

# Quality Engineering for Early Stage of Environmentally Conscious Design

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## Abstract

**Purpose** – This paper proposes application of quality engineering in the early phase of environmentally conscious design (Ecodesign).

**Methodology/approach** – Utilizing Kano Model and willingness to pay, it presents a framework for classification of environmental characteristics of products/services (i.e. offers) in two dimensions. The framework is connected to design management, i.e. design itself and external communication, where strategies for companies are given. The integration of the classification and the strategies is applied to three environmental characteristics against Japanese markets.

**Findings** – The classification framework was proved to be effective as it generates much richer implication than other existing methods. In addition, it works well especially for environmental characteristics. Generation of strategies was also found to work effectively. They suggested some potential of using quality-engineering oriented methods/tools to deal with customer perception in the early phase of Ecodesign.

**Research limitation/implication** – The results imply the needs for research on further utilizing quality-engineering approach and methods in the early stage of Ecodesign. This would be effective as how customers perceive offers has been neglected in the research and practice of Ecodesign and the focus of Ecodesign has been rather in its technical aspects. This research, in a broader sense, exists in integration of marketing and design disciplines.

**Originality/value** – This paper has brought light into the arena where customer aspects in Ecodesign are addressed and has proved some potential for quality-engineering approach and method to tackle the aspects.

**Keywords** – Kano model, design management, offer development, communication to customer, willingness to pay, sustainability.

**Paper type** – Research paper.

## 1. Introduction

Environmental problems such as the global warming problem (IPCC, 2001) and the waste processing problem (OECD, 2001) have been quite serious over a couple of decades. Thus, it is recognized that our society at present is not environmentally sustainable. In fact, companies are required to decrease environmental impacts caused by their products/services while they compete in their markets. To do so, designers/developers play a crucial role; the environmental impacts are determined mainly by design. The activity required for designers in this context is called Ecodesign (environmentally conscious design), which is defined in this paper as “design activity reducing the environmental impacts throughout the life cycle of a product with conforming the market”.

One problem of current Ecodesign (Fiksel, 1996; UNEP, 1997; Karlsson and Luttrupp, 2006; Rahimifard and Clegg, 2007) consists in difficulty to embed competitiveness on products or services just by following current Ecodesign methods as is suggested by (Stevens, 2005). Many of the environmental properties of offers, i.e. products or/and services, which those methods support to be implemented are becoming established as part of regulations or legislations that for manufacturers must comply with. Thus, current Ecodesign methods support manufacturers to satisfy necessary conditions but not sufficient conditions so as to obtain competitiveness in their markets. I.e. they help companies with be *defensive*, but not be *offensive*. In the business world as well, how to raise competitiveness with environmental consciousness is becoming a hot issue, since environmental consciousness could be a killer content (Anonymous, 2007).

To be *offensive* in Ecodesign business, a company should understand what kinds of environmental characteristics contribute to the economy. (Note that an environmental characteristic in this article means the characteristic making meaningful distinction as such to other alternatives from environmental aspects. For instance, consuming less energy by a product and using recycled materials in a service are environmental characteristics.) However, the *defensive* aspect of Ecodesign should not be forgotten: There are quite a few environmental properties that must be implemented according to standards or regulations as described above. Furthermore, it is a fact that there is a *softer* aspect as well that companies have in mind: Even without a hard number, i.e. economic performance, per a product or a service, some companies decide they should fulfil Ecodesign. This may be due to their belief that Ecodesign contribute to establishing their corporate branding. Thus, an integrated view of the *offensive* and *hard*, the *defensive*, and the *softer* issues in relation to environmental characteristics is needed.

This challenge cannot be tackled by addressing only product design. The three issues addressed in the previous two paragraphs lift us to the world of design management, where the parameters to be controlled exist in how to design their offers as well as how to communicate the offer properties to the customers. This research tackles how to manage Ecodesign in a company keeping the three issues in mind. Quality engineering has big potential to do so, as it can address competitiveness of products/services and the perception by customers.

