and a dysfunctional form question, which captures the customers' response if the product does not have that attribute. The questionnaire is deployed to a number of customers, and each answer pair is aligned with the Kano evaluation table (Berger et al., 1993), revealing an individual customer's perception of a product attribute. The final classification of a product attribute is made based on a statistical analysis of the survey results of all respondents.

1.1 Qualitative vs. quantitative evaluation

The Kano diagram provides a rough sketch of the customer's satisfaction in relation to the product performance level. In such a sense, it only allows qualitative assessment of product attributes (Wassenaar et al., 2005; Rivière et al., 2006). A convenient way to incorporate quantitative measures is to assign some scales in terms of the levels of customer satisfaction/dissatisfaction (Matzler and Hinterhuber, 1998). However, the resulting Kano category is still qualitative in nature, which could not precisely reflect the extent to which the customers are satisfied (Berger et al., 1993). Hence, the application of Kano model in engineering design is primitive in comparison with other quantitative methods, such as conjoint analysis (Green and DeSarbo, 1978), stated choice methods (Louviere et al., 2000), and decision-based design (Hazelrigg, 1998).

1.2 Classification criteria

Different criteria have been adopted for classifying customer requirements, such as empirical observation, mode statistics, and customer satisfaction coefficient (Berger et al., 1993). Timko (Berger et al., 1993) proposes a two-dimensional representation of Kano quality category based on the customer satisfaction coefficients. In particular, a positive number is used to represent the relative value of meeting the respective customer requirement, whilst a negative number is used to reflect the relative cost of not meeting this customer requirement. However, classification criteria are not explicitly defined in this model. DuMouchel (Berger et al., 1993) proposes a graphical Kano diagram that is based on predefined scales related to the customer's satisfaction and dissatisfaction. Each customer requirement can be represented as a pair of satisfaction and dissatisfaction values. The nature of a customer requirement can be delineated by the quadrant into which that point falls. However, it is very subjective to classify the customer requirements into four quadrants because of a lack of logical classification criteria.

1.3 Decision support

The ultimate goal of customer need analysis is to provide decision support to product design. Although the Kano categories may enhance designers' understanding of customer needs, they fall short as concrete decision criteria. In general, the categories of the Kano model signify different priorities in designing products. For example, a designer is directed toward fulfilling all must-be FRs, staying competitive with market leaders on the one-dimensional FRs, and including some attractive FRs (Berger et al., 1993). However, such approaches do not distinguish FRs within the same category. Hence, the Kano classification is deemed to be inadequate to facilitate decisions in product design.

1.4 Producer's capacity

The Kano model is inherently customer-driven, i.e., it focuses exclusively on addressing the concerns of customers (Sireli et al., 2007). As a decision-making tool used by engineers, the Kano model fails to account for the producer's concerns in terms of the capacity to fulfill the CNs. Cost constraints are usually accommodated by the product development team based on expertise, such that the product will only include those features that are affordable to the producers (Matzler and Hinterhuber, 1998). In practice, without accurate cost estimation, such an assumption seldom holds true. Lai et al. (2004) propose a linear cost function to constrain the selection of product features in product development. Tan and Shen (2000) propose an approximation transformation function based on Kano analysis to adjust the improvement ratio of customer attributes. However, these cost models are primitive and are inadequate to reflect the complexities of design and manufacturing costs. From an engineering perspective, engineers have to seek for a leverage of the customer-perceived value and the producer's capacity.

2 A-Kano model

The A-Kano model entails a series of interactions between the customers and the producers, as shown in Figure 1. In general, the CNs tend to be imprecise and ambiguous due to their linguistic origins (Jiao and Chen, 2006). And hence it is difficult to apply analytical tools for CN analysis. As a quick fix, the CNs are translated into explicit and objective statements, namely the FRs. The distinction between CNs and FRs is in line with the domain mapping principle proposed by Suh (2001). Essentially, what a customer de facto perceives is the CNs in the customer domain, rather than FRs in the functional domain. While providing customer-perceived diversity in CNs, the producer must seek for an economy of scale in product fulfillment, which is meant by FRs. In this research, analysis is carried out in the functional domain, and the FRs are assigned different priorities for product fulfillment. From the customer's perspective, the priority assignment corresponds to different customer perceptions. From the producer's perspective, the FRs are mapped onto various product attributes, which represent the physical form of a product in fulfillment of the FRs.

Customer perception can be explicitly measured as the overall customer satisfaction with respect to a combination of product attributes. On the other hand, the legacy producer's capacity has to be assessed in terms of delivery of the

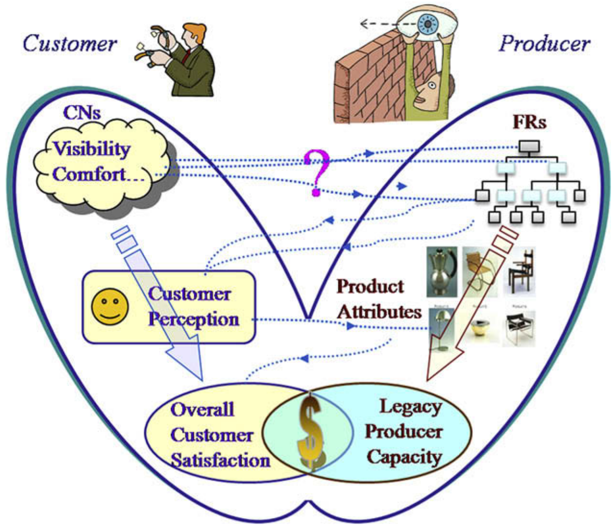

Figure 1 Customer−producer interactions along the product value chain

desired product attributes. The value chain converges when the customer's satisfaction overlaps with the legacy producer's capacity. Ultimately the business success is achieved by maximizing such an overlap, either by expanding the producer's capacity to meet the CNs or by directing the customers to the total capacity of the producer so that customers are better served (Jiao et al., 2003a).

