How Can a Quantitative Analysis of Kano's Model Be Improved Further?

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Abstract

Kano's model is very effective in classifying different customer requirements into different categories considering their impact on customer satisfaction. Since the analysis of the Kano's model is mostly qualitative, however, S-CR relationship functions were earlier proposed as a quantitative approach, and they were applied to many studies successfully. Although the relationship functions are attractive, they have several limitations. This paper proposes new functions, called S-CR+ relationship functions, to overcome the limitations of the previous relationship functions. The new functions also resolve the contradiction between the traditional definition and graph of Kano attributes. The new and previous relationship functions were compared through two examples to demonstrate the effectiveness of the newly proposed functions. The two examples show that the new functions can successfully be implemented to quantify the relationships between customer satisfaction and CR fulfillment level more accurately.

Keywords: Kano's Model, Kano Categorization, Customer Satisfaction, Customer Requirements, New Product Design, S-CR Relationship Functions, S-CR+ Relationship Functions,

1. Introduction

It is more and more challenging to achieve success in new product development (Sireli *et al*., 2007; Cho *et al*., 2016). Companies attempt to reduce product development time and to enter the market more quickly, considering shortening product life cycles. On the other hand, customers require the quick fulfillment of their needs through customized products. Thus, it is essential for companies to understand customer needs and to reflect such information on product design, to be competitive in the market. Companies should focus on accurate identification of customer needs and the design of customer-tailored products so that faster and more satisfactory solutions can be provided to their target customers.

A variety of approaches have been developed to help companies identify customer needs better (Wang and Ji, 2010). Among others, Kano's model has been widely used for understanding customer needs and their impact on customer satisfaction. Other approaches often assume that linear relationships exist between customer satisfaction and fulfillment of customer requirements (CRs) (Tontini, 2007). However, certain customer requirements provide more satisfaction than others. With the linear assumption, wrong decisions can also be made about which customer requirements should be improved for more customer satisfaction and how much. Kano's model, on the other hand, categorizes customer requirements considering how much they can achieve customer satisfaction. It defines three main types of customer requirements, must-be, one-dimensional, and attractive attributes, with different impacts on customer satisfaction. On top of the three main categories, customer requirements can be further classified into three additional categories: Indifferent, reverse, and questionable.

A problem with the Kano's model is that the model focuses on the classification and qualitative descriptions of various relationships between customer satisfaction and fulfillment of customer requirements (Wang and Ji, 2010). Research on the quantitative analysis of the Kano's model has been limited (Ji *et al*., 2014). In order to overcome this limitation, Wang and Ji (2010) proposed new functions, called S-CR relationship functions, to improve the Kano's model by quantifying the relationships between customer satisfaction and fulfillment of customer requirements (S-CR). Since then, many studies adapted and applied the relationship functions to their problems: Atlason *et al*. (2014), Ji *et al*. (2014), Borgianni and Rotini (2015), Meng *et al*. (2016), Violante and Vezzetti (2017), Liu *et al*. (2018), Atlason *et al*. (2018), to name a few.

Although the relationship functions proposed by Wang and Ji (2010) are intriguing, they also have room for improvement as in any other approach. First of all, their functions deal with three main attributes only, without indifferent attributes. Customers often do not care about indifferent attributes, particularly as they are initially introduced. That, however, does not mean that indifferent attributes are not valuable. They can be innovative by nature. Indifferent attributes may turn into attractive ones in the near future so that they should not be ignored (Kano, 2001; Chaudha *et al*., 2011). Secondly, the proposed relationship functions deviate from the original definitions of quality attributes. As a result, substantial improvement is required to correct the deviations.

This research presents a new approach that refines Kano's model. First of all, a new function is proposed to resolve the contradiction between the traditional Kano definition and graph of indifferent attributes. The previous S-CR relationship functions are also reinforced by the new function for indifferent attributes. Additional new relationship functions are defined to improve the previous S-CR functions between customer satisfaction and fulfillment of customer requirements. The new relationship functions, called S-CR+ relationship functions, can represent quality attributes more precisely by correcting the flaws of the previous S-CR functions considering the definitions of Kano categorization. Through such a quantitative Kano's model, the most valuable alternatives can be selected better (Borgianni and Rotini, 2015). Eventually, the new relationship functions can enhance the understanding of customer requirements for superior product design. This approach can also avoid ignoring potential innovative attributes by dealing with indifferent attributes.

The rest of this paper is organized as follows. Section 2 provides a brief review of Kano's model and S-CR relationship functions of quality attributes. New S-CR+ relationship functions are defined to reinforce and correct the previous S-CR functions in Section 3. Two examples are used to demonstrate the effectiveness of the new approach in Section 4. Conclusions are presented in Section 5.

2. Methods

2.1 Kano's model

Kano's model is very useful in understanding customer requirements and their influence on customer satisfaction (Chaudha *et al*., 2011; Yadav *et al*., 2013). This model classifies customer requirements into three main attributes: Must-be, Attractive, and One-dimensional. Each quality attribute differently affects customers. The three main quality attributes can be defined as follows:

Must-be attributes (M): Their fulfillment does not bring customer satisfaction. When the customer requirements are not fulfilled, however, customers will extremely be dissatisfied.

Attractive attributes (A): In this category, a quality attribute has great impact on customer satisfaction. The fulfillment of an attractive attribute leads to a higher level of customer satisfaction (CS). The absence of the attribute, on the other hand, does not cause customer dissatisfaction (DS), because customers do not expect the attribute in advance.

One-dimensional Attributes (O): The fulfillment of these attributes is positively and linearly related to the level of customer satisfaction. In other words, the higher the level of fulfillment is, the higher the level of customer satisfaction is.

[Figure 1]

On top of the three main attributes, three additional attributes are proposed by the Kano's model: indifferent (I), questionable (Q), and reverse (R). If one attribute is classified into an indifferent attribute (I), customers are not interested in it, whether it is given or not. When a CR is classified into a questionable attribute (Q), it means that the question was not understood well by customers or the question was not prepared correctly. Reverse attributes (R) indicate that customers do not want them and expect their reverse. That is, customers are satisfied, when the attributes are not fulfilled. Among the six attributes, Figure 1 shows four important quality attributes (Borgianni and Rotini, 2015; Lo *et al*., 2017). In Figure 1, the vertical axis represents the level of customer satisfaction, and the horizontal axis denotes the level of fulfillment of a customer requirement (Ji *et al*., 2014).

2.2 Customer satisfaction coefficients

Berger *et al*. (1993) suggested customer satisfaction (CS) coefficients as the numerical values of customer satisfaction and dissatisfaction coming from the fulfillment or unfulfillment of a customer requirement (Chaudha *et al*., 2011). CS coefficients indicate the percentage of customers who expressed satisfaction in case of the existence of a CR and that of customers who expressed dissatisfaction by its unfulfillment (Tontini, 2007). CS coefficients are determined by the following equations:

$$\text{Customer satisfaction index } SI_i = \frac{f_{A,i} + f_{O,i}}{f_{I,i} + f_{A,i} + f_{O,i} + f_{M,i}} \tag{1}$$

$$\text{Customer dissatisfaction index } DI_i = -\frac{f_{O,i} + f_{M,i}}{f_{I,i} + f_{A,i} + f_{O,i} + f_{M,i}} \tag{2}$$

where $f_{I,i}$, $f_{A,i}$, $f_{O,i}$, and $f_{M,i}$ are the number of indifferent, attractive, one-dimensional, and must-be attributes for customer requirement i, respectively. Negative sign '-' in Equation (2) means customer dissatisfaction. The value of each index ranges from 0 to 1 for SI_i and from -1 to 0 for DI_i. The closer the value of SI_i is to 1, the stronger the impact on customer satisfaction is. The closer the value of DI_i is to -1, the higher the influence on customer dissatisfaction is. A value of '0' indicates that there is very little impact on customer satisfaction or dissatisfaction.

