A Study on Quantification of Kano's Quality Model

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Abstract

This paper proposes a method for quantifying the types of quality elements proposed by Kano; namely: attractive quality, one-dimensional quality, and must-be quality. Kano's classification of required quality has helped us improve our thinking in product development. However, his classification is conceptual rather than quantitative, and the conventional techniques of questionnaire and group interview cannot provide quantification of the relationship between the degree of customer satisfaction and the degree of sufficiency of required qualities. This paper describes how a quality element under Kano's quality model can be expressed as a utility function, and describes an application to quality design of a cellular phone.

Key Words : Kano's quality model, quantification of quality element, customer satisfaction, utility function

1. Introduction

In product development, customer requirements are identified through market research, deployed, and converted into quality elements using a procedure called "quality function deployment." Clarifying the types of quality elements is an important step in this conversion of customer requirements into quality elements, because quality elements of greater value do not necessarily satisfy customer requirements. Kano (1984) has proposed a quality model where required qualities are classified into attractive qualities, one-dimensional qualities, and must-be qualities.

Kano's quality model has greatly enhanced our understanding of customer's quality requirements and contributed to improvement of product development. Conventionally, however, qualities are investigated by use of the questionnaire and group interview techniques. Classification is arranged so as to construct a matrix composed of required qualities and type of quality. However, the conclusions of the investigation merely summarize the classification of qualities as conceptual definitions and cannot express the magnitude of a quantity, such as a mathematical relationship between the degree of sufficiency of required qualities and the degree of customer satisfaction. If quantification of a relation were to be obtained, the evaluation of quality elements could be reflected in the product planning process. This paper proposes a method for associating customer preference with the value of required qualities, as well as the classification and quantification of qualities under Kano's quality model by application of a utility function. Further, this paper describes the application of the proposed method to the quality plan for a cellular phone.

2. Kano's quality model and utility function

2.1 Kano's quality model

Kano (1996) defines the quality concept as follows.

- **Attractive quality:** the quality elements that when fulfilled provide satisfaction but when not fulfilled are acceptable.
- **One-dimensional quality:** the quality elements that result in satisfaction when fulfilled and in dissatisfaction when not fulfilled.
- **Must-be quality:** the quality elements that are absolutely expected (taken for granted when fulfilled) but result in dissatisfaction when not fulfilled.
- **Indifferent quality:** the quality elements that neither result in satisfaction nor dissatisfaction, regardless of whether they are fulfilled or not.
- **Reverse quality:** the quality elements that result in dissatisfaction when fulfilled and satisfaction when not fulfilled.

In order to classify these quality elements, Kano proposed the questionnaire shown in

Table 1 for estimating a tendency of these quality elements. Besides, he presumes that the tendency of the quality obtained from Table 1 is treated as the characteristic of the quality based on majority rule. In this paper, we classify the characteristic of qualities as referring to Kano's method stated above, and focus on evaluating three kinds of quality elements: attractive qualities, one-dimensional qualities, and must-be qualities.

2.2 Utility function

Utility is a numerical representation of value and is a convenient quantitative expression of preferences; preference is used for the qualitative or comparative mode of value (Moder, 1978), and a utility function has conventionally been used as the function for quantitatively evaluating the preference of the decision-maker towards risk at the time of decision-making (Tamura, 1997).

Three kinds of utility functions are defined, as follows:

- **Risk prone type:** a risk prone type utility function indicates a preference to take a high risk rather than to accept an expected value.
- **Risk neutral type:** a risk neutral type function indicates a natural tendency to accept an expected value that offsets a risk.
- **Risk aversion type:** a risk aversion type utility function indicates a preference to accept an expected value rather than to take a high risk.

We consider these utility functions to be associated with Kano's quality model because of the corresponding types of curves shown in Figure 1. In the right figure, the x-axis represents the performance of a quality item, and the y-axis represents the utility function level. The performance value corresponding to 0.5 for utility is called the certainty equivalent. The worst value of performance is set to the utility function level $U(x)=0$, and the best value is set to

Table 1. Questionnaire for Quality Classification (Kano, 1984)

		Being un-sufficient.				
		satisfied.	Must-be.	feel not at all.	unavoidable.	not pleased.
Sufficiency	satisfied.	⑥	②	②	②	①
	Must-be.	⑤	④	④	④	③
	feel not at all.	⑤	④	④	④	③
	unavoidable.	⑤	④	④	④	③
	not pleased.	⑤	⑤	⑤	⑤	⑥

①One-dimensional quality ③Must-be quality ⑤Reverse quality
②Attractive quality ④Indifferent quality ⑥Skeptical reply

utility function level $U(x)=1$.