2.1 Kano indices for quantification of customer satisfaction

Kano survey is carried out within specific market segments that consist of customers with similar demographic information. Let s denote the market segment which contains a total of J customers (respondents), i.e., $s \equiv \{t_j | j = 1, 2, \ldots, J\}$. A set of FRs is identified as $F \equiv \{f|_i i = 1, 2, \ldots, I\}$. Surveys are carried out to collect the respondents' evaluation of f_i ($\forall i = 1, 2, \ldots, I$) according to the functional and dysfunctional forms of Kano questions (Table 1). The preliminary category of the FR is determined using the Kano evaluation table (Table 2). For each respondent $t_j \in s(\forall j = 1, 2, \ldots, J)$, the evaluation of $f_i(\forall i = 1, 2, \ldots, I)$ is represented as $e_{ij} = (x_{ij}, y_{ij}, w_{ij})$, where x_{ij} is the score given to an FR for the dysfunctional form question, y_{ij} is the score given to an FR for the functional form question, and w_{ij} is the self-stated importance, which is the respondent's perception of the importance of an FR. Similar to the method proposed by DuMouchel (Berger et al., 1993), this research adopts a scoring scheme that defines customer's satisfaction and dissatisfaction as shown in Table 3. The scale is designed to be asymmetric because positive answers are considered to be stronger responses than negative ones. Hence, the scaling has the effect of diminishing the influence of negative evaluations (Berger et al., 1993). Furthermore, the self-stated importance score is normalized such that it falls within a range of 0−1, as shown in Table 4.

Next, for each FR (f_i), the average level of satisfaction for the dysfunctional form question within market segment s is defined as $\overline{X}_i$, and the average level

Table 1 Kano questionnaire

Kano question	Answer
Functional form of the question (*e.g., if the car has air bags, how do you feel?*)	☐I like it that way ☐It must be that way ☐I am neutral ☐I can live with it that way ☐I dislike it that way
Dysfunctional form of the question (*e.g., if the car does not have air bags, how do you feel?*)	☐I like it that way ☐It must be that way ☐I am neutral ☐I can live with it that way ☐I dislike it that way

of satisfaction for the functional form question within the same market segment is defined as $\overline{Y}_i$, i.e.,

$$\overline{X}_i = \frac{1}{J}\sum_{j=1}^{J} w_{ij}x_{ij}, \quad \overline{Y}_i = \frac{1}{J}\sum_{j=1}^{J} w_{ij}y_{ij} \tag{1}$$

The value pair $(\overline{X}_i, \overline{Y}_i)$ can be plotted in a two-dimensional diagram, where the horizontal axis indicates the dissatisfaction score and the vertical axis stands for the satisfaction score. Most $(\overline{X}_i, \overline{Y}_i)$ should fall in the range of 0−1 because the negative values are results of either Questionable or Reverse categories. A questionable category will not be included in the averages, and a Reverse category can be transformed out of the category by reversing the sense of functional and dysfunctional of questions (Berger et al., 1993). Accordingly, the classification of an FR can be defined based on the corresponding location of the value pair in the diagram, as shown in Figure 2.

From the customer's perspective, the characteristics of an FR (f_i) can be represented as a vector, i.e., $f_i \sim \vec{r_i} \equiv (r_i, \alpha_i)$, where $r_i = |\vec{r_i}\,| = \sqrt{\overline{X}_i^2 + \overline{Y}_i^2}$ is the magnitude of $\vec{r_i}$ and $\alpha_i = \tan^{-1}(\overline{Y}_i/\overline{X}_i)$ is the angle between $\vec{r_i}$ and the horizontal axis. The rationale of representing the satisfaction and dissatisfaction as a vector $\vec{r_i}$ is that it becomes equivalent to a polar form, i.e., the magnitude

Table 2 Kano evaluation table

		Dysfunctional form of the question				
		Like	Must-be	Neutral	Live with	Dislike
Functional form of the question	Like	Q	A	A	A	O
	Must-be	R	I	I	I	M
	Neutral	R	I	I	I	M
	Live with	R	I	I	I	M
	Dislike	R	R	R	R	Q

A, Attractive; O, One-dimensional; M, Must-be; I, Indifferent, R, Reverse; Q, Questionable.

Table 3 Scores for functional/dysfunctional features

Answers to the Kano question	Functional form of the question	Dysfunctional form of the question
I like it that way (like)	1	−0.5
It must be that way (must-be)	0.5	−0.25
I am neutral (neutral)	0	0
I can live with it that way (live with)	−0.25	0.5
I dislike it that way (dislike)	−0.5	1

of the vector denotes the overall importance of f_i to the customers belonging to segment s, and the angle α_i determines the relative level of satisfaction and dissatisfaction. Therefore, the magnitude of the vector (r_i) is called the importance index; and the angle (α_i) is called the satisfaction index. Both $0 \le r_i \le \sqrt{2}$ and $0 \le \alpha_i \le \pi/2$ are collectively called the Kano indices. In the extreme situation, $\alpha_i = 0$ means that dysfunction of f_i causes dissatisfaction, while functioning of f_i does not enhance satisfaction, and hence it is an ideal must-be element. Conversely, $\alpha_i = \pi/2$ means that f_i is an ideal attractive element.

2.2 Kano classifiers for categorization of customer needs

Based on the above formulation, the FRs can be classified into four categories, i.e., indifferent, must-be, attractive and one-dimensional, as shown in Figure 3. A threshold value of the importance index, r_0, is used to differentiate important FRs from less important ones. If $r_i \le r_0$, f_i is considered as unimportant, and thus called an indifferent FR. The region defined by the sector OFI in Figure 3, where the radius is smaller than r_0, is considered as the indifferent region. Hence r_0 is called an indifference threshold.

Likewise, a lower threshold value of the satisfaction index is defined as α_L, such that for f_i, if $r_i > r_0$ and $\alpha_i \le \alpha_L$, it is considered as a must-be FR. The region of the must-be FRs corresponds to the sector DEFG.

A higher threshold value of the satisfaction index is defined as α_H, such that for f_i, if $r_i > r_0$ and $\alpha_i > \alpha_H$, it is considered as an attractive FR. The region of the attractive FRs is shown as sector ABHI.