2.3 S-CR relationship functions

The quantitative analysis of Kano's model begins with determining customer satisfaction coefficients SI_i and DI_i by Equations (1) and (2). 'The existence of a CR and its unfulfillment' are used to calculate the values of SI_i and DI_i for *CRi* (Ji *et al*., 2014). The level of fulfillment of a CR, however, has a vagueness. As a result, it is difficult to use the values of SI_i and DI_i directly in the quantitative analysis of Kano's model. An alternative is to define points SI_i and DI_i for *CRi* with the following two assumptions:

- If *CRi* is fully fulfilled by a product, the fulfillment level of the *CRi* is 1.
- If *CRi* is fully unfulfilled by a product, the fulfillment level of the *CRi* is 0.

Two points SI_i and DI_i can now be defined by the two assumptions. The point SI_i for CRi, (1, SI_i), indicates the level of customer satisfaction, as *CRi* is fully fulfilled. The point DI_i for CRi, (0, DI_i), means that of customer dissatisfaction, when CRi is fully unfulfilled.

After the two points SI_i and DI_i are defined, the relationship between the levels of customer satisfaction and fulfillment of a customer requirement can be plotted. The vertical axis denotes the degree of customer dissatisfaction or satisfaction ranging from -1 to 1. The horizontal axis represents the fulfillment level of a CR from 0 to 1. Suppose *CRi* is an attractive attribute with two points SI_i and DI_i. Then, the *CRi* can be plotted as an exponential curve that passes the two points SI_i and DI_i. In a similar way, one-dimensional and must-be attributes can also be plotted. The three quality attributes are plotted in Figure 2.

[Figure 2]

Relationship functions can be defined as S-CR functions to approximately show the relationships between the levels of customer satisfaction and fulfilment of CRs by Equation (3):

$$S_i = a_i f(x_i) + b_i \tag{3}$$

where S_i is the level of customer satisfaction brought by CR_i, x_i represents the level of fulfillment of CR_i, and a_i and b_i denote the parameters of the S_i for CR_i.

The relationship for one-dimensional CRs can be quantified uniquely, because there exists only one line crossing any two points. The S-CR function is defined by $S_i = a_i x + b_i$, where a_i

means the slope and b_i indicates the intercept of the linear function. For two points, (1, SI_i) and (0, DI_i), two parameters can be defined as

$$a_i = SI_i - DI_i, \quad b_i = DI_i \tag{4}$$

The relationship function for attractive attributes cannot be defined uniquely by two points only. Therefore, the S-CR function is estimated by exponential function, $S_i = a_i e^x + b_i$, for two points, (1, SI_i) and (0, DI_i), where

$$a_i = (SI_i - DI_i)/(e-1), \quad b_i = -(SI_i - eDI_i)/(e-1) \tag{5}$$

For must-be attributes, the S-CR function is estimated by exponential function, $S_i = a_i(-e^{-x}) + b_i$. For two points, (1, SI_i) and (0, DI_i), two parameters can be defined by

$$a_i = e(SI_i - DI_i)/(e-1), \quad b_i = (eSI_i - DI_i)/(e-1) \tag{6}$$

Table 1 provides the S-CR functions and their parameters for three main attributes.

[Table 1]

2.4 Previous studies that applied the S-CR relationship functions

Ji *et al*. (2014) applied the S-CR relationship functions to the design of notebook computers and integrated the results of Kano's model into Quality Function Deployment (QFD). Atlason *et al*. (2014) adopted the S-CR relationship functions to identify which features were preferred by maintenance engineers at Icelandic power plants. In order to support product and service design better, Borgianni and Rotini (2015) also applied the S-CR relationship functions to three revisited product and service examples: notebooks, websites, and banks.

Meng *et al*. (2016) used the S-CR relationship functions to formalize the relationship between sufficiency of service quality elements and customer satisfaction quantitatively. Violante and Vezzetti (2017) adopted several qualitative and quantitative Kano approaches, including the S-CR relationship functions, to identify the relationships between classification requirements and the approaches. Liu *et at*. (2018) applied the S-CR relationship functions to the selection of important product function attributes for customer collaborative product innovation design. Atlason *et al*. (2018) used the S-CR relationship functions as an effort to help product developers evaluate which functional requirements provide the highest satisfaction for different customer segments.

3. New S-CR+ Relationship Functions

The S-CR functions proposed by Wang and Ji (2010) cover three main Kano categories: must-be, one-dimensional, and attractive attributes. Indifferent attributes, however, are not addressed by the S-CR relationship functions. As a result, all studies that applied the relationship functions excluded indifferent attributes without a persuasive explanation. Indifferent attributes can be very innovative by nature and useful. They may become attractive attributes in the near future so that they should be noted (Kano, 2001; Chaudha *et al*., 2011).

Specifically, indifferent attributes are defined as those that do not contribute to customer satisfaction or dissatisfaction whether they are present or not (Tontini, 2007; Wang, 2013; Violante and Vezzetti, 2017; Song, 2018). Figure 1 revisited plots four important Kano attributes including indifferent attributes (Wang, 2013; Borgianni and Rotini, 2015; Lo *et al*., 2017; Violante and Vezzetti, 2017). It is obvious that the definition of indifferent attributes contradicts the dotted oval for the indifferent attributes in Figure 1. In order to resolve the contradiction between the definition and graph of the indifferent attributes, this research proposes a new relationship function for indifferent attributes.

In addition to the indifferent attributes, it is also obvious that the graph of the other three main quality attributes in Figure 1 contradicts that of the previous S-CR relationship functions in Figure 2. First of all, the graph of the previous S-CR relationship functions is limited to the right two quadrants in Figure 2, while that of the quality attributes in Figure 1 covers all four quadrants. Secondly, must-be attributes do not bring customer satisfaction, and attractive attributes do not cause customer dissatisfaction, by their definitions. However, it is observed that must-be attributes can be bigger than 0, while attractive attributes can be smaller than 0 on the Y-axis of Figure 2. In order to resolve the contradictions between the definitions and S-CR relationship functions of three main quality attributes, this research also defines their new relationship functions.

The new relationship functions starts with calculating new customer satisfaction coefficients SI_i and DI_i by Equations (1) and (2). The new SI_i and DI_i are now denoted as SI_i^* and DI_i^*, respectively, to be distinguished from those in the previous S-CR functions. Two points SI_i^* and DI_i^* for *CRi* are defined with the following two new assumptions:

- If *CRi* is fully fulfilled, its fulfillment level is 1.
- If *CRi* is fully unfulfilled, its fulfillment level is -1.

The two points SI_i^* and DI_i^* can be defined by the two new assumptions. The point SI_i^* for CR*i*, (1, SI_i^*), is the level of customer satisfaction, when *CRi* is fully fulfilled. The point DI_i^* for CR*i*, (-1, DI_i^*), indicates the level of dissatisfaction, as CR*i* is fully unfulfilled.