Using these three points, we can calculate an appropriate utility function, according to the type of function.

2.3 Correspondence of utility function and quality models

(1) Attractive quality vs. Risk prone type

Although lack of an attractive quality element is not felt to pose inconvenience, customers perceive that provision of the element makes the product attractive. In contrast, with the risk prone type function, high performance is pursued even if the behavior presents a high risk. Therefore, this risk can be identified as the degree to which a quality element is provided.

(2) One-dimensional quality vs. Risk neutral type

A one-dimensional quality is a quality for which the greater the degree of substantial sufficiency, the greater the degree of customer satisfaction. However, with a risk neutral type function, risk increases linearly. Therefore, the risk can be identified as the degree to which customer satisfaction increases linearly with provision of the quality element.

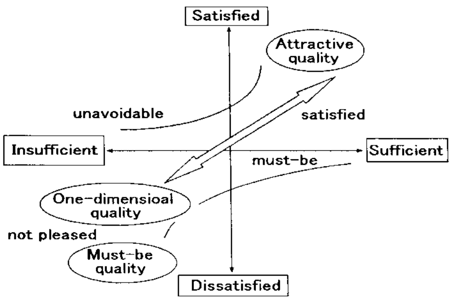
(3) Must-be quality vs. Risk aversion type

A must-be quality is an indispensable quality. In contrast, risk aversion is the view that risk is to be avoided as much as possible. Considering the risk that the quality requirements are not satisfied, this risk is a risk that must be avoided.

3. Quality classification and the procedure of identifying a utility function

After the type of a required quality is identified by use of Table 1, the degree of customer value and satisfaction associated with sufficiency of the required quality can be estimated by use of a utility function.

The procedures for identifying a utility



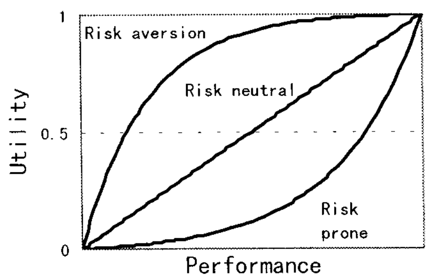


Figure 1. Kano's Quality Model (Kano, 1984) and Utility Function.

function are as follows (Sawaragi, 1981):

(1) Designate the worst quality level u (x^0) and the best quality level u (x^*), in order to determine the degree of sufficiency of the quality element.

(2) Set the degree of sufficiency of the worst quality level to 0, and that of the best quality level to 1.

(3) For the case of an attractive quality and/or a must-be quality, estimate the certainty equivalent value at the quality level $x^{0.5}$ for which the utility value equals 0.5 (See Appendix).

If the certainty equivalent is $x^{0.5}=(x^0+x^*)/2$, then the utility function is risk neutral type, and is identified as a utility value associated with the degree of sufficiency for a one-dimensional quality element. Otherwise, the utility function is identified as either risk aversion type or risk prone type.

(4) For a utility function of risk aversion type or that of risk prone type (6.1), estimate the unknown parameters, B and C, by applying the Newton-Raphson method to the three points x^0, $x^{0.5}$, and x^* (Kainuma, 1986).

$$u(x) = B[1-\exp\{-C(x-x^0)/(x^*-x^0)\}] \quad (6.1)$$

$$u(x) = (x-x^0)/(x^*-x^0) \quad (6.2)$$

Equation (6.1) is for risk aversion type and risk prone type functions, which are essentially the same, except for the sign of coefficient, B and C. Equation (6.2) is identified as the utility function of a one-dimensional quality element. For the case where the certainty equivalent of the quality element results in the average value of the best level and the worst level of performance, any attractive or must-be quality element must be changed for a risk neutral type.

4. Case study - Quality of Cellular phone

We applied the proposed method to the analysis of cellular phones. Figure 2 illustrates the tree diagram of quality elements extracted from five commercially available cellular phones, the quality elements having been identified by use of quality deployment. We established 20 items at the lowest level and 4 items at the top level. According to Kano's matrix, the 20 quality items were classified into the three quality concepts. The quality classification yields seven attractive qualities, eleven must-be qualities, and two one-dimensional qualities.

In order to determine the utility function of each quality item, the best level, the worst level, and the certainty equivalent are established, as shown in Table 2. The worst level of the quality items is the worst level among the five cellular phones under study. Further, we determined the expected performance of a cellular phone being developed as a replacement of the present best phone.

Figure 3 to 8 show example results of the utility function for a quality element as determined by the proposed method. The open square symbols in these figures represent present performance, and the open triangle symbols show, from the left, the worst level, the certainty equivalent, and the best level.

