Preliminary Study on Kano Model in the Conceptual Design Activities for Product Lifecycle Improvement

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Abstract. Product manufactured with short life cycle had only one major issue, it can lead to increasing volume of waste. Day by day, this untreated waste had consumed many landfill spaces, waiting for any possible alternatives. Lack of product recovery knowledge and recyclability features imprinted into product design are one of the main reason behind all this. Sustainable awareness aspect should not just be implied into people’s mind, but also onto product design. This paper presents a preliminary study on Kano model method in the conceptual design activities to improve product lifecycle. Kano model is a survey-type method, used to analyze and distinguished product qualities or features, also how the customers may have perceived them. Three important attributes of Kano model are performance, attractive and must-be. The proposed approach enables better understanding of customer requirements while providing a way for Kano model to be integrated into engineering design to improve product’s end-of-life. Further works will be continued to provide a better lifecycle option (increase percentage of reuse, remanufacture or recycle, whereby decrease percentage of waste) of a product using Kano model approach.

1. Introduction

Traditionally, products are made based on simple open-loop system. It started with raw materials, proceed into manufacturing process, and lastly into the user’s hand. The cycle is considered complete once it reached the users or customers. Manufacturers have no responsibility or whatsoever over products once it reaches end-of-life cycle. Over time, this open-loop manufacturing system had lead to one major problem, decreasing availability of landfill disposal space. This matter had made concern by some committee, for example Waste Electrical and Electronic Equipment (WEEE) Directive in Europe and Japanese Specified Home Appliances Recycling Law (SHARL) to overcome this serious problem [1]. A solution is being drawn to overcome such matter. They are forced to authorize product take-back initiative and recycling legislation all over the country. The law enforces manufacturers to implement closed-loop system into their manufacturing process, while considering technical and economical implications of possible disposal alternatives. The alternatives included six sustainability awareness aspects, reduce, recover, reuse, recycle, redesign, and remanufacturing [2]. It is possible to implement this system for most product available in market nowadays, with several highlighted advantages. First, the system offer reduction in environmental impact over lifecycle of a product.
Secondly, the cost for compliance with this law can be lowered, while increasing product sales to green customers. Green customer includes those who purchasing green products or products made from manufacturer which associated with green image.

Product end-of-life is a stage in lifecycle which currently gaining interest in market worldwide. Companies and manufactures are pouring every available resource into understanding how to improve and lower environmental impact of their product end-of-life. All this must be achieve without sacrificing any profits and still being economically feasible. Therefore the concepts of closed-loop manufacturing system must be forcefully promoted in design process to save our landfill disposal sites in the future. Resources recovery and recycling must be further implied into product design to minimize waste reduction.

Products are being manufacture continuously every day [3]. Once these products reach it end-of-life cycle, most of them will end up in disposal, rather than being recycled or even remanufacture. In addition, CalRecycle [3] has found that around 73 million tons of material wastes are generated in California during the year 2010. Among this, estimated of 37 million tons went directly into landfills, while the rest are being recycled. At this rate, we might end up with large quantity of disposal wastes in the future and have no idea how to deal with it. The best scenario for the product is either being reuse, recycle, or even remanufacture, which will be much more beneficial option for the user rather than disposal. Lack of product recovery knowledge and recyclability features lead to increasing value of wastes. Sustainable awareness aspect should be implied into product design, reducing percentages of disposal and materials wastes. Due to those reasons, this paper presents a preliminary study on Kano model method in the conceptual design activities to improve product lifecycle where Kano model is a survey-type method, used to analyze and distinguished product qualities or features, also how the customers may have perceived them. Three important attributes of Kano model are performance, attractive and must-be. In this study, Kano model approaches will help in deciding which product suitable for sustainable improvement and how to achieve it. The impact analysis of this recovery option incorporated into product case study will results in lower percentages of disposal wastes.

2. Methodology

2.1 Data Acquisition Method

There are two major data acquisition and data procurement method involved in completing this research, the primary data and the secondary data. Both play an important role in retrieving reliable data and information for this research.

2.1.1. Primary Data. The primary data is the data or information gathered through empirical method, such as direct observation or questionnaires surveys [4]. Primary data is crucial for this research in deciding and determining the work path of the research. The data obtained will be used for analysis and the results may lead to further research based on the issues of potential implementation of sustainability in product design. The major data acquisition method for this research have been decided, which will be done through questionnaire surveys method.

2.1.2. Secondary Data. Secondary data is the data or information gathered directly from previous researches or experiments. The information is gathered through written materials, such as journals, books, magazines, thesis, and documented paperwork or from internet [4]. All secondary data might related to this research was translated into the literature review as in second chapter of this thesis.