New relationship functions can now be defined as S-CR+ functions to approximately describe the relationships between the levels of customer satisfaction and fulfilment of customer requirements by Equation (3). The relationship for one-dimensional attributes can uniquely be quantified with two different points. The S-CR+ function for one-dimensional attributes can be defined by $S_i = a_i x + b_i$. For given two points, (1, SI_i^*) and (-1, DI_i^*), two parameters are defined by

$$a_i = (SI_i^* - DI_i^*)/2, \quad b_i = (SI_i^* + DI_i^*)/2 \tag{7}$$

This research also defines the S-CR+ function for indifferent attributes as a linear function. Note that customer satisfaction or dissatisfaction is not affected by indifferent attributes. The S-CR+ function for indifferent attributes is defined as $S_i = a_i x + b_i$, where

$$a_i = 0, \quad b_i = 0 \tag{8}$$

This means that both points $SI_i^*$and DI_i^* are ignored according to the definition of indifferent attributes.

For attractive attributes, the relationship function cannot be defined uniquely by only two points. As a result, the S-CR+ function for attractive attributes is estimated by exponential function, $S_i = a_i e^x + b_i$, for given two points, (1, SI_i^*) and (-1, 0), where

$$a_i = eSI_i^*/(e^2 - 1), \quad b_i = -SI_i^*/(e^2 - 1) \tag{9}$$

Similarly, the S-CR+ function for must-be attributes is estimated by exponential function, $S_i = a_i(-e^{-x}) + b_i$. For given two points, (1, 0) and (-1, DI_i^*), two parameters are defined as

$$a_i = eDI_i^*/(1 - e^2), \quad b_i = DI_i^*/(1 - e^2) \tag{10}$$

Table 2 summarizes the new S-CR+ functions and their parameters for all four important Kano attributes: one-dimensional, indifferent, attractive, and must-be attributes

[Table 2]

The relationship between the levels of customer satisfaction and fulfillment of a CR can be plotted. The vertical axis is the degree of customer satisfaction that ranges from -1 to 1. The horizontal axis denotes the fulfillment level of a customer requirement ranging from -1 to 1. If *CRi* is an attractive attribute, the *CRi* is plotted by an exponential curve passing two points SI_i^* and (-1, 0). When *CRi* is a must-be attribute, the *CRi* is plotted as an exponential curve that connects two points DI_i^* and (1, 0). If *CRi* is an one-dimensional attribute, the *CRi* is plotted by a single line connecting two points SI_i^* and DI_i^*. Finally, when *CRi* is an indifferent attribute, the *CRi* is plotted as a single line that passes two points (1, 0) and (-1, 0). Figure 3 depicts the four important quality attributes.

[Figure 3]

4. Examples

4.1 Notebook example

In order to demonstrate the effectiveness of the proposed S-CR+ relationship functions, an example for the design of notebooks is adopted from Wang and Ji (2010). The primary objective of this example is to investigate the impact of the customer requirements on customer satisfaction for notebook computers by comparing the previous and new relationship functions.

Target customers are university students, a major customer segment of the notebook computer market.

[Tables 3 and 4]

The previous S-CR relationship functions for different customer requirements are identified based on the survey results. Table 3 shows the S-CR relationship functions for this example (Wang and Ji, 2010). The first two columns list the customer requirements for the notebook design and their Kano categories. Points SI_i and DI_i are then calculated for each customer requirement and given in the third and fourth columns. A S-CR relationship function is determined by calculating the values of a_i and b_i for each customer requirement. All the S-CR functions are provided in the last column of Table 3.

Table 4 presents the new S-CR+ relationship functions for the same example. Two points SI_i^* and DI_i^* are determined for each customer requirement and shown in the third and fourth columns. An S-CR+ relationship function is determined by selecting an appropriate equation from Table 2 and calculating the values of a_i and b_i for each CR. All the S-CR+ relationship functions are presented in the last column of Table 4. When Tables 3 and 4 are compared, differences are observed in the following four columns of the two tables: points DI_i and DI_i^*, a_i, b_i, and $S_i = a_i f(x_i) + b_i$.

[Figures 4 and 5]

Another, and probably easier, way to check the differences between the S-CR and S-CR+ relationship functions in Tables 3 and 4 is through Figures 4 and 5. It is obvious that the new S-CR+ functions in Figure 5 reflects the definitions of the Kano's model better than the previous S-CR functions in Figure 4. First of all, the graphs of the previous S-CR functions are limited to the right two quadrants in Figure 4. Secondly, although attractive quality attributes do not cause customer dissatisfaction, Figure 4(a) plots the curves even on the fourth quadrant. Finally, Figure 4(c) shows that the curves are plotted up to the first quadrant, despite the definition of must-be quality attributes that they do not bring customer satisfaction even in their presence.

4.2 Car interior example

A problem with the example of the notebook design is that indifferent attributes were not addressed. Exactly speaking, the survey results of Wang and Ji (2010) included five indifferent attributes, but they were intentionally excluded in the further analysis. In order to show how the proposed S-CR+ relationship functions deal with indifferent quality attributes, an example with car interior design is newly introduced for this research. Target customers are MBA students who mostly drive their own cars.

[Tables 5 and 6]

A Kano classification (Tontini, 2007; Yadav *et al*., 2013) was performed with the survey data. Table 5 shows all customer requirements and their Kano categories: attractive, one-dimensional, and indifferent. Based on the survey results, the S-CR relationship functions for different customer requirements are identified as an effort to reflect the impact of different customer requirements on customer satisfaction for car interior design. Table 5 includes the results of the previous S-CR functions for this example. Two points SI_i and DI_i are determined for each CR as shown in the third and fourth columns. The values of a_i and b_i are calculated to determine a S-CR relationship function for each customer requirement. The last column of Table 5 gives all the S-CR relationship functions.

Table 6 provides the results of the new S-CR+ functions for the same example. Points SI_i^* and DI_i^* are calculated for each CR as given in the third and fourth columns. Each Kano category of Table 6 is used to choose a proper equation from Table 2. A proper equation for CR_i is chosen to obtain the values of a_i and b_i of relationship function $S_i = a_i f(x_i) + b_i$. All new S-CR+ functions were estimated and shown in Table 6. With Tables 5 and 6 compared, differences are also observed in the last four columns of the two tables: points DI_i and DI_i^*, a_i, b_i, and $S_i = a_i f(x_i) + b_i$.

[Figures 6 and 7]

The differences between the S-CR and S-CR+ functions in Tables 5 and 6 can also be noticed through Figures 6 and 7. The new S-CR+ relationship functions in Figure 7 reflects the definitions of the Kano's model better than their previous S-CR functions in Figure 6. The first obvious difference is that the previous S-CR functions cannot deal with indifferent quality attributes. In addition, Figure 6 still shows the first two limitations of the S-CR relationship functions observed in the example of the notebook design.

5. Conclusions

Kano's model is an effective approach to classifying different customer requirements into different categories based on their impact on customer satisfaction (Wang and Ji, 2010). The Kano's model, however, focuses mostly on classification methods and qualitative descriptions of various relationships between customer satisfaction and fulfillment of customer requirements. S-CR relationship functions were earlier proposed to quantify the relationships between customer satisfaction and fulfillment of customer requirements and were successfully applied to many studies. Despite their advantages, the S-CR relationship functions dealt with only three main quality attributes: must-be, attractive, and one-dimensional attributes. Additionally, the S-CR functions deviated from the original definitions of Kano quality attributes from several aspects.

This research proposes new S-CR+ relationship functions as an effort to overcome the limitations of the previous S-CR relationship functions. Two examples are introduced to demonstrate the effectiveness of the proposed S-CR+ functions by comparing them with the previous S-CR functions. The two examples indicate that the proposed S-CR+ functions can successfully be implemented to identify the diverse relationships between customer satisfaction and CR fulfillment more accurately.