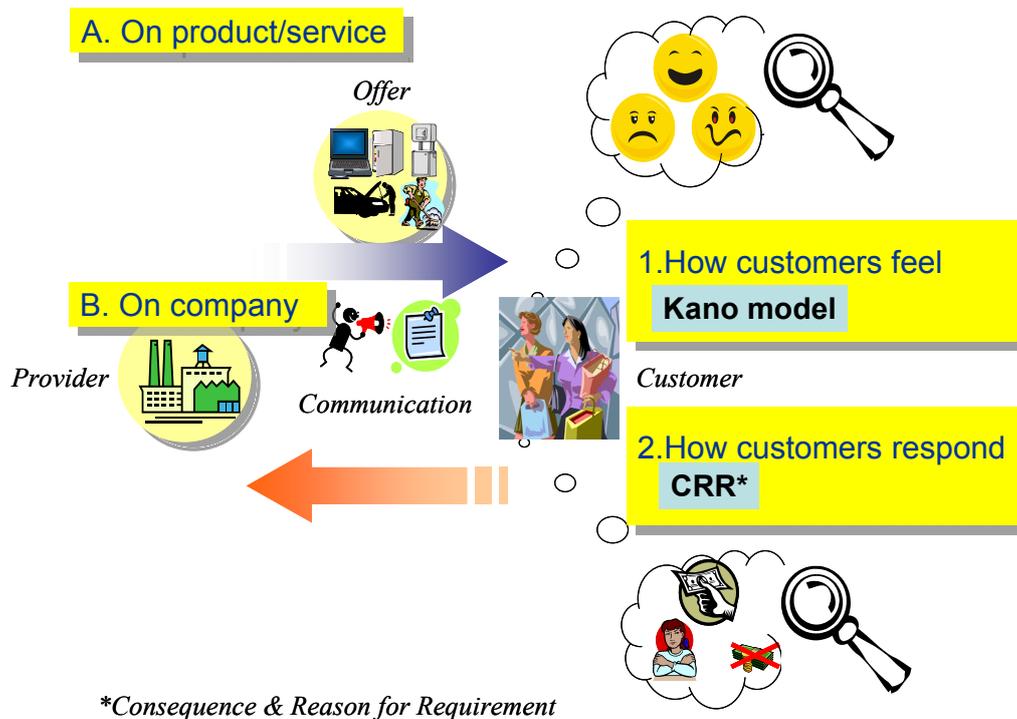
As a first attempt to prove the potential of quality engineering in Ecodesign, this paper proposes a framework for classification of environmental characteristics of offers after (Sakao and Fargnoli, 2006; Sakao, 2008) based on Kano model and willingness to pay. The framework is connected to some design strategies which are also described in this paper. This method, i.e. integration of the classification framework and the design strategies, is applied to three typical environmental characteristics against Japanese markets. The results obtained from the method are discussed for verification. Finally, some future research implications are also presented.

## **2. Framework of classifying environmental characteristics**

### **2.1. Framework**

Figure 1 depicts the overview of the framework. First, this framework introduces simply 1. “how customers feel” and 2. “how customers respond”. The latter here specifically means how their willingness to pay (WtP) is. WtP in this article is represented by the amount of money that customers value and would pay for given environmental characteristics. On the

other hand, it also distinguishes the targets for the customers to feel on or respond to; either the specific offer (product or/and service) or the company providing the offer. In order to obtain the information for each combination of the elements in Figure 1 from each customer in a systematic way, several structured methods are adopted as shown in Table I. Thus, the proposed framework tells to which class a given environmental characteristics for a concerned customer belongs in each of the four types of the customer's activities; feeling on the offer, response to the offer, feeling on the provider, and response to the provider.



**Figure 1. Viewpoints introduced for classifying environmental characteristics**

First, Kano model (Kano, Seraku, *et al.*, 1996), which is widely utilized in case of addressing quality for such a purpose, is adopted so as to obtain how customers feel on a specific offer. This allows us to reveal whether the environmental characteristics belongs to an indifferent, attractive, one-dimensional, must-be, or reverse one (denoted as *I*, *A*, *O*, *M*, and *R*). Additional advantage of utilizing Kano model is the predictability on evolving of the class for a customer towards the future. As suggested in (Miyagawa, 1990) and (Finster, Eagan, *et al.*, 2001), the trend of evolving of the class of a characteristics for a given person is; indifferent → attractive → one-dimensional → must-be. Regarding feeling on the company, Kano model is extended just through changing the targets.