Table 4 Scores for self-stated importance

Not important		Somewhat important		Important		Very important		Extremely important	
0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0

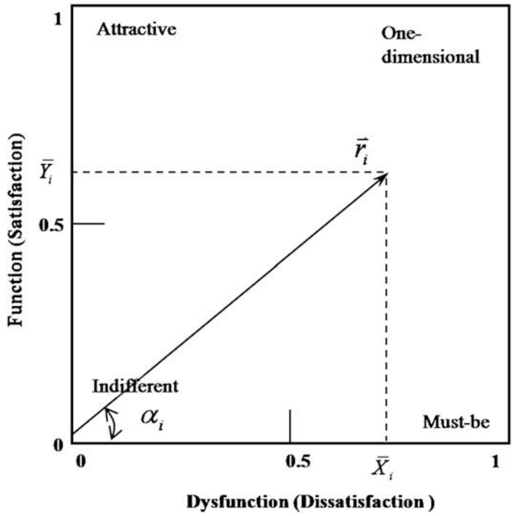

Figure 2 Vector representation of customer perception on a Kano diagram

If $r_i > r_0$ and $\alpha_L < \alpha_i \le \alpha_H$, f_i is considered as a one-dimensional FR. The region of the one-dimensional FRs is shown as sector BCDGH.

The set of thresholds r_0, α_L, and α_H are collectively called Kano classifiers, denoted as $\kappa = (r_0, \alpha_L, \alpha_H)$. According to the Kano principles, the classification of FRs provides a decision criterion for selecting the FRs that constitute a product configuration. To do so, this research proposes the following heuristic to simulate the consequence of Kano classification on product configuration design.

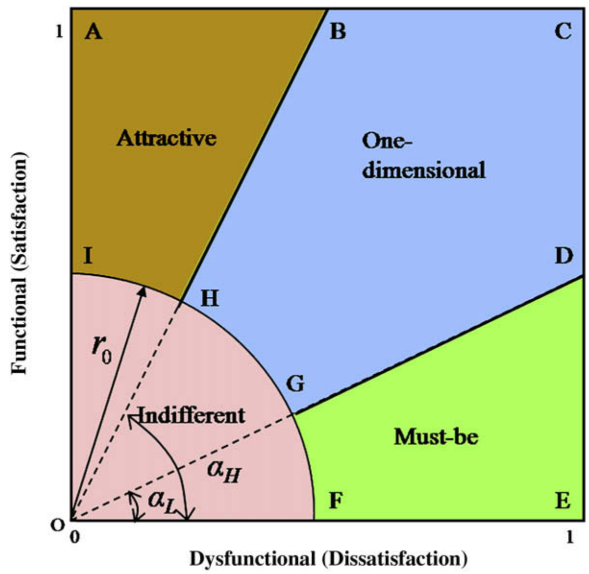

Figure 3 Kano classifier and Kano categories

Heuristic 1: A product configuration (p) is generated as a combination of FRs (f_i, $\forall i = 1, 2, \ldots, I$). A binary variable, z_i, is used to indicate whether f_i is contained in the product or not, such that

$$z_i = \begin{cases} 1, & \text{if } \zeta_i \geq \text{Random}(0, 1), \\ 0, & \text{otherwise.} \end{cases}$$

where the Random(0,1) generates a random number between 0 and 1, and ζ_i denotes the probability that f_i be included in the product configuration. The probability ζ_i is dependent on the Kano category that an FR belongs to, i.e.,

$\zeta_i = 1$, if f_i is a must-be FR,
$\zeta_i = 0.8$, if f_i is a one-dimensional FR,
$\zeta_i = 0.2$, if f_i is an attractive FR,
$\zeta_i = \text{Random}(0, 1)$, if f_i is an indifferent FR.

Determining appropriate values of Kano classifiers is challenging in that these threshold values may be problem-specific and context-aware for different applications. In practice, it is deemed to be difficult to define universal thresholds for different products. This research uses sensitivity analysis to select and testify the appropriate settings of the Kano classifiers. Moreover, a proper performance indicator must be defined to justify the significance of the classification with respect to different settings of Kano classifiers, as is discussed in Section 2.4.

2.3 Configuration index for product configuration design

Decision-making based on the Kano classification inevitably suffers the discontinuity problem, i.e., data points located near the borders of two adjacent regions may be classified as different categories, while their distinction is actually minor. To alleviate such a problem, this research proposes a configuration index to indicate the priority of an FR in fulfillment of customer expectations. The purpose of this strategy is to provide better decision support to product configuration design. The configuration index (ρ_i) is defined as a function of Kano indices (r_i, α_i) to indicate the probability that an FR is contained in a production configuration.

$$\rho_i = \frac{2\sqrt{2}}{3}\left(1 - \frac{\alpha_i}{\pi}\right) r_i \tag{2}$$

Given a particular α_i, the configuration index ρ_i is proportional to the importance index r_i, which agrees with the observation that an FR with greater influence on customer's satisfaction/dissatisfaction is more likely to be included in the product configuration. At the same time, for a specific value of r_i, ρ_i decreases with an increase of the satisfaction index α_i, which reflects the decreasing priorities associated with the Kano categories in the order of must-be, one-dimensional and attractive.

The selection of FRs that contribute to a product configuration is contingent on the configuration indices. In particular, a product configuration p is represented as a combination of FRs (f_i, $\forall i = 1, 2, \ldots, I$). The following heuristic is used to simulate the effect of configuration index on product design.

Heuristic 2: A binary variable, z_i, is used to indicate whether f_i is contained in the product or not.

$$z_i = \begin{cases} 1, & \text{if } f_i \text{ is contained in product } p, \\ 0, & \text{otherwise.} \end{cases}$$

The value of z_i is assigned in the product design stage based on a stochastic procedure. Let Random(0,1) be a function that generates a random number between 0 and 1. Variable $z_i = 1$, when $\rho_i \geq \text{Random}(0, 1)$; and $z_i = 0$, when $\rho_i < \text{Random}(0, 1)$.

Based on this heuristic, an FR with a larger configuration index has a higher chance to be included in the product. It should be noted that product configuration design is subject to other configuration constraints. For example, two FRs may be incompatible with each other such that only one of them may be selected in the configuration.