Quantitative Kano's models can provide a way to integrate themselves into other mathematical models or methods for optimizing customer-focused product design. The new S-CR+ relationship functions resolve the contradictions involved in traditional Kano definitions and previous S-CR relationship functions, to describe quality attributes more precisely. As a result, the new relationship functions can help understand customer needs in a more accurate way. They can also select the most valuable alternatives better. This approach expands the coverage of the previous S-CR relationship functions by additionally considering indifferent attributes as potentially innovative attributes.

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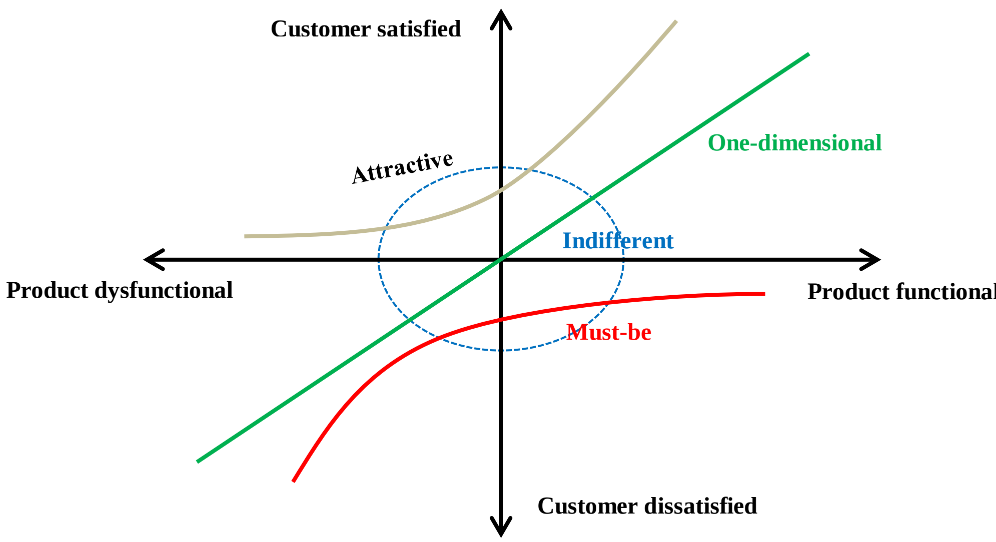