2.2. Questionnaire

A set of questionnaire are constructed based on Kano-model approaches and distributed among target respondents. These questionnaires are crucial to required data and information needed from target respondent. To collect a sufficient amount of data in a very short period of time required such
dedication and commitment. This data acquisition process required distributing questionnaires forms to target respondents to gain valuable feedback [5].

2.3. Product Identification
Kano-based questionnaire feedback gathered form respondents are very important and valuable. The results of the questionnaire will determine what products will be focused on for this case study. Respondent's feedback will decide which product is best suited to be investigated and improved its sustainability. Besides that, questionnaire results also will determine and identify the best recovery option most preferable by the respondents. This information might prove useful for further product analysis.

2.4. Product Analysis and Investigation
Determine product result from previous data acquisition process will be further analyze and investigate in this stages. Products will be disassemble and separated into each individual components or parts. Later, a thorough investigation will be conducted on each of these components to extract any reliable and useful information. The data obtain proceed to analyze and the results will identify the best recovery options of each particular components. Analyses are being conducted based on manufacturing aspects, which includes materials usage, manufacturing process involve and product design.

2.5. Product Redesign
Analysis results will identify best recovery option to be implemented on each component to improve product end-of-life cycle. Each component will be refigured with recovery option installed within its design. A whole new product design is constructed using computer modeling software, SolidWorks. A three dimensional model of the new product design will be generated, with recovery features implemented in its design.

2.6. SolidWorks Sustainability Verification
Once the model of the new design has been generated, it must go through analysis of sustainability by using one of the features available in SolidWorks software. The software will help verify the sustainability level of the new conceptual design. Sustainability analysis provides the user a screening-level life cycle assessment (LCA) of the environmental impact of the new design, with integration to design process [6]. The diverse tools available in software also includes both parts and assemblies assessment, carbon content, alternative materials search, environmental impact, transportation mode, and energy consumption [7]. The results obtain from this analysis will determine product design capability to be recycled by the use of particular materials in its production.

2.7. Methodology Summary
In the summary, this study begin with distribution of questionnaires form to the target users to evaluate their awareness in product sustainability, and determine which product they intend to improve end-of-life cycle. New product design concepts will be generated by evaluating the results of sustainability elements from the surveys. SolidWorks software will help in producing a detailed drawing and sustainability analysis of the new design.

3. An Integrated Approach in the Conceptual Design Activities

3.1. Market Analysis
Market analysis is the first stage in the proposed approach as shown in Figure 1. This stage will focus on analyzing the data from the questionnaires series. The questionnaires then will be used to determine features needed for the targeted product. This stage is crucial to help respondent decide features and characteristic they desire for designated product. The result of the questionnaires will explain market
needs and came up with a solution to the main problems. Based on this procedure, varieties ideas and design can be generated and proposed, enough to fulfill all prospect of designated product.

![Proposed approach for product life cycle improvement.](image)

### Figure 1. Proposed approach for product life cycle improvement.

#### 3.2. Questionnaires Categorization

Sets of questionnaires were distributed to respondent personally, which consist of 44 peoples. Among the respondent are students, lectures, engineers and others who's reliable to provide competent data's. Their respond is crucial to obtain enough information needed for this research. The information will provide sufficient understanding on the product function and characteristic desired by the customers.

The first section of the questionnaires is mainly focused on introducing researches to the respondent. It explained the project background and objectives of this research generally. A gratitude also expressed in this section on behalf of the researcher to thank respondent for their cooperation on helping this project. Respondents were asked to determine which of the current products they would like to improve the products’ end-of-life. The choices given are common household appliances such as desk fan, rice cooker, water heater, steam iron, and vacuum cleaner. The results are shown in Table 1 below.

Based on the results, this research focuses on improvement of water heater at the end-of-life. From this point forward, the questions will be based on this product. Kano Model method is implied into second section of the questionnaires to determine respondent’s satisfaction with product features. A total of 20 set of questions are included in this section, and each set consist of two questions, functional and dysfunctional form.