2.4 Kano evaluator for leveraging customer's satisfaction and producer's capacity

The Kano classifiers and configuration indices provide two alternative mechanisms to determine the FRs to be included in a product. While the resulting product configuration reflects the customer's preferences, the producers have to strive to design products at affordable costs. Therefore, product development involves two interrelated perspectives, i.e., increasing customer's satisfaction and enhancing producer's capacity. In this respect, the A-Kano model explicitly defines a Kano evaluator to estimate the value of the planned products.

2.4.1 Objective function

This research adopts the concept of shared surplus to leverage upon both customer's and producer's concerns. The consumer surplus is modeled as the overall customer's satisfaction (U) of the product, and the producer surplus is simulated as the overall cycle time index (C). Accordingly, the Kano evaluator (E) is defined as a shared surplus-based performance indicator, i.e.,

$$E = \frac{U}{C} \tag{3}$$

Based on the customer's responses to the functional/dysfunctional form of Kano questions, the configuration index reflects the customer's satisfaction level for individual FRs. Hence, the customer's satisfaction (U) is defined as the summation of the configuration indices (ρ_i) of FRs contained in the product configuration, i.e.,

$$U = \sum_{i=1}^{I} \rho_i z_i \tag{4}$$

where

$$z_i = \begin{cases} 1, & \text{if } f_i \text{ is contained in product } p, \\ 0, & \text{otherwise} \end{cases}$$

On the other hand, producer's capacity is related to the technical feasibility of a design and the engineering cost, which refers to the producer surplus. This research proposes the cycle time index (C) to estimate the producer's capacity as discussed next.

2.4.2 Cycle time index

The cycle time index (C) is based on the concept of process capability index which provides an economic latitude of process variations due to product customization (Jiao and Tseng, 1999). The process capability index gives an indication of how expensive of a customization is to be if implemented in production. The idea is to allocate costs to those established time standards from previously reported work and time studies and thereby circumvent the tedious tasks of identifying various cost drivers and cost related activities. To do so, it is necessary to find the mapping relationships between different attribute levels and their expected consumptions of standard times within legacy process capabilities. These part-worth standard time accounting relationships are built into the product and process platforms (Jiao et al., 2003b). Any product configured from available attribute levels is justified based on its expected cycle time, which demonstrates the distinctions between variables that differ as a result of random error and are often well described by a normal distribution (Tielemans, 1995). The one-side specification limit process capability index (P^{CI}) can be formulated as:

$$P^{\mathrm{CI}} = \frac{\mathrm{USL}^{\mathrm{T}} - \mu^{\mathrm{T}}}{3\sigma^{\mathrm{T}}} \tag{5}$$

where $\mathrm{USL}^{\mathrm{T}}$, μ^{T}, and σ^{T} are the upper specification limit, the mean, and the standard deviation of the estimated cycle time, respectively. Variations in the cycle time are characterized by μ^{T}, and σ^{T}, reflecting the compound effect of multiple products on production in terms of process variations. The $\mathrm{USL}^{\mathrm{T}}$ can be determined ex ante based on the worst case analysis of a given process platform, in which standard routings can be reconfigured to accommodate various products derived from the corresponding product platform (Jiao et al., 2003b).

Owing to the close correlation between costs and the cycle time, P^{CI} indicates how expensive a product is expected to be if produced within the existing process capabilities. Thus, the cycle time index C corresponding to a product p can be formulated based on the respective process capability index:

$$C = \lambda \exp\left(\frac{1}{P^{\mathrm{CI}}}\right) = \lambda \exp\left(\frac{3\sigma^{\mathrm{T}}}{\mathrm{USL}^{\mathrm{T}} - \mu^{\mathrm{T}}}\right) \tag{6}$$

where λ is a constant indicating the average dollar cost per variation of process capabilities. The meaning of λ is consistent with that of the dollar loss per deviation constant widely used in Taguchi's loss functions. It can be determined ex ante based on the analysis of existing product and process platforms. Such a cost function produces a relative measure, instead of actual dollar figures, for evaluating the extent of overall process variations among multiple products.

The estimated cycle time for product p, namely (μ^{T}, σ^{T}), is assumed to be a linear function of the part-worth standard times for the FRs assumed by product p, i.e.,

$$\mu^{\mathrm{T}} = \sum_{i=1}^{I}\left(\zeta_i \mu_i^{\mathrm{T}} z_i + \omega\right) \tag{7a}$$

$$\sigma^{\mathrm{T}} = \sqrt{\sum_{i=1}^{I}\left(\sigma_i^{\mathrm{T}} z_i\right)^2} \tag{7b}$$

where ζ_i and ω are regression coefficients, μ_i^{T} and σ_i^{T} are the mean and the standard deviation of the part-worth standard time associated with f_i, respectively, and z_i is defined the same as in Eq. (4).

3 A-Kano decision-making

The product planning stage features a series of processes including elicitation, analysis, and fulfillment of the CNs. The A-Kano model can assist decision-making in the process by prioritizing the FRs according to their impacts on the customers and producers. A coherent A-Kano process model is developed to combine the various analytical techniques presented in Section 2, and a general roadmap is shown in Figure 4.

3.1 Identification of functional requirements

The A-Kano model requires the survey results of customer's satisfaction using the Kano questionnaire. In general, the questionnaire is designed according to a set of CNs. To allow for unambiguous understanding, the CNs are translated into FRs, $F \equiv \{f_i | i = i, 2, \ldots, I\}$. For example, visibility of the gauges in a car dashboard is a CN, and is manifested by the size and lighting conditions of the gauges, namely the FRs. In this research, the FRs are typically related to customizable product attributes from which the customers can choose according to his/her preferences.