Figure 1. Kano's Model

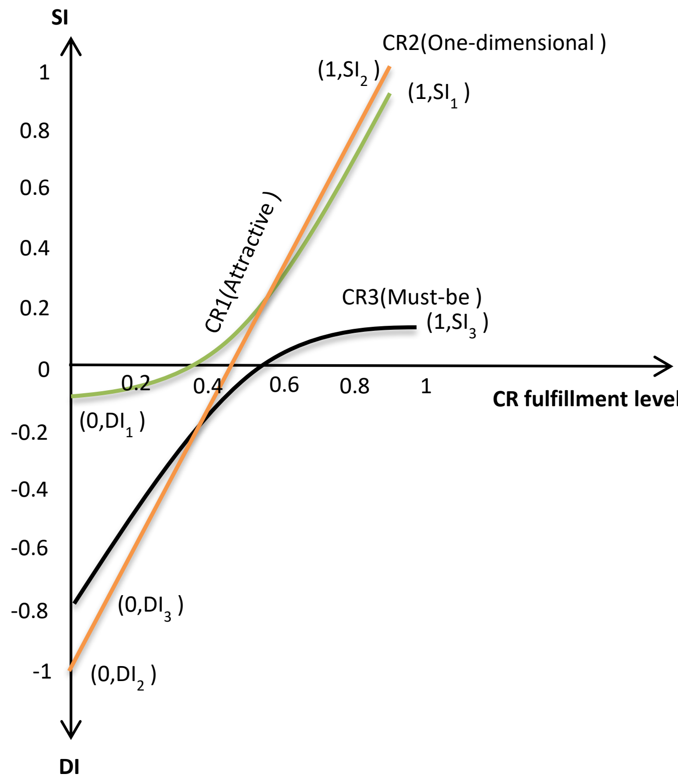


Figure 2. Relationships between Customer Satisfaction and Fulfillment of CRs

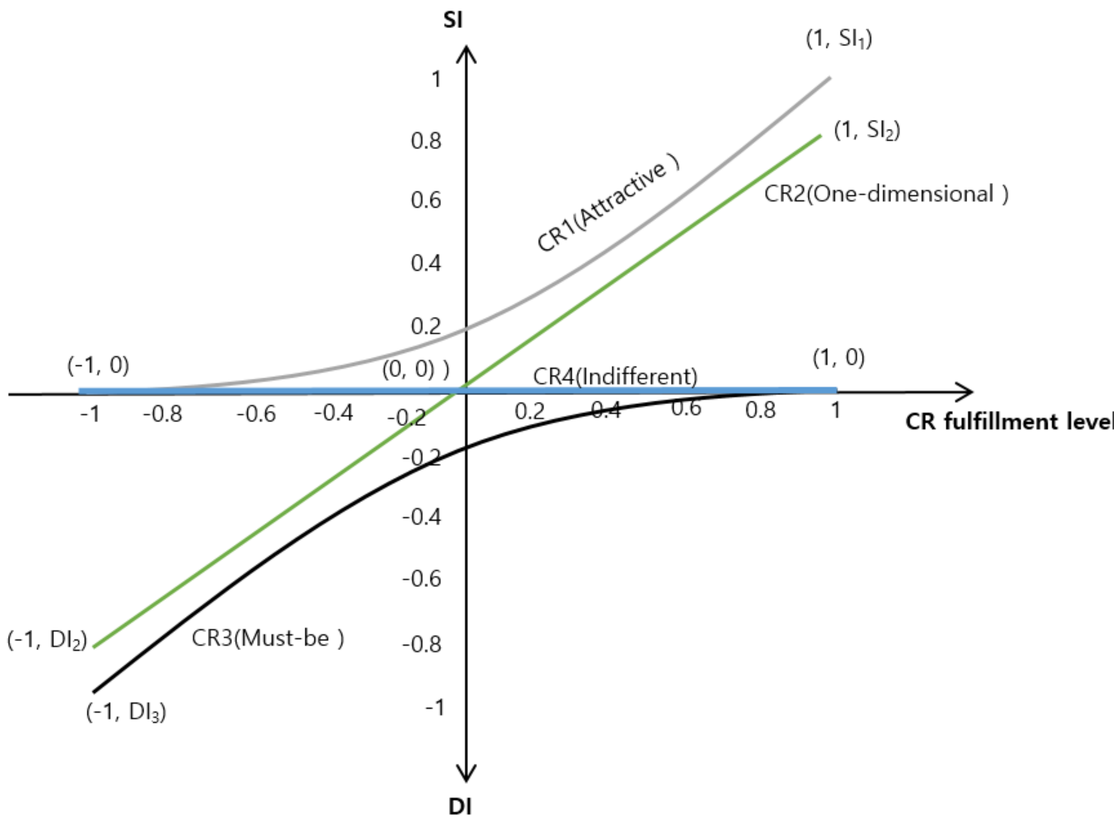
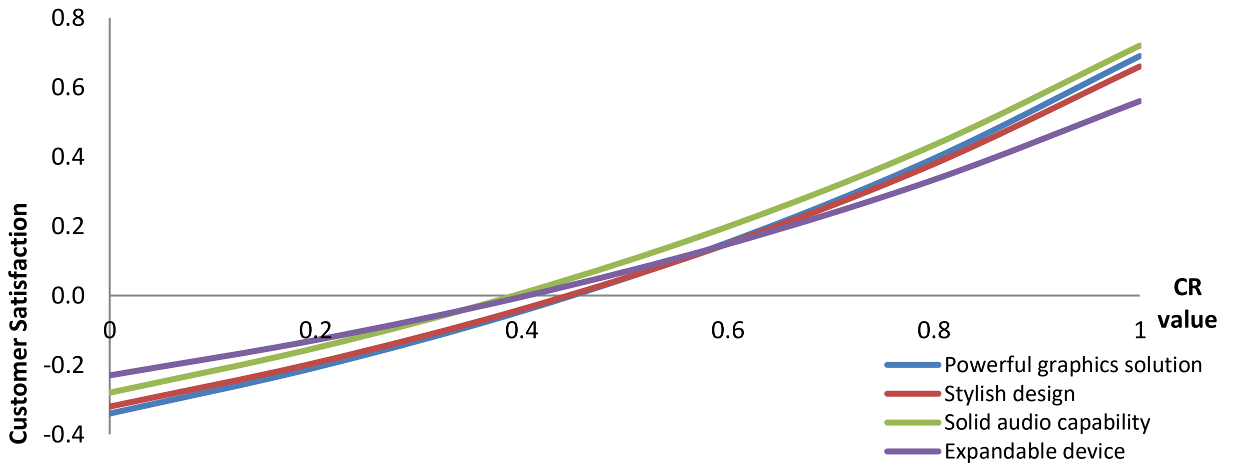
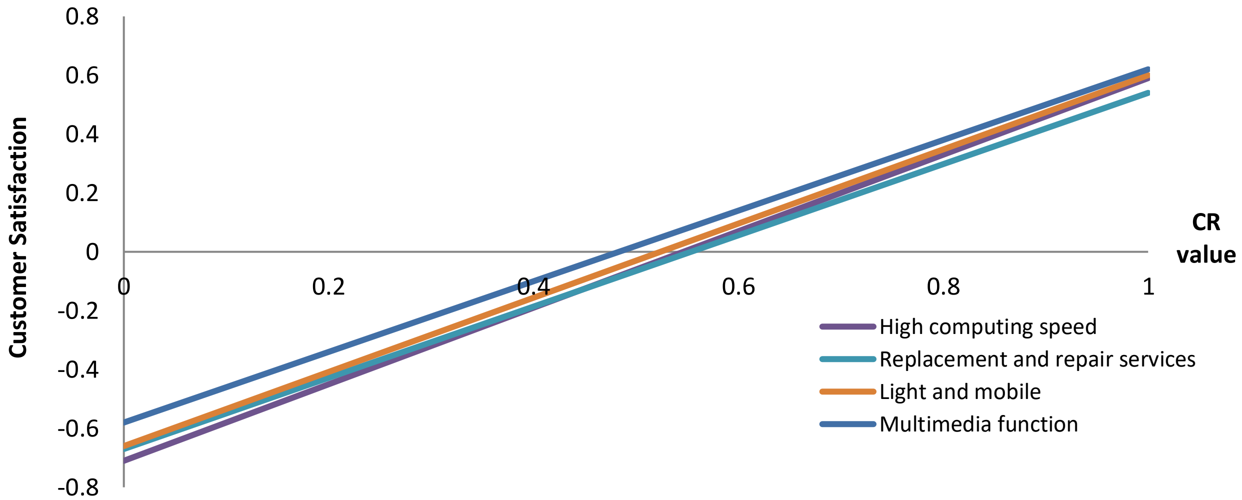


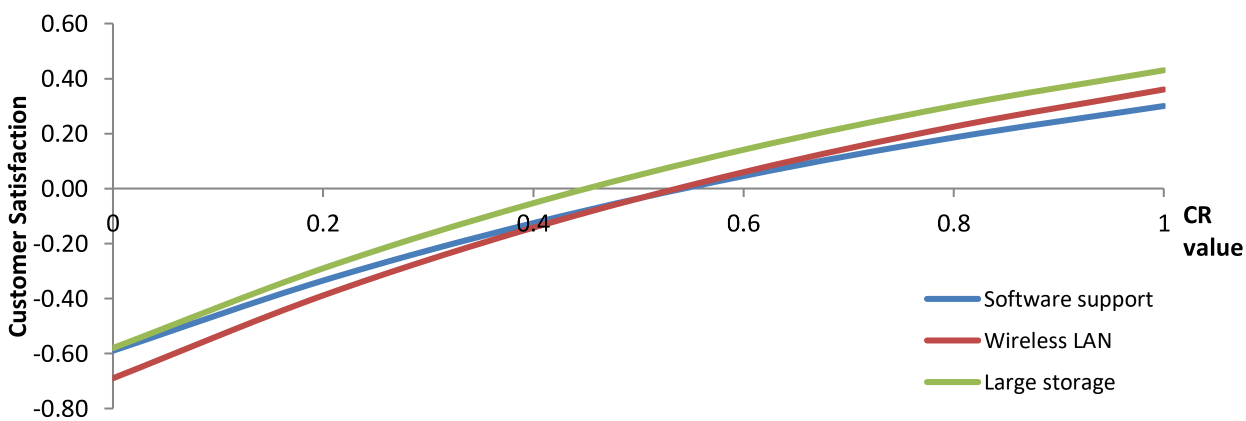
Figure 3. New Relationships between Customer Satisfaction and Fulfillment of CRs