As regards the response, a newly developed method for classifying environmental characteristics called the Consequence & Reason for Requirement (CRR) method is adopted. The CRR method is considered to be a method as it is associated with questionnaire and how to process the answers as shown in Section 2.2. The CRR method first discovers whether the environmental characteristic belongs to any of the following four classes. The first class is *compliance* (*c*) with law or regulation. The second one is termed *need* (*n*) meaning what they pay some money for. The third one called *want* (*w*) is what they want but do not pay any money for. The last is for the rest, being called *indifference* (*i*). The discrimination between the second and the third ones originates from such criticality in Ecodesign as pointed out in

(Sakao and Fargnoli, 2006). In addition, the CRR method reveals the reason why they *need* or *want* the concerned environmental characteristics. This information is crucial for how to communicate the characteristics to the customers.

**Table I. Adopted methods and their classes**

	1.How customers feel	2.How customers respond
A. On offer (product/service)	Kano model: Indifferent, Attractive, One dimensional, Must-be, Reverse	CRR method: Compliance, Need (& Reason), Want (& Reason), Indifference
B. On company	Extended Kano model: Indifferent, Attractive, One dimensional, Must-be, Reverse	CRR method: Compliance, Need (& Reason), Want (& Reason), Indifference

## 2.2. Questionnaire developed to identify the classes within the framework

The questionnaire is designed to grasp the class for the four types of information, and is in more detail described below.

### *Questions for A-1; feeling on the offer*

The same questions as in the original Kano method (Kano, Seraku, *et al.*, 1996) are adopted.

### *Questions for B-1; feeling on the provider*

The difference with the questions in the original Kano method is the target which customers feel on. The target is the company who provides the offer. One of the two questions is:

How do you feel on the company if the company provides a product (has a product line) with the concerned environmental characteristics?

### *Questions for A-2; response to the offer*

The questions are designed so that they capture the needed information as precisely as possible. Thus, they assume a buying situation where customers compare two offers. The format of the questions is:

- i) Which offer do you purchase, a or b? Offer a has the concerned environmental characteristics while offer b does not. Choose one from the followings.
  - 1)purchase offer a, if its price is higher than that of offer b but the difference can be accepted.
  - 2)purchase offer a, if its price is equivalent to that of offer b.
  - 3)purchase the offer with a lower price.
  - 4)purchase offer b, if its price is equivalent to that of offer a.
  - 5)purchase offer b, if its price is higher than that of offer a but the difference can be accepted.
  - 6)others.
- ii) What is the reason for i)? Choose one from the followings.
  - 1)it contributes to solve the environmental problems.
  - 2)it is beneficial for me.
  - 3)others.

Answering 1), 2) and 3) to the question i) is understood so that the answerers consider the characteristics to be *need*, *want*, and *indifference*, respectively. Answering 4) and 5) to the question i) means that the characteristics influences the answerers negatively. Answering 1) and 2) to the question ii) shows that the reasons of the answerers are environmental and non-environmental, respectively.

### *Questions for B-2; response to the provider*

The difference with the questions for A-2 is the target customers feel on. The target is the company who provides the offer.

### 3. Design-management strategies

This section briefly discusses the newly introduced strategies taken by a company according to the classification regarding the perception of an offer. The strategies are intended for both development and communication within a company as proposed in (Sakata and Suzuki, 2007). Therefore, these strategies are beneficial for design management, rather than product-design strategies in a narrow sense. Table II shows some orthodox strategies depending on the Kano classes, whilst Table III presents strategies according to the CRR classes. It should be noted that this paper focuses more on development issues rather than communication as well as the offer rather than the company as a whole. Thus, this section discusses strategies only on an offer with focus on development.

For instance, a must-be characteristics, as shown in Table II, should be implemented, while it should not be appealed to be efficient in communication since customers take its implementation for granted. Table III shows that the development team should deal with a *need* depending on its importance to the customers and its cost. On the other hand, a *want* should be incorporated and treated only when no critical impacts are available.

**Table II. Strategies suggested from the Kano classes**

Kano class	Development	External Communication
Attractive	Implement depending on importance & cost.	Do appeal if implemented.
One-dimensional	Enhance depending on importance & cost.	Appeal quantitatively.
Must-be	Do implement.	Do not appeal.
Indifferent	Do not implement.	With contents in causes/effects or metaphor if wanted.