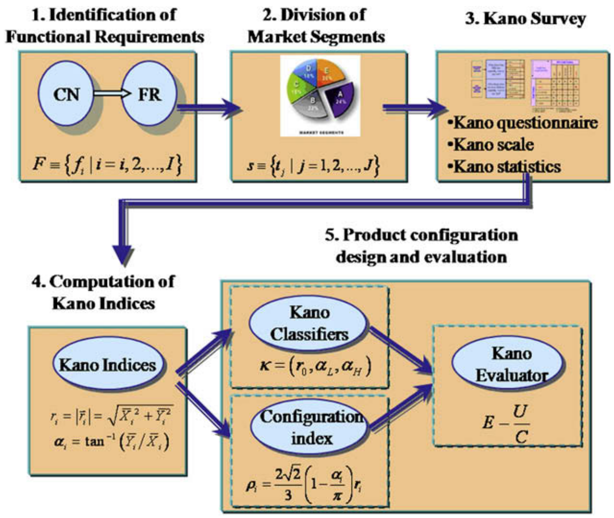

Figure 4 A design process model of analytical Kano

3.2 Division of market segments

Customers are grouped into different market segments based on their demographic information, such as age, gender, income, etc. If the division of market segments is not evident, it becomes necessary to carry out market investigations to differentiate the customer groups. Many methods and tools are available to assist the process, such as conjoint analysis (Green and DeSarbo, 1978), perceptual mapping (Moore and Pessemier, 1993), and data mining (Jiao and Zhang, 2005).

3.3 Kano survey

With respect to the FRs, the Kano questionnaire is fabricated and surveys are conducted to acquire the customers' assessment of the FRs according to the functional and dysfunctional forms of questions. In addition, the customers' immediate perceptions of the importance of the FRs are extracted according to the self-stated importance (Table 4).

3.4 Computation of Kano indices

For each market segment, the customer's average satisfaction/dissatisfaction with respect to the functional/dysfunctional form question is computed according to Eq. 1. Next, the Kano indices are computed and plotted in the A-Kano diagram. Accordingly, the configuration index for each FR is computed, which indicates the priority of the FR in product configuration design.

3.5 Product configuration design and evaluation

Two alternative methods are adopted for product configuration design, namely (1) the Kano classification-based method, and (2) the configuration index-based method. In each method, the candidate product configuration is evaluated against the Kano evaluator. As a prerequisite, part-worth standard time $(\mu_i^{\mathrm{T}}, \sigma_i^{\mathrm{T}})$ is identified from the standard routing that constitutes the process platform. Subsequently, the customer's satisfaction (U) and cycle time index (C) of the products are evaluated, leading to an expected value of the Kano evaluator (E). The optimal product configuration is generated as the one that produces the largest Kano evaluator.

3.5.1 Kano classification-based configuration design

The threshold values of the Kano classifiers, namely $\kappa = (r_0, \alpha_L, \alpha_H)$ are tested such that the FRs are classified as four categories. Different threshold values lead to different classification schemes, which in turn influence the design of product configuration and the expected value of the product. Sensitivity analysis is carried out to examine different settings of Kano classifiers, using the Kano evaluator as the performance indicator. Sensitivity analysis entails an iterative process of evaluating the Kano evaluator based on specific FR classification schemes. This research adopts a strategy where r_0 changes from 0.1 to 0.9 with an increment of 0.1, α_L changes from 5° to 45° with an increment of 5°, and α_H changes from 50° to 90° with an increment of 5°. A full-factorial experiment requires $9 \times 9 \times 9 = 729$ runs of experiment. In each run, the FRs are classified according to each set of Kano classifier $\kappa = (r_0, \alpha_L, \alpha_H)$, and a set of N product configurations are generated based on Heuristic 1. Subsequently, the customer satisfaction (U) and cycle time index (C) of the set of N products are evaluated according to Eqs. (4) and (6), leading to an expected value of the Kano evaluator (E). The optimal values of Kano classifiers are selected as those that produce the largest Kano evaluator.

3.5.2 Configuration index-based configuration design

Product configuration is generated using Heuristic 2. This is a typical combinatorial optimization problem where a large search space needs to be explored. Genetic algorithms (GAs) have been proven to excel in solving combinatorial optimization problems in comparison with traditional calculus-based or approximation optimization techniques. In this regard, a heuristic GA (Jiao and Zhang, 2005) is adopted to solve such a combinatorial optimization problem.

4 Case study

The proposed method is applied to car dashboard design in an automobile company. The dashboard is an important subassembly in the automobile with a number of customizable components and features (Figure 5). These components can be represented as FRs in the design stage. The actual selection of the FRs collectively constitutes the car interior environment, which influences the driver's perceptions, and ultimately determines his/her satisfaction. However, the exact correspondence between FRs and customer's satisfaction is not evident. Moreover, the relationship between the selection of FRs and the producer's production capability is not considered in product design. Therefore, it is necessary to gain insight of the FRs with respect to the customer's satisfaction and the producer's capacity.

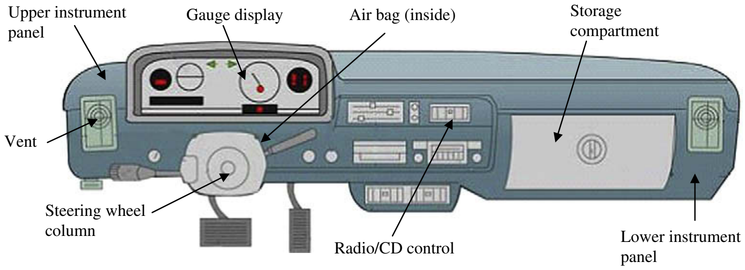

Figure 5 Main components and features of car dashboard subassembly

The company has conducted extensive market studies to collect the CNs which are represented according to well-known FR descriptors. This case study focuses on a set of 10 CNs, which are refined as 25 FRs, as shown in Table 5.

4.1 Kano survey

A total of 50 car drivers constituted the Kano survey respondent set. The respondents were divided into three groups based on their age, gender and income levels, representing three market segments as shown in Table 6. Each respondent was required to answer the Kano questions with respect to each and every FR, and give the perception of the importance of an FR using the self-stated importance (Table 4). The form of Kano questions used in this survey is shown in Table 1, including both the functional and dysfunctional forms.