#### Table 1. Preferred product to be improved based on the customer feedback.

| Product             | Frequency | Percentage |
|---------------------|-----------|------------|
| Desk fan            | 10        | 15.6%      |
| Rice cooker         | 10        | 15.6%      |
| Water heater        | 18        | 28.2%      |
| Steam iron          | 13        | 20.3%      |
| Vacuum cleaner      | 13        | 20.3%      |
| **Total**           | **64**    | **100%**   |
3.3. Questionnaire Result Analysis

The results of the surveys are discussed in this section. The same procedures are repeated to respondent to categorize each feature. The list of features involved in this study is listed in Table 2, corresponding to their questions number. There are total of 20 features involved, and the survey results are crucial in determining which to be implemented into product’s new design.

| Questions Number | Features                                      |
|------------------|-----------------------------------------------|
| 1                | Product made from current materials           |
| 2                | Product made from green materials             |
| 3                | Modular design                                |
| 4                | Product recyclability                         |
| 5                | Product reusability                           |
| 6                | Product remanufacturability                   |
| 7                | Product disposability                         |
| 8                | Toxic contained materials                     |
| 9                | Take-back initiative                          |
| 10               | Trade-in/replace initiative                   |
| 11               | High energy/resources consumption             |
| 12               | Recyclable packaging                          |
| 13               | Maintenance serviceability feature            |
| 14               | Extendable life cycle upgrade                 |
| 15               | Number of parts recovered                     |
| 16               | High valued recycled materials                |
| 17               | Recovery option cost                          |
| 18               | Multiple disposal option                      |
| 19               | Product’s number of parts                     |
| 20               | Product capability to be turns to other products |

The total of 20 product’s features or attributes are being questioned in this survey. These features must be determined which category they fall into through the questionnaire. The Kano model helps in the categorization process, separating which features to be focused on into and which can be eliminated. The outcome will be a series of handful features, which if successfully executed into product design, will significantly increase customer’s satisfaction. The full results of the survey are tabulated in Table 3. The majority votes for each question determine which category the features belong to. Table 3 shows the full result of survey conducted for each feature has been allocated to their respective category based on the results obtained. In this form, the results seem to be dispersed and unorganized. The results are sorted and properly organized into their respective category, as in Table 4 to easily interpreted and analyzed.

For this study, only performance, attractive, and must-be requirements are being taken into consideration for product design. The reverse and questionable results obtained are ignored. Further studies in this requirement required extensive research, either redistributing the questionnaire or alter the questions to obtain different results, which is both time consuming [8]. The execution of indifferent requirements proves to be pointless in satisfying customers, but the data are useful in the following equations. Based on the results tabulated in Table 4, there are two values possible to calculated, both namely as customer satisfaction (CS) and customer dissatisfaction (DS) [9]. The first value, CS, can be expressed as following equation:

\[
CS_i = \frac{f_A + f_P}{f_A + f_P + f_M + f_I}
\]
Table 3: Features categorization.

| Feature | M | P | A | I | R | Q | Σ | Category  |
|---------|---|---|---|---|---|---|---|-----------|
| 1       | 8 | 22| 7 | 3 | 0 | 4 | 44| Performance |
| 2       | 19| 8 | 11| 0 | 4 | 2 | 44| Must-be    |
| 3       | 0 | 4 | 16| 14| 6 | 4 | 44| Attractive |
| 4       | 20| 1 | 15| 4 | 4 | 0 | 44| Must-be    |
| 5       | 3 | 0 | 9 | 14| 11| 7 | 44| Indifferent |
| 6       | 3 | 10| 17| 7 | 7 | 0 | 44| Attractive |
| 7       | 0 | 5 | 14| 18| 5 | 2 | 44| Indifferent |
| 8       | 10| 9 | 0 | 8 | 2 | 15| 44| Questionable |
| 9       | 3 | 0 | 7 | 5 | 9 | 20| 44| Questionable |
| 10      | 10| 0 | 11| 9 | 2 | 12| 44| Questionable |
| 11      | 0 | 7 | 7 | 19| 10| 1 | 44| Indifferent |
| 12      | 14| 10| 8 | 0 | 12| 0 | 44| Must-be    |
| 13      | 0 | 9 | 1 | 14| 9 | 11| 44| Indifferent |
| 14      | 0 | 15| 20| 5 | 4 | 0 | 44| Attractive |
| 15      | 6 | 4 | 14| 11| 9 | 0 | 44| Attractive |
| 16      | 4 | 0 | 7 | 12| 0 | 21| 44| Questionable |
| 17      | 7 | 0 | 0 | 8 | 17| 12| 44| Reverse    |
| 18      | 12| 21| 7 | 1 | 3 | 0 | 44| Performance |
| 19      | 2 | 8 | 0 | 8 | 14| 12| 44| Reverse    |
| 20      | 0 | 16| 14| 5 | 9 | 0 | 44| Performance |

Table 4: Features sort into respective category.