**Table III. Strategies suggested from the CRR classes**

CRR class		Development	External Communication	
Compliance		Implement.	Communicate only the compliance in case of customers' attention.	
Need	Non-env.	Implement/enhance depending on importance & cost.	In language of receivers' benefits.	High priority
	Env.		In language of environment's benefits.	
Want	Non-env.	Implement/enhance only with no critical impact on costs, etc.	In language of receivers' benefits.	Low priority
	Env.		In language of environment's benefits.	
Indifferent		Do not implement.	With contents in causes/effects or metaphor if wanted.	

### 4. Application of the classification

The classification has been applied to three typical environmental characteristics on Japanese markets. The questionnaire was fulfilled in August 2007 against 1,000 persons living in Japan. They consist of 10 groups each of which is composed of 100 persons who are characterized by the age, gender, and occupation. The three environmental characteristics are as follows.

1. energy-saving performance in a refrigerator
2. adoption of hybrid engine in an automobile
3. adoption of plant-based plastics in a chassis of a notebook-typed PC (personal computer)

It should be noted that explanation for each environmental characteristics was given to the answerers such as what a hybrid engine is. It was also pointed out that the strength of the concerned plant-based plastics of the PC is equivalent to that of other types of plastics normally used in a PC.

**Table IV. Percentage of answerers on the offer: Businessmen (males) over 50 years old**

1. energy-saving performance

Kano WtP	<i>I</i>	<i>A</i>	<i>O</i>	<i>M</i>	<i>tl.</i>
<i>n</i>	5	2	9	14	30
<i>w</i>	20	16	12	9	57
<i>i</i>	6	0	0	0	6
<i>tl.</i>	31	18	21	23	

2. hybrid engine

Kano WtP	<i>I</i>	<i>A</i>	<i>O</i>	<i>M</i>	<i>tl.</i>
<i>n</i>	4	15	9	5	33
<i>w</i>	17	25	4	3	49
<i>i</i>	6	0	0	0	6
<i>tl.</i>	27	40	13	8	

3. plant-based plastics

Kano WtP	<i>I</i>	<i>A</i>	<i>O</i>	<i>M</i>	<i>tl.</i>
<i>n</i>	3	3	5	3	14
<i>w</i>	26	22	4	7	59
<i>i</i>	18	0	0	0	18
<i>tl.</i>	47	25	9	10	

Notes for Tables IV to VII:

“tl.” means total.

Unit; percentage

Legend;

The largest share	The second largest	The third largest
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**Table V. Percentage of answers on the offer: Housewives over 50 years old**

1. energy-saving performance

Kano WtP	<i>I</i>	<i>A</i>	<i>O</i>	<i>M</i>	<i>tl.</i>
<i>n</i>	7	7	21	8	43
<i>w</i>	16	14	10	6	46
<i>i</i>	4	0	0	0	4
<i>tl.</i>	27	21	31	14	

2. hybrid engine

Kano WtP	<i>I</i>	<i>A</i>	<i>O</i>	<i>M</i>	<i>tl.</i>
<i>n</i>	7	12	15	3	37
<i>w</i>	19	22	1	9	51
<i>i</i>	4	0	0	0	4
<i>tl.</i>	30	34	16	12	

3. plant-based plastics

Kano WtP	<i>I</i>	<i>A</i>	<i>O</i>	<i>M</i>	<i>tl.</i>
<i>n</i>	5	5	6	4	20
<i>w</i>	21	27	9	4	61
<i>i</i>	8	0	0	1	9
<i>tl.</i>	34	32	15	9	

**Table VI. Percentage of answerers on the provider: Businessmen (males) over 50 years old**

1. energy-saving performance

Kano WtP	<i>I</i>	<i>A</i>	<i>O</i>	<i>M</i>	<i>tl.</i>
<i>n</i>	1	4	3	1	9
<i>w</i>	13	11	10	16	50
<i>i</i>	15	0	0	10	25
<i>tl.</i>	29	15	13	27	

2. hybrid engine

Kano WtP	<i>I</i>	<i>A</i>	<i>O</i>	<i>M</i>	<i>tl.</i>
<i>n</i>	1	5	7	1	14
<i>w</i>	13	15	8	10	46
<i>i</i>	17	0	1	2	20
<i>tl.</i>	31	20	16	13	