(a) S-CR relationship functions of Attractive CRs

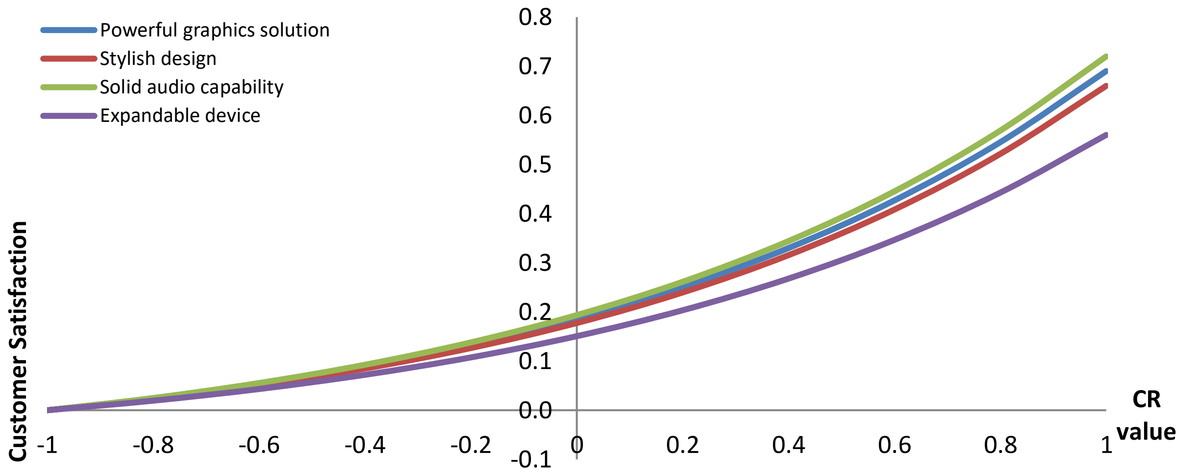


(b) S-CR relationship functions of One-dimensional CRs

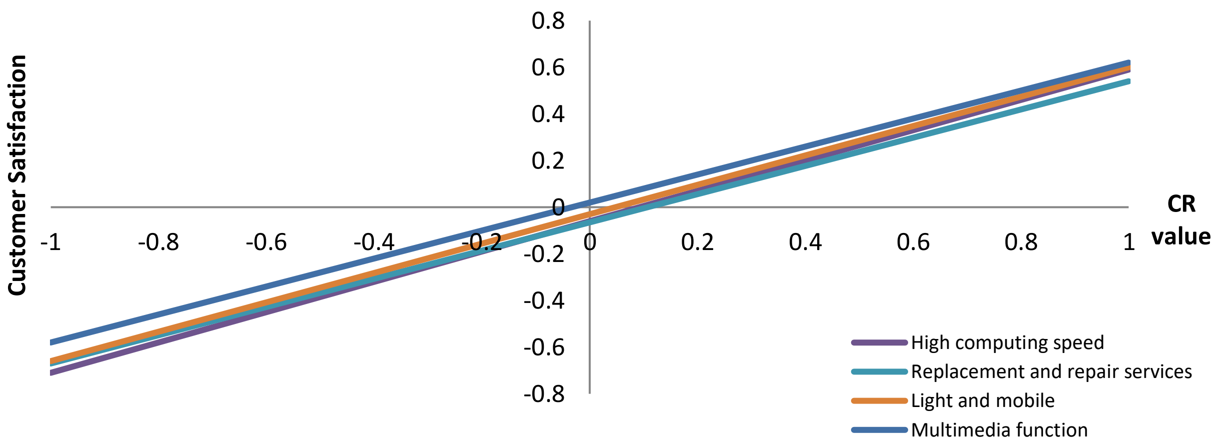


(c) S-CR relationship functions of Must-be CRs

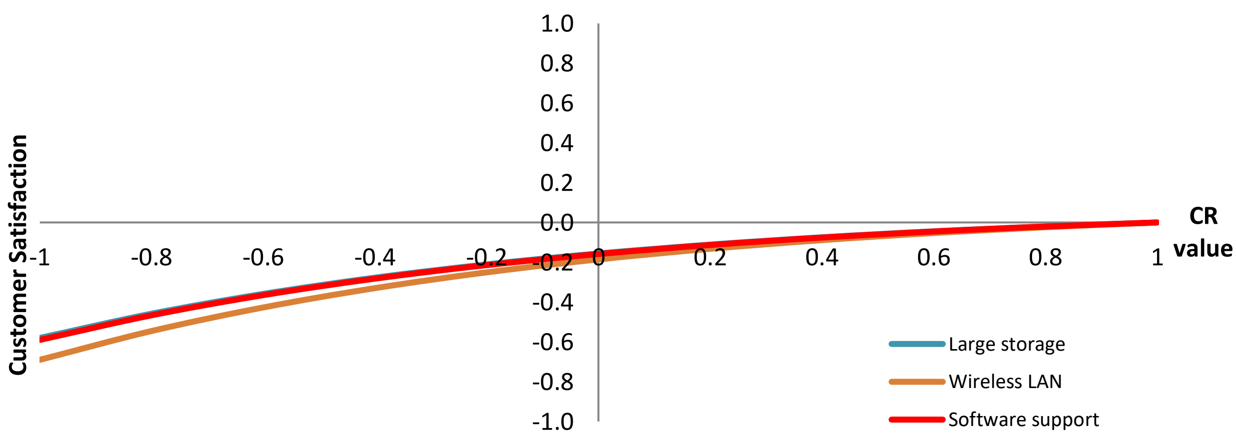
Figure 4. Graphs of S-CR Relationship Functions for Notebook Design