Figure 3 and 4 illustrate quality elements classified as attractive qualities. Figure 3 shows only 20 - 30% user satisfaction at the present level of performance. Therefore, if performance is improved from the present value, the degree of satisfaction is expected to increase. After the number of downloadable melodies reaches 20, which represent the best level available at the time of the study, the degree of satisfaction rises steeply. Thus, a new phone will become more attractive if the performance is improved over that of the existing best. We suggest that we can regard the types of quality model as an approximately one-dimensional quality though it is attractive as shown in the Figure 4.

Figure 5 and 6 illustrate quality elements classified as one-dimensional qualities. These figures show that the present level of performance yields a degree of satisfaction of less than 50%. Since the qualities are one-dimensional qualities, the degree of satisfaction improves if the level of performance is raised.

Figure 7 and 8 illustrate quality elements classified as must-be qualities. The present levels of performance yield degrees of satisfaction of just 50%. Although the degree of satisfaction may seldom be raised, we suggest that steadily increasing the level of performance is necessary, because the elements are indispensable. For example, if the call record function is changed to about 70, the degree of satisfaction becomes 90% and call record capacity will become a mostly satisfying function. We also suggest that we can regard the types of quality model as an approximately one-dimensional quality because the relation between performance and satisfaction is nearly linear as shown in Figure 8.

As mentioned above, once the relationship between quality level and the degree of customer value is quantified, a product plan will improve extensively.

Cellular phone	Quality classification
Price	
Purchase price	M
Function	
Voice message	O
Voice message time	M
Schedule	M
Voice search	A
Fundamental performance	
Redial	M
Call record	M
Mail inbox	A
Mail outbox	M
Mail address	M
Memory group	O
Memory dial	M
Charging time	M
Waiting receptacle time	M
Continuation call time	M
Ring tone	
Mail ring tone	A
Melody download	A
Incicator	A
Melody ring tone	M
Ring tone total	A

Note M: Must-be quality
O: One-dimensional quality
A: Attractive quality

Figure 2. Tree Diagram and Quality Classification.

Table 2. Initial Conditions of Utility Functions.

		Unit	Worst level	Certainty equivalent	Best level
Price	Purchase price	Yen	31800	15000	1
Function	Voice message	Second	3	12	20
	Voice message time	Numbers	20	50	240
	Schedule	Numbers	1	150	200
	Voice search	Numbers	0	70	100
Fundamental performance	Redial	Numbers	9	20	100
	Call record	Numbers	9	30	100
	Mail inbox	Numbers	50	200	300
	Mail outbox	Numbers	10	30	100
	Mail address	Numbers	0	750	2000
	Memory group	Numbers	10	25	40
	Memory dial	Numbers	500	650	1000
	Charging time	Minute	40	70	110
	Waiting-receptacle-time	Minute	200	350	650
	Continuation call time	Minute	95	115	180
Ring tone	Mail ring tone	Numbers	0	30	50
	Melody download	Numbers	0	20	30
	Indicator	Numbers	0	12	20
	Melody ring tone	Numbers	0	5	20
	Ring tone total	Numbers	5	35	50

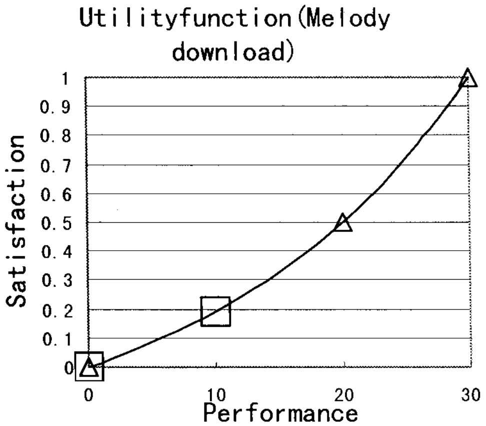


Figure 3. Attractive Quality (Melody download).

$u(x_i) = -0.309\ [1 - \exp\{\ 1.44\ (x_i / 30\ )\}]$

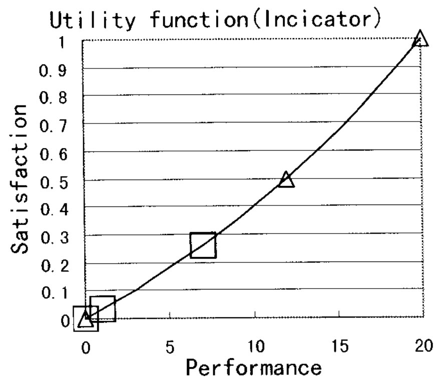


Figure 4. Attractive Quality (Indicator).