3. plant-based plastics

Kano WtP	<i>I</i>	<i>A</i>	<i>O</i>	<i>M</i>	<i>tl.</i>
<i>n</i>	1	4	3	1	9
<i>w</i>	14	16	4	13	47
<i>i</i>	25	0	0	2	27
<i>tl.</i>	40	20	7	16	

**Table VII. Percentage of answers on the provider: Housewives over 50 years old**

1. energy-saving performance

Kano WtP	<i>I</i>	<i>A</i>	<i>O</i>	<i>M</i>	<i>tl.</i>
<i>n</i>	4	3	7	5	19
<i>w</i>	8	18	22	14	62
<i>i</i>	6	0	2	2	10
<i>tl.</i>	18	21	31	21	

2. hybrid engine

Kano WtP	<i>I</i>	<i>A</i>	<i>O</i>	<i>M</i>	<i>tl.</i>
<i>n</i>	4	4	7	6	21
<i>w</i>	10	24	15	10	59
<i>i</i>	6	0	2	1	9
<i>tl.</i>	20	28	24	17	

3. plant-based plastics

Kano WtP	<i>I</i>	<i>A</i>	<i>O</i>	<i>M</i>	<i>tl.</i>
<i>n</i>	3	7	5	2	17
<i>w</i>	9	26	13	12	60
<i>i</i>	12	0	1	0	13
<i>tl.</i>	24	33	19	14	

Tables IV and V show a part of the results of the questions A-1 and A-2; the former table from businessmen and the latter from housewives of the same age range (over 50 years old). The part of reason in CRR is omitted so that only the WtP information is shown from the results of CRR. It is relatively clearly shown in Table IV (3.) that adoption of plant-based plastics in a chassis of a notebook-typed PC for the group is indifferent (*I*, 47%) and it is need (*n*, 14%) for a small portion. The hybrid engine is attractive (*A*) for the majority either in the

men (40%) and the women (34%) (see Table IV (2.) and Table V (2.), respectively). Over 30 % find positive WtP on the hybrid engine, i.e. regard the hybrid engine as need (*n*), either in the men (33%) and the women (37%). The energy-saving performance is one-dimensional need (*On*) for the most (21%) in the women (see Table V (1.)).

From Tables IV and V as a whole, it may be interpreted commonly for the two groups that energy-saving performance, hybrid engine, and plant-based plastics in this order are regarded as characteristics more of *M* side as opposed to *I*. This is in line with the maturity of the characteristics on the markets. Regarding the WtP, there is distinction between the plant-based plastics and the rest: Relatively fewer people have positive WtP on the plant-based plastics.

Tables VI and VII show the results of the questions B-1 and B-2 in the same format as Tables IV and V. From Tables VI and VII as a total, the same interpretation as from Tables IV and V, i.e. from the offer, holds true that energy-saving performance, hybrid engine, and plant-based plastics in this order are regarded as characteristics more of *M* side commonly for the two groups. Regarding the WtP, there is no distinction among the three characteristics either for men or for women, except for the hybrid engine for the men. This may be caused by bias from an easy link between a hybrid engine and Toyota. This implies that the positive effect on a corporate branding in terms of WtP is independent of the concerned characteristics and the product, but depends on the concerned customer group. The independence is quite reasonable since the payment is not intended for the offer with the characteristics, but for the offer without the characteristics provided by the company.

## 5. Discussions

### 5.1. Validity of the classification

As demonstrated in Section 4, the classification was proved to be effective because, first of all, it generates much richer implication than other existing methods. This reveals both the quantity and the quality of the importance on characteristics. It is evident, for instance, if compared to quantitative weighting (scoring) of the importance on characteristics, which is a most-widely adopted method. In the field of Ecodesign method, Bovea and Wang have addressed WtP (Bovea and Wang, 2007), however they fail to handle the quality part. Conjoint analysis (Green and Srinivasan, 1978) is helpful to grasp the WtP, however it cannot discriminate clearly between *need* and *want*. The proposed classification method is powerful especially for environmental characteristics, since it gets hold of *want* whose share is high for environmental characteristics in general. It should be noted that environmental characteristics are wanted for many people but are not worthwhile to pay for as revealed in Section 4. On the other hand, Kano model is among the few methods that can reveal the quality of the importance. However, Kano model has a disadvantage that it shows no information on the consequence of the customers, i.e. whether they will pay some money or not. Thus, the CRR method compensates for it.