(a) S-CR+ relationship functions of Attractive CRs

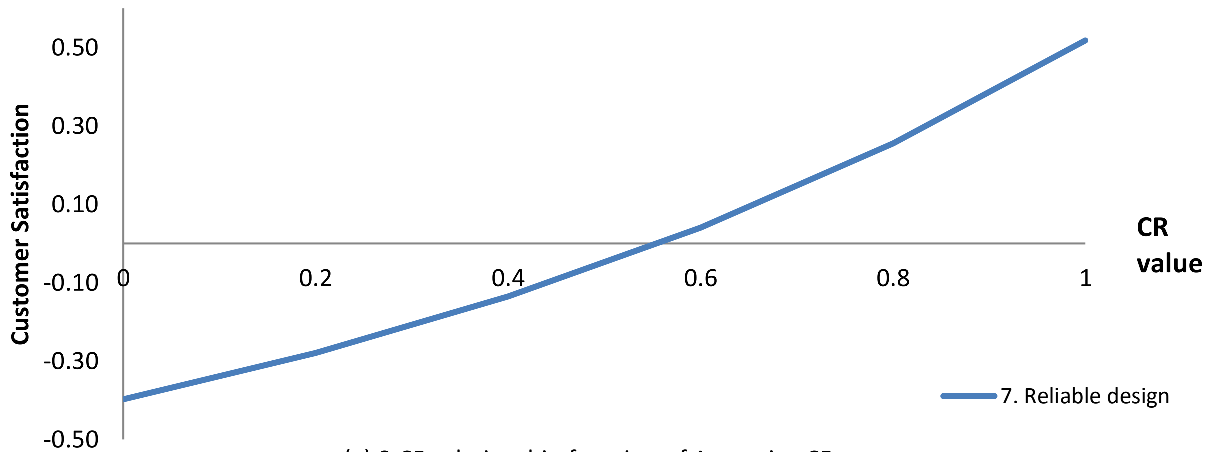


(b) S-CR+ relationshop functions of One-dimensional CRs

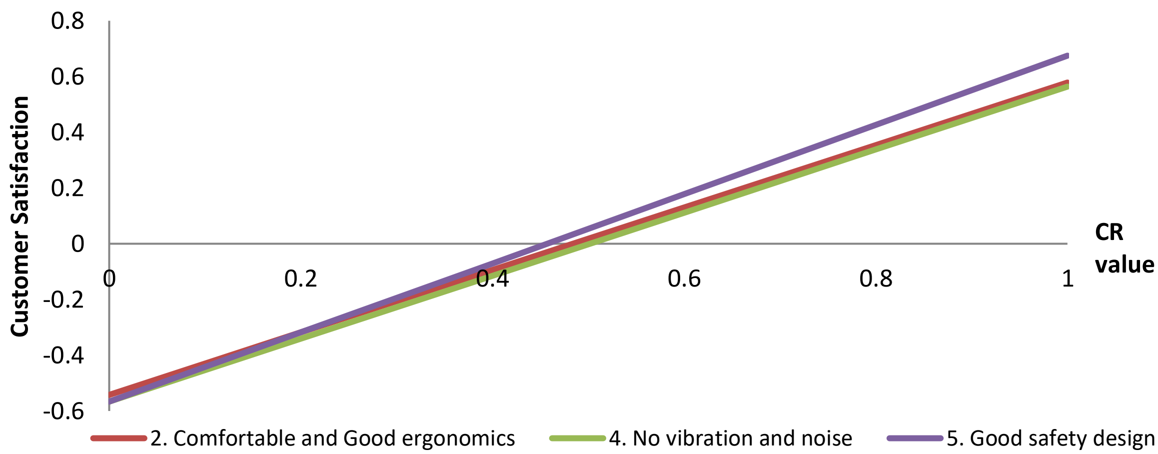


(c) S-CR+ relationship functions of Must-be CRs

Figure 5. Graphs of S-CR+ Relationship Functions for Notebook Design



(a) S-CR relationship function of Attractive CR

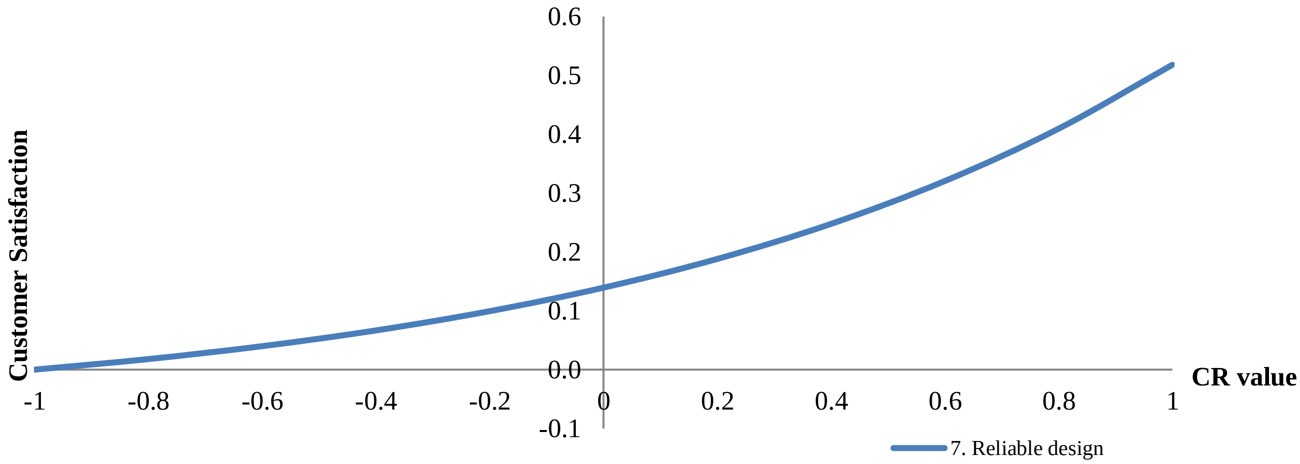


(b) S-CR relationship functions of One-dimensional CRs

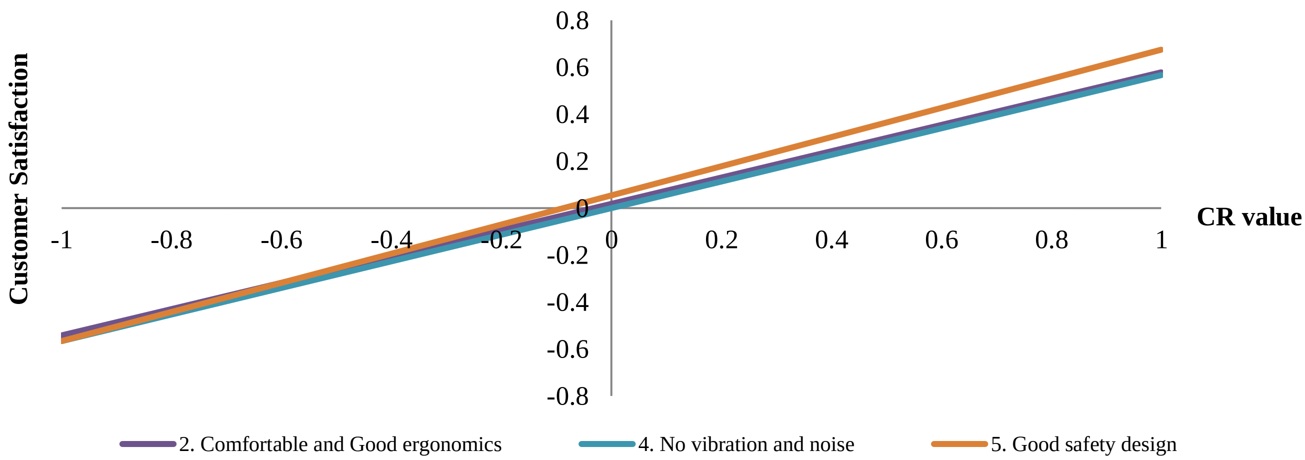
Not Available

(c) S-CR relationship functions of Indifferent CRs

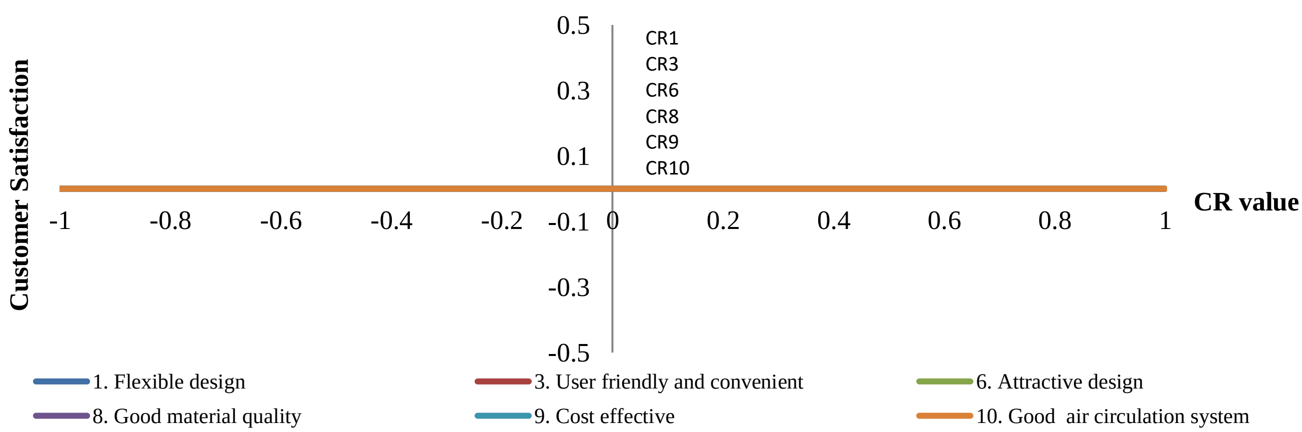
Figure 6. Graphs of S-CR Relationship Functions for Car Interior Design



(a) S-CR+ relationship function of Attractive CR



(b) S-CR+ relationship functions of One-dimensional CRs



(c) S-CR+ relationship functions of Indifferent CRs

Figure 7. Graphs of S-CR+ Relationship Functions for Car Interior Design

Table 1. S-CR Relationship Functions

KC	a_i	b_i	$f(x_i)$	$S_i = a_i f(x_i) + b_i$
O	$\mathrm{SI_i - DI_i}$	$\mathrm{DI_i}$	x	$\mathrm{S_i = (SI_i - DI_i)x + DI_i}$
A	$\frac{\mathrm{SI_i - DI_i}}{\mathrm{e - 1}}$	$-\frac{\mathrm{SI_i - eDI_i}}{\mathrm{e - 1}}$	$\mathrm{e^x}$	$\mathrm{S_i} = \frac{\mathrm{(SI_i - DI_i)}}{\mathrm{e - 1}}\mathrm{e^x} - \frac{\mathrm{SI_i - eDI_i}}{\mathrm{e - 1}}$
M	$\frac{\mathrm{e(SI_i - DI_i)}}{\mathrm{e - 1}}$	$\frac{\mathrm{eSI_i - DI_i}}{\mathrm{e - 1}}$	$\mathrm{-e^{-x}}$	$\mathrm{S_i} = -\frac{\mathrm{e(SI_i - DI_i)}}{\mathrm{e - 1}}\mathrm{e^{-x}} + \frac{\mathrm{eSI_i - DI_i}}{\mathrm{e - 1}}$