$u(x_i) = -0.784\ [1 - \exp\{\ 0.822\ (x_i / 20\ )\}]$

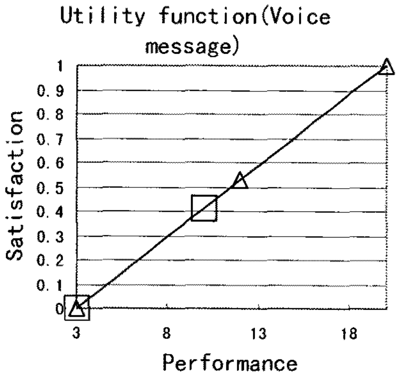


Figure 5. One-dimensional Quality (Voice message).

$$u(x_i) = (x_i - 3)/17$$

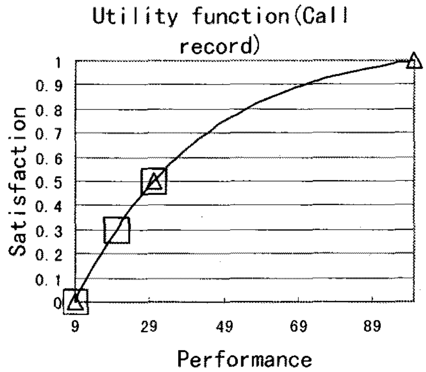


Figure 7. Must-be Quality (Call record).

$$u(x_i) = 1.07[1 - \exp\{-2.73(x_i - 9)/91\}]$$

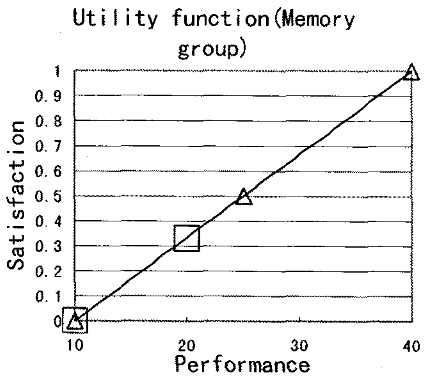


Figure 6. One-dimensional Quality (Memory group).

$$u(x_i) = (x_i - 10)/30$$

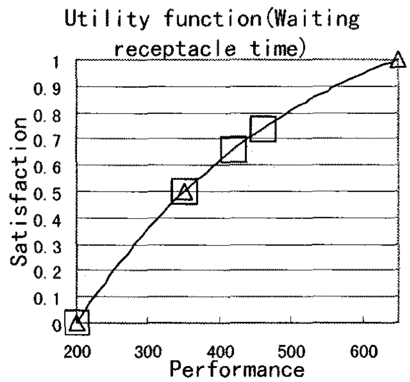


Figure 8. Must-be Quality (Waiting-receptacle-time).

$$u(x_i) = 1.31[1 - \exp\{-1.44(x_i - 200)/450\}]$$

□ present level,

△ estimated worst level, certainty equivalent, and best level.

5. Conclusions

We have proposed a method for quantifying a quality model by associating a utility function with Kano's quality model. The method enables us to quantify a customer utility function corresponding to the degree of sufficiency of a quality element. Further, we can compare the degree of importance of each quality element with corresponding required qualities.

We also applied the method to quality design of a cellular phone, and the results enabled us to judge which quality item is more important.

However, attractive qualities, which are desired in products and services, usually change with the times. Therefore, we recommend that product developers strive to always grasp changes in market needs.

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Appendix: The method of setting the certainty equivalent

Let L be a lottery yielding consequences X_1 and X_2 each with probability 0.5. We call this a 50-50-chance lottery. The certainty equivalent of a 50-50-chance lottery is an amount $\hat{x}$ such that the decision maker is indifferent to L and $\hat{x}$ is certain.

A developer asks a customer some questions.

For example, the following question may be asked about the preference toward the amount of money to be paid for the mail inbox capability of a cellular phone, while showing a respondent questionnaires No. 1 to No. 5 shown in Figure 9, one at a time. "There are two boxes M and L. Box M contains a 100 lottery having a performance value $\hat{x}$, whereas Box L contains a 50-50 lotteries having performance values X_1 and X_2. Please write <, = or > in the blank box to indicate whether you would prefer Box M or Box L, ion consideration of performance." Figure 10 shows an example set of responses.

The certainty equivalent is the answer for which the respondent writes "=." In this example, the certainty equivalent is 200.

	Box M		Box L
No. 1	100		0, 300
No.2	150		0, 300
No.3	200		0, 300
No.4	250		0, 300
No.5	300		0, 300

Figure 9. Question Example.

	Box M		Box L
No. 1	100	<	0, 300
No.2	150	<	0, 300
No.3	200	=	0, 300
No.4	250	>	0, 300
No.5	300	>	0, 300

Figure 10. An example of answers.