From the questionnaire results, it has been found that no class is dominant throughout the different characteristics while considerable difference exists among the different characteristics. This means that the method can work as a good indicator.

At the same time, it must be pointed out that the Indifferent (*I*) of Kano has much higher percentage than the indifference (*i*) of CRR in every characteristic as shown in Tables IV and V when asked regarding an offer. This is considered to be influence of how the questions were described. The biggest difference between Kano and CRR is existence of an offer to be compared with: The question of Kano asks only on the concerned offer, whilst that of CRR

asks with comparison to another offer. Since the latter imposes answerers severer decision, it is more likely to catch fewer people with indifference.

## 5.2. Validity of integration with the strategies

The proposed set of strategies in conjunction to the classification generates the followings. In case of energy-saving performance in a refrigerator for housewives over 50 years old, for instance, the development strategy is to enhance depending on importance and cost whilst the communication one is to appeal quantitatively. On the other hand, plant-based plastics in a chassis of a notebook-typed PC for businessmen over 50 years old cannot be recommended to be adopted within the development team. Thus, these were also found to work effectively. However, it should be emphasized that those strategies are quite orthodox and are focusing only on a specific offer. A company can make a different decision rationally: For instance, a notebook-PC provider can reasonably adopt plant-based plastics in the chassis for those businessmen by focusing on the specific segment with the *need* (14%; see Table IV (3.)) in the group. The company could also remark the positive effect on its corporate branding (9% of the group find positive WtP on a PC offered by the company even without such environmental characteristics; see Table VI (3.)).

## 5.3. Representation of the results from the questionnaire

Figure 2 shows a chart developed to represent the results from the questions A-1 and A-2 (and B-1 and B-2) given an environmental characteristics on a certain group of people. For simplification, the *reverse* of Kano model and the *compliance* of CRR are omitted. This makes twelve combinations from the four classes of Kano model and the three classes of CRR (as shown in Tables IV to VII), each of which has a share of people. In Figure 2, the four classes of Kano model are placed from the first to the fourth quadrant according to the evolving order explained in Section 2.1. The three CRR classes are located from the centre to the outer skirt according to the order; *indifference*, *want*, and *need*. The size of each blob represents that of its share.

Though not the major issue of the paper, this image is quite helpful for a company to manage their design in a middle or long term as well. One of the thick arrows shows the generally acknowledged evolving of the Kano classes, while the other horizontal one may be wished by the company considering the money to be earned. For instance, a segment belonging to “*On*” (One-dimensional need) is more likely to arrive at “*Mn*” (Must-be need) later in the future. In addition, a company in some cases wishes the shift of the segment belonging to “*Aw*” (Attractive want) to “*An*” (Attractive need). Thus, a product-development team may visually have in mind a big blob in the first quadrant (*I*) which will move unclockwisely to the second quadrant (*A*) in the future, so that they hesitate less to implement the concerned characteristics. In addition, a marketing section may communicate to customers to attempt to push out a big blob on the *want* circle to the *need*.