Table 5 Functional requirements of car dashboard

Customer need	Functional requirement	Code
Gauge display type	Analog display	f_{1-1}
	Digital display	f_{1-2}
Gauge display size	Large (15 inch)	f_{2-1}
	Small (10 inch)	f_{2-2}
Gauge display lighting	Back light	f_{3-1}
	External light	f_{3-2}
Instrument panel material	Plastic–wooden	f_{4-1}
	Plastic	f_{4-2}
	Plastic–metal	f_{4-3}
Instrument panel color	Cream	f_{5-1}
	Gray	f_{5-2}
	Black	f_{5-3}
Steering wheel material	Plastic–wooden	f_{6-1}
	Plastic	f_{6-2}
	Plastic–leather	f_{6-3}
Steering wheel height	High (24 inch)	f_{7-1}
	Low (20 inch)	f_{7-2}
Position of CD/radio control	Integrated in steering wheel	f_{8-1}
	On control panel	f_{8-2}
Storage configuration	Top	f_{9-1}
	Side	f_{9-2}
	Front	f_{9-3}
	Passenger side	f_{9-4}
Air bag	Front	f_{10-1}
	Side	f_{10-2}

Table 6 Customer groups in Kano survey

Market segment	Age	Gender	Income (10^3S$/year)
Segment 1 (s_1)	46+	M/F	120+
Segment 2 (s_2)	31–45	M/F	60–119
Segment 3 (s_3)	21–30	M	30–59

Next, for each FR, the average level of satisfaction/dissatisfaction for the functional/dysfunctional form question within each market segment is computed, resulting in the data point $(\overline{X}_i, \overline{Y}_i)$ as shown in Figure 6. Accordingly, the Kano indices $\vec{r}_i \equiv (r_i, \alpha_i)$ are derived, which is further used to compute the configuration index. The configuration index with respect to three market segments is summarized in Table 7.

Table 7 also shows the part-worth standard times of the FRs. The company fulfills customer orders through assembly-to-order production while importing all components and parts via global sourcing. With assembly-to-order production, the company has identified and established standard routings as basic constructs of its process platform. The part-worth standard time of each FR is established based on time and motion studies of the related assembly and testing operations.

4.2 Comparative study

A comparative study is carried out to validate the effectiveness of the A-Kano method. The study involves three independent procedures to design products based on the same set of survey data. In the first procedure, the FRs are

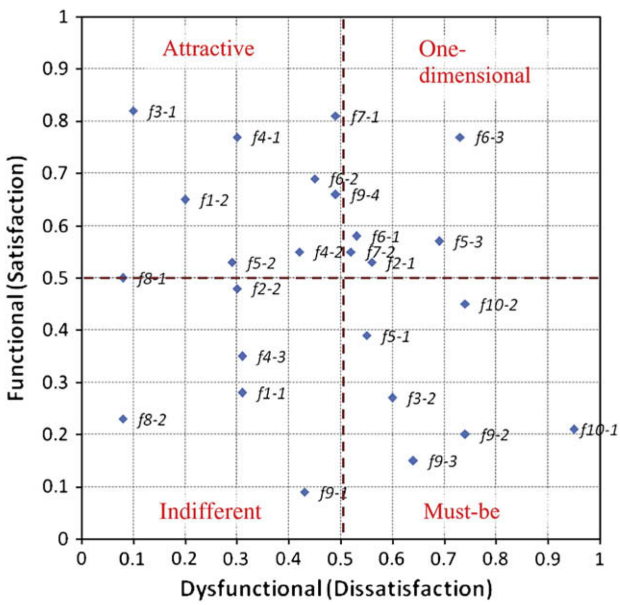

Figure 6 Kano model of functional requirement classification

Table 7 Configuration index and part-worth standard time

FR	Configuration index (*market segment*)			Part-worth standard time	
	s_1	s_2	s_3	μ_i^T(s)	σ_i^T(s)
f_{1-1}	0.30	0.2	0.31	498	21
f_{1-2}	0.38	0.33	0.2	557	35
f_{2-1}	0.55	0.3	0.56	505	22
f_{2-2}	0.36	0.33	0.3	493	20
f_{3-1}	0.42	0.35	0.1	90	6
f_{3-2}	0.54	0.74	0.6	50.5	4
f_{4-1}	0.48	0.44	0.3	462	15.5
f_{4-2}	0.46	0.38	0.42	465	18
f_{4-3}	0.32	0.4	0.35	411	13
f_{5-1}	0.51	0.22	0.61	50	5.5
f_{5-2}	0.38	0.56	0.29	47.5	5.5
f_{5-3}	0.66	0.55	0.69	45	6
f_{6-1}	0.54	0.46	0.53	442	28
f_{6-2}	0.53	0.48	0.45	365	30.4
f_{6-3}	0.74	0.7	0.63	483	32
f_{7-1}	0.60	0.43	0.52	365	30.4
f_{7-2}	0.53	0.23	0.35	483	32
f_{8-1}	0.26	0.19	0.08	99	9.4
f_{8-2}	0.14	0.09	0.08	99	9.4
f_{9-1}	0.39	0.55	0.47	69	8
f_{9-2}	0.66	0.69	0.74	54	5.6
f_{9-3}	0.57	0.49	0.64	80.3	5.6
f_{9-4}	0.55	0.56	0.49	40.6	4
f_{10-1}	0.85	0.55	0.74	216	33
f_{10-2}	0.67	0.59	0.95	247	40

classified using the Kano method proposed by DuMouchel (Berger et al., 1993). In the second procedure, the respective FRs are classified using the Kano classifiers proposed in the A-Kano method. In both methods, the FR classification is applied to assist the generation of product configurations. In the third procedure, the configuration indices of the FRs are used to guide the design of product configurations following the decision framework presented in Section 3. The merits of the three methods are compared according to the product performance in terms of the Kano evaluator. In this case study, the results of only one market segment (s_1) are presented for purpose of brevity. The analysis of the other market segments can be carried out following the same procedures.