Table 2. S-CR+ Relationship Functions

KC	a_i	b_i	$f(x_i)$	$S_i = a_i f(x_i) + b_i$
O	$(SI_i^* - DI_i^*)/2$	$(SI_i^* + DI_i^*)/2$	X	$\mathrm{S_i} = \frac{1}{2}(SI_i^* - DI_i^*)\mathrm{x} + \frac{1}{2}(SI_i^* + DI_i^*)$
I	0	0	X	$\mathrm{S_i} = 0$
A	$\frac{eSI_i^*}{e^2 - 1}$	$-\frac{SI_i^*}{e^2 - 1}$	$\mathrm{e^x}$	$\mathrm{S_i} = \frac{eSI_i^*}{e^2 - 1}\mathrm{e^x} - \frac{SI_i^*}{e^2 - 1}$
M	$\frac{\mathrm{e}DI_i^*}{1 - e^2}$	$\frac{DI_i^*}{1 - e^2}$	$-\mathrm{e^{-x}}$	$\mathrm{S_i} = -\frac{\mathrm{e}DI_i^*}{1 - e^2}\mathrm{e^{-x}} + \frac{DI_i^*}{1 - e^2}$

Table 3. S-CR Relationship Functions for Notebook Design

Customer Requirements	KC	Point SI_i	Point DI_i	a_i	b_i	$S_i = a_i f(x_i) + b_i$
Light and mobile	O	(1, 0.60)	(0, −0.66)	1.26	−0.66	S = 1.26x−0.66
High computing speed	O	(1, 0.59)	(0, −0.71)	1.30	−0.71	S = 1.30x−0.71
Multimedia function	O	(1, 0.62)	(0, −0.58)	1.20	−0.58	S = 1.20x−0.58
Replacement and repair services	O	(1, 0.54)	(0, −0.67)	1.22	−0.67	S = 1.22x−0.67
Stylish design	A	(1, 0.66)	(0, −0.32)	0.57	−0.90	S = 0.57e^x −0.90
Solid audio capability	A	(1, 0.72)	(0, −0.28)	0.59	−0.87	S = 0.59e^x −0.87
Powerful graphics solution	A	(1, 0.69)	(0, −0.34)	0.60	−0.93	S = 0.60e^x −0.93
Expandable device	A	(1, 0.56)	(0, −0.23)	0.46	−0.70	S = 0.46e^x −0.70
Large storage	M	(1, 0.43)	(0, −0.58)	1.59	1.01	S = −1.59e^{-x}+1.01
Wireless LAN	M	(1, 0.36)	(0, −0.69)	1.66	0.97	S = −1.66e^{-x}+0.97
Software support	M	(1, 0.30)	(0, −0.59)	1.40	0.81	S = −1.40e^{-x}+0.81

Table 4. S-CR+ Relationship Functions for Notebook Design

Customer Requirements	KC	Point SI_i^*	Point DI_i^*	a_i	b_i	$S_i = a_i f(x_i) + b_i$
Light and mobile	O	(1, 0.60)	$(-1, -0.66)$	0.63	−0.03	S = 0.63x−0.03
High computing speed	O	(1, 0.59)	$(-1, -0.71)$	0.65	−0.06	S = 0.65x−0.06
Multimedia function	O	(1, 0.62)	$(-1, -0.58)$	0.60	0.02	S = 0.60x+0.02
Replacement and repair services	O	(1, 0.54)	$(-1, -0.67)$	0.605	−0.065	S = 0.605x−0.065
Stylish design	A	(1, 0.66)	$(-1, -0.32)$	0.2808	−0.1033	S = 0.2808e^x −0.1033
Solid audio capability	A	(1, 0.72)	$(-1, -0.28)$	0.3063	−0.1127	S = 0.3063e^x −0.1127
Powerful graphics solution	A	(1, 0.69)	$(-1, -0.34)$	0.2936	−0.1080	S = 0.2936e^x −0.1080
Expandable device	A	(1, 0.56)	$(-1, -0.23)$	0.2383	−0.0876	S = 0.2383e^x −0.0876
Large storage	M	(1, 0.43)	$(-1, -0.58)$	0.2468	0.0908	S = −0.2468e^{-x}+0.0908
Wireless LAN	M	(1, 0.36)	$(-1, -0.69)$	0.2936	0.1080	S = −0.2936e^{-x}+0.1080
Software support	M	(1, 0.30)	$(-1, -0.59)$	0.2510	0.0923	S = −0.2510e^{-x}+0.0923

Table 5. S-CR Relationship Functions for Car Interior Design

Customer Requirements	KC	Point SI_i	Point DI_i	a_i	b_i	$S_i = a_i f(x_i) + b_i$
Flexible design	I	(1, 0.1744)	(0, −0.1860)	N/A	N/A	N/A
Comfortable and Good ergonomics	O	(1, 0.5783)	(0, −0.5422)	1.1205	−0.5422	S=1.1205x−0.5422
User friendly and convenient	I	(1, 0.4524)	(0, −0.3571)	N/A	N/A	N/A
No vibration and noise	O	(1, 0.5663)	(0, −0.5663)	1.1325	−0.5663	S=1.1325x−0.5663
Good safety design	O	(1, 0.6747)	(0, −0.5663)	1.2410	−0.5663	S=1.2410x−0.5663
Attractive design	I	(1, 0.4235)	(0, −0.2000)	N/A	N/A	N/A
Reliable design	A	(1, 0.5181)	(0, −0.3976)	0.5329	−0.9305	S=0.5329e^x −0.9305
Good material quality	I	(1, 0.4048)	(0, −0.2738)	N/A	N/A	N/A
Cost effective	I	(1, 0.3375)	(0, −0.2375)	N/A	N/A	N/A
Good air circulation system	I	(1, 0.4762)	(0, −0.5000)	N/A	N/A	N/A

Table 6. S-CR+ Relationship Functions for Car Interior Design

Customer Requirements	KC	Point SI_i^*	Point DI_i^*	a_i	b_i	$S_i = a_i f(x_i) + b_i$
Flexible design	I	(1, 0.1744)	$(-1, -0.1860)$	0	0	S=0
Comfortable and Good ergonomics	O	(1, 0.5783)	$(-1, -0.5422)$	0.5602	0.0181	S=0.5602x+0.0181
User friendly and convenient	I	(1, 0.4524)	$(-1, -0.3571)$	0	0	S=0
No vibration and noise	O	(1, 0.5663)	$(-1, -0.5663)$	0.5663	0	S=0.5663x
Good safety design	O	(1, 0.6747)	$(-1, -0.5663)$	0.6205	0.0542	S=0.6205x+0.0542
Attractive design	I	(1, 0.4235)	$(-1, -0.2000)$	0	0	S=0
Reliable design	A	(1, 0.5181)	$(-1, -0.3976)$	0.2204	-0.0811	S=0.2204e^x -0.0811
Good material quality	I	(1, 0.4048)	$(-1, -0.2738)$	0	0	S=0
Cost effective	I	(1, 0.3375)	$(-1, -0.2375)$	0	0	S=0
Good air circulation system	I	(1, 0.4762)	$(-1, -0.5000)$	0	0	S=0