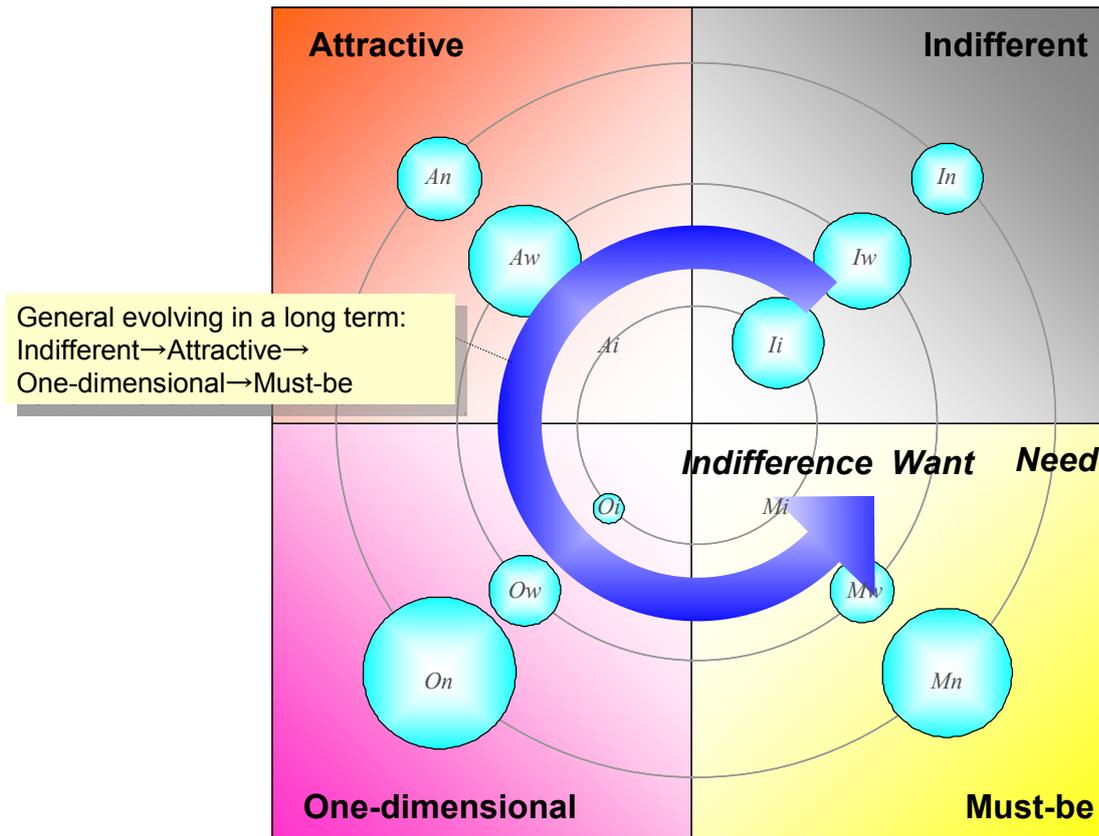


Figure 2. Representation of a group of customers' feeling and response

#### 5.4. Implication for Quality Engineering

The discussion so far in Section 5 showed some potential of using quality-engineering oriented methods/tools to deal with customer perception in the early phase of Ecodesign. Successful utilization of Kano model in Ecodesign has been reported in another literature (Finster, Eagan, *et al.*, 2001). However, there remain very few attempts to do so. On the other hand, in practice of Ecodesign, addressing customer perception is indeed an important issue as shown in some existing literature: For instance, Meyer showed the importance of such issues in apparel industry (Meyer, 2001). In addition, Stevels pointed out relative unsuccessfulness of green marketing strategies in consumer-electronics industry and showed some examples of categorizing consumers from the viewpoint of their environmental consciousness (Stevels, 2000). Namely, high demand to address customer perception is found in this field.

It should be noted that some methods/tools from the field of quality engineering have been successfully developed to be applied to later stages of Ecodesign: For example, there are quite a few QFD-based methods incorporating environmental aspects (Cristofari, Deshmukh, *et al.*, 1996; Zhang, Wang, *et al.*, 1999; Masui, Sakao, *et al.*, 2003; Sakao, 2007).

Thus, the current Ecodesign methods (Fiksel, 1996; UNEP, 1997; Karlsson and Luttrupp, 2006; Rahimifard and Clegg, 2007) fail to incorporate quality issues in a systematized and holistic manner. In other words, there is still a gap between demand for methods/tools from practice and supply from theories in the early phase of Ecodesign. Big potential of contribution from quality engineering should be found to fill in the gap. Otherwise, for

instance, mis-specification of ecodesigned offers would remain in our world, although this is pointed out more than a decade ago (Wong, Turner, *et al.*, 1996).

## 6. Conclusion and future research implication

This paper first proposed to adopt a quality-engineering approach to Ecodesign. Then, a framework of classifying characteristics upon incorporating environmental consciousness in an early stage of design is presented. To do so, two viewpoints were addressed; offer value and corporate value. In addition, Kano model and CRR were adopted for representing how customers feel and respond, respectively. Furthermore, several design strategies depending on the classes were presented. This classification method was shown to work effectively to classify the environmental characteristics according to the results from the Japanese market. If applied together with the design strategies, this method is a powerful tool for the company who carries out environmental-offer planning.

Future works include to investigate possibilities for other methods/tools in quality engineering to be applied to Ecodesign. In parallel, the method will be applied to real offer-planning in industry. The author's research group has begun the application in housing industry in Japan, where environmental consciousness is nowadays among the key issues for their business partially due to the considerable amount of environmental impacts originating of houses.

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