4.2.1 Kano-based product configuration design

Based on the method proposed by DuMouchel (Berger et al., 1993), a two-dimensional Kano diagram is established according to customers' satisfaction and dissatisfaction levels, as shown in Figure 6. According to this model, the diagram is divided into four quadrants, and accordingly the FRs are classified into four categories. Heuristic 1 is adopted to generate product configurations based on the Kano classification. The product configuration, called Product I, is generated manually and is shown in Table 8, where a number '1' indicates

Table 8 Product configurations generated based on three methods

FR	Product I (Kano-based)	Product II (A-Kano: classifier)	Product III (A-Kano: configuration index)
f_{1-1}			1
f_{1-2}	1	1	
f_{2-1}	1	1	1
f_{2-2}			
f_{3-1}		1	
f_{3-2}	1	1	1
f_{4-1}			
f_{4-2}			1
f_{4-3}	1	1	
f_{5-1}	1	1	1
f_{5-2}	1		
f_{5-3}		1	1
f_{6-1}	1		
f_{6-2}		1	1
f_{6-3}			
f_{7-1}			1
f_{7-2}	1	1	
f_{8-1}			1
f_{8-2}	1	1	
f_{9-1}	1		
f_{9-2}	1	1	1
f_{9-3}	1	1	1
f_{9-4}			1
f_{10-1}	1	1	1
f_{10-2}	1	1	1
Customer satisfaction	7.03	7.33	7.71
Cycle time index	14.63	7.23	6.63
Kano evaluator	**0.48**	**1.01**	**1.16**

that the respective FR is included in the product; otherwise, it is left blank. The Kano evaluator is computed using Eqs. (3)–(7), such that Product I results in a Kano evaluator of 0.48.

4.2.2 A-Kano-based product configuration design – Kano classifiers

The Kano classification is implemented based on the Kano indices and Kano classifiers. To select the appropriate values of Kano classifiers, an iterative process of sensitivity analysis is carried out. Each set of Kano classifiers, i.e., $\kappa = (r_0, \alpha_L, \alpha_H)$ results in a scheme of FR classification, which in turn guides the generation of the product configurations following Heuristic 1. Once the product configurations are created, the Kano evaluator is computed.

The sensitivity analysis involves three variables, namely r_0, α_L and α_H. Hence, it is difficult to visualize the response surface using a three-dimensional graph. A graphical illustration can be made by setting one variable at a fixed value while changing the values of the other two variables. For example, Figure 7 shows the result of sensitivity analysis when the Kano classifier r_0 is fixed as $r_0 = 0.3$, α_L varies from 5° to 45°, and α_H varies from 50° to 90°. The Kano evaluator is normalized for purpose of illustration. Base on the sensitivity analysis, the largest Kano evaluator is 1.01, which is obtained when the Kano classifiers are $r_0 = 0.5$, $\alpha_L = 25°$, and $\alpha_H = 65°$, respectively. The A-Kano diagram for FRs classification is shown in Figure 8, and the product configuration derived from this classification is called Product II, which is shown in Table 8.

4.2.3 A-Kano-based product configuration design – configuration index

The A-Kano method proposes using the category index to guide the generation of product configurations. A heuristic GA is adopted to generate a set of solutions, each of which is evaluated against the Kano evaluator. The product configuration (Product III) derived from this method is shown in Table 8, which leads to a Kano evaluator of 1.16.

4.3 Results and analysis

The major difference between the three methods lies in the criteria to select the FRs that constitute the product configuration. In the traditional Kano method, FRs are selected manually based on the Kano category. Although the process is straightforward, it does not reflect the differences among FRs within the same category. For example, both f_{2-2} and f_{8-2} are classified as indifferent FRs. However, these two FRs represent different customer perceptions considering their importance and relative customer satisfaction. Such a difference is effectively captured by the configuration index in the A-Kano method, where the configuration indices are 0.36 and 0.14, respectively. Interestingly, the polar form A-Kano classification assigns two FRs into one-dimensional and indifferent categories, respectively, which reflects the difference between them.

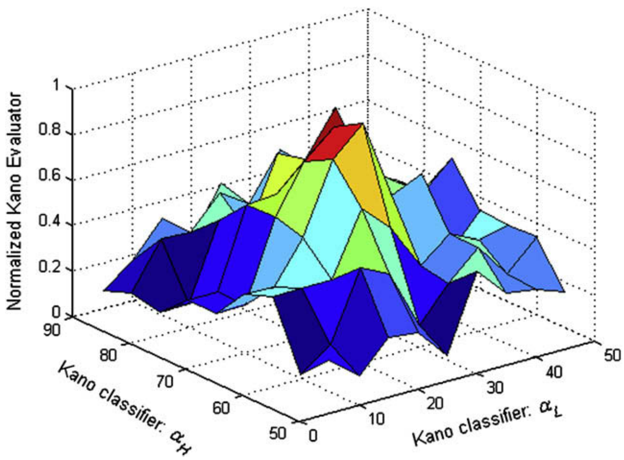

Figure 7 Sensitivity analysis of Kano evaluator w.r.t. α_L and α_H

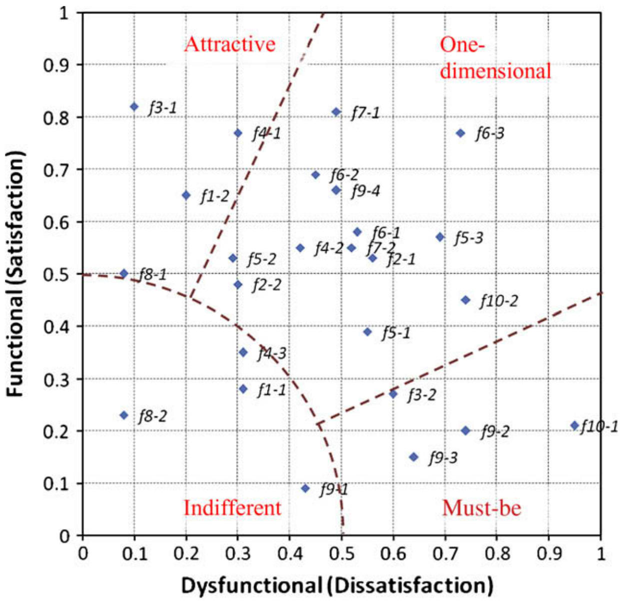

Figure 8 A-Kano model of functional requirement classification

On the other hand, both the traditional Kano method and A-Kano method based on Kano classifiers suffer the discontinuity problem, i.e., they make clear-cut distinctions between FRs that fall into different categories, even when these FRs are actually located close to each other in the Kano diagram. For example, FRs f_{2-2} and f_{5-2} which are located closely to each other are classified as indifferent and attractive FRs in the traditional Kano. However, such a distinction is not evident based on the Kano indices. A slight change of the classification threshold value, e.g., moving the horizontal dashed line higher, would make both f_{2-2} and f_{5-2} fall into the indifferent category. Hence, it is subjective to assign the threshold values. On the other hand, in the A-Kano method, the configuration indices of these two FRs are 0.36 and 0.38, thus indicating identical customer preferences. Interestingly, the classification using A-Kano classifiers reflects such similarities so that the two FRs both fall in the one-dimensional region.

A further comparison can be made between the product configurations resulted from the traditional Kano model and the A-Kano (Table 8). The merit of the product configurations is evaluated against the Kano evaluator. As can be seen from the results, the product configurations lead to different customer's satisfaction and cycle time index, and in turn the Kano evaluator. The overall performance of the Product I is 0.48, while those of Products II and III are 1.01 and 1.16, respectively. The latter two products offer larger expected shared surplus values, which indicate better strategies to leverage upon customer's satisfaction and the producer's capacity. As can be seen from the results, the overall customer satisfaction values are 7.03, 7.33 and 7.71 for the three products, which are almost identical. The major difference in the

Kano evaluator lies in the varied cycle time indices, which are 14.63, 7.23, and 6.63, respectively. Such a distinction reflects that Products II and III effectively account for the producer's capacity in the configuration design. It should be noted the absolute value of the Kano evaluator is not significant. But rather, it denotes the relative superiority of a classification in terms of the shared surplus.

5 Discussions

The A-Kano method extends traditional Kano method by adopting quantitative measures of customer's satisfaction. The Kano classifiers and configuration indices enhance decision support in product design. Furthermore, it proposes a performance indicator that gives dual considerations of customer's satisfaction and producer's capacity to fulfill customer needs. The main contribution of this research is to extract useful customer need information from Kano survey for decision support in product design. In comparison with traditional Kano model that relies on qualitative Kano categories, the A-Kano method establishes a coherent decision framework that deals with the interactions between the customer domain and the producer domain. The polar form of Kano indices $\vec{r_i} \equiv (r_i, \alpha_i)$ excels the Cartesian form $(\overline{X}_i, \overline{Y}_i)$ proposed by DuMouchel (Berger et al., 1993) as a quantification measurement of customer preferences, in the sense that it facilitates intuitive understanding of the FRs. In particular, the magnitude of the vector, r_i, represents the importance of an FR and the angle α_i represents the relative level of satisfaction and dissatisfaction, thus representing different aspects of customer perceptions.

The quantification of customer's satisfaction based on Kano indices distinguishes the A-Kano method from other research techniques, such as conjoint analysis (Green and DeSarbo, 1978), stated choice methods (Louviere et al., 2000), and discrete choice analysis (Wassenaar and Chen, 2003; Wassenaar et al., 2005). The major difference lies in the different denotations of customer preference. In classical conjoint analysis as well as the stated choice methods, customer preference/demand is modeled as a utility function of various product attributes. In discrete choice analysis, the economic benefits to the producer are modeled as a utility function of customer attributes, prices and socioeconomic and demographic background of the market population (Wassenaar and Chen, 2003; Wassenaar et al., 2005). In contrast, the A-Kano method models customer preference based on customer's satisfaction and dissatisfaction. Apparently, the meanings of satisfaction and dissatisfaction in the A-Kano model are different from those used in the utility theory. For example, the questions 'How satisfied are you with this product?' and 'How useful/valuable is this product to you?' are in fact quite different. An outdated product may be very unsatisfying, but very useful because one may rely on it to carry out important work. In such a respect, the Kano model implies two different perspectives − proper functioning of a product feature arouses customer satisfaction, while the dysfunction of a product

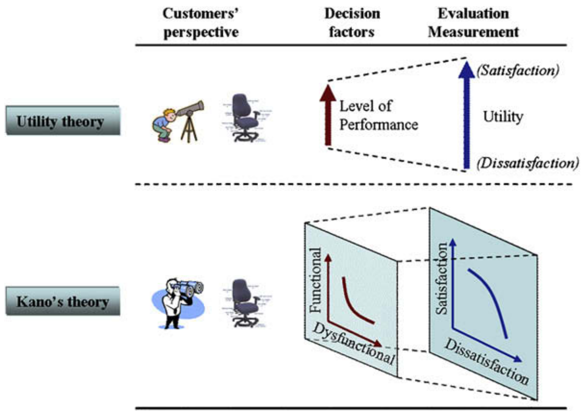

Figure 9 Comparison of the utility theory and Kano's theory

feature generates dissatisfaction, as shown in Figure 9. This is a useful extension to the one-dimensional utility measurement. However, this research does not assert that the Kano's perspective is more reasonable than that used in the utility theory. Nevertheless, it provides an alternative measurement of customer preferences.

6 Conclusions

Product development for customer's satisfaction with considerations of producer's capacity necessitates logical prioritization of customer needs. A few major challenges remain unaddressed for customer need analysis, such as quantitative measure of customer satisfaction, decision support, and capacity assessment of the producers. This paper presents an analytical Kano model for customer need analysis, following the basic principles of traditional Kano model, while consolidating the theoretical foundation. The A-Kano model adopts the Kano indices for measuring customer's satisfaction and dissatisfaction. By adopting a polar form representation scheme, the Kano indices are conducive to exploring the nature of customer satisfaction. In accordance with the Kano indices, the Kano classifiers are deemed to outperform traditional classification criteria based on the logical polar form. As an alternative decision process, the configuration index is defined to prioritize the functional requirements so as to provide decision support to product configuration design. The merit of the designed product is evaluated against the Kano evaluator, leveraging upon both customer's satisfaction and the producer's capacity. The configuration index in combination with the Kano evaluator is deemed to be useful extensions to traditional Kano where the classification criteria are subjective and unjustifiable. The A-Kano method defines systematic procedures to elicit the customer needs, and to conduct surveys for customer need analysis. The overall A-Kano framework address the customer need analysis from a broader scenario, such that the customizable product features can be better managed at the product planning stage.

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