| Category      | Features                                                      |
|---------------|---------------------------------------------------------------|
| Performance   | Product made from current materials                           |
|               | Multiple disposal option                                      |
|               | Product capability to be turns to other products              |
| Attractive    | Modular design                                               |
|               | Product remanufacturability                                  |
|               | Extendable life cycle upgrade                                 |
|               | Number of parts recovered                                    |
| Must-be       | Product made from green materials                             |
|               | Product recyclability                                         |
|               | Recyclable packaging                                         |
| Indifferent   | Product reusability                                          |
|               | Product disposability                                        |
|               | High energy/resources consumption                             |
|               | Maintenance serviceability feature                            |
| Reverse       | Recovery option cost                                         |
|               | Product’s number of parts                                    |
| Questionable  | Toxic contained materials                                    |
|               | Take-back initiative                                         |
|               | Trade-in/replace initiative                                   |
|               | High valued recycled materials                                |
As $f_A$ represent the number of attractive, $f_P$ the number of performance, $f_M$ the number of must-be, and $f_I$ as the number of indifferent responses. Likewise, to calculate the value of DS can use the following equation:

$$DS_i = \frac{f_P + f_M}{f_A + f_P + f_M + f_I}$$

The customer satisfaction coefficient values ranges from 0 to 1. The closer the value obtained to 1, the higher customer’s satisfaction if the attributes fulfilled. While on the dissatisfaction coefficient, a negative sign is added in the result to emphasize its negativity influence on customer’s satisfaction if the attributes is not executed [8]. Now there are two points allocated for each requirement, plotted as $(1, CS_i)$ and $(0, -DS_i)$ [9]. The relationship function for each requirement can be identify as $S = f(x, a, b)$, where $S$ represent customer satisfaction, $x$ the level of execution, $a$ and $b$ as the adjustment parameters for Kano categories of customer requirements [10]. For performance attributes, the linear function is represented as $S = a_1 x + b_1$, where $a_1$ as the slope and $b_1$ denotes the DS value when customer requirement ($x$) is at 0. Substituting CS and DS values into the equation produced $a_1 = CS_i + DS_i$ and $b_1 = DS_i$. The function for linear performance product attributes represented as [9]:

$$S_i = (CS_i - DS_i)x_i + DS_i$$

If the customer’s requirement belong to attractive attribute, the function expressed as an exponential, $S = a_2 e^x + b_2$. From the equation, we get $a_2 = (CS_i + DS_i)/ e - 1$ and $b_2 = -(CS_i - eDS_i)/ e - 1$. Thus the function for attractive attributes denotes as [9]:

$$S_i = \frac{CS_i - DS_i}{e - 1} e^x_i - \frac{CS_i - eDS_i}{e - 1}$$

By using exponential function, the must-be attributes function can also be estimated. For this attributes the function is $S = a_3 (e^{-x} + b_3)$. The values for $a_3$ and $b_3$ can be calculated using [9]:

$$a_3 = \frac{e(CS_i - DS_i)}{e - 1}$$

and

$$b_3 = \frac{eCS_i - DS_i}{e - 1}$$

The function for must-be attributes can be plotted as [9]:

$$S_i = -\frac{e(CS_i - DS_i)}{e - 1} e^{-x} + \frac{eCS_i - DS_i}{e - 1}$$

These equations can be used to calculate function for each customer requirements. The functions then can be translated into graph, representing Kano model diagram. The results of the calculation are tabulated in Table 5 for each customer requirement of performance, attractive and must-be category.
### Table 5: Function calculations for customer requirements.

| Customer requirements                                      | CS point | DS point | a   | b   | \( f(x) \) | \( S = af(x) + b \) |
|------------------------------------------------------------|----------|----------|-----|-----|-------------|----------------------|
| Performance                                                |          |          |     |     |             |                      |
| Product made from current materials                        | (1.073)  | (0.75)   | 1.48| -0.75| \( x \)    | \( S = 1.48x - 0.75 \) |
| Multiple disposal option                                   | (1.068)  | (0.81)   | 1.49| -0.81| \( x \)    | \( S = 1.49x - 0.81 \) |
| Product capability to be turns to other products            | (1.086)  | (0.46)   | 1.32| -0.46| \( x \)    | \( S = 1.32x - 0.46 \) |
| Attractive                                                 |          |          |     |     |             |                      |
| Modular design                                             | (1.059)  | (0.12)   | 0.41| -0.53| \( e^x \)  | \( S = 0.41e^x - 0.53 \) |
| Product remanufacturability                                | (1.073)  | (0.35)   | 0.63| -0.98| \( e^x \)  | \( S = 0.63e^x - 0.98 \) |
| Extendable life cycle upgrade                              | (1.088)  | (0.38)   | 0.73| -1.11| \( e^x \)  | \( S = 0.73e^x - 1.11 \) |
| Number of parts recovered                                  | (1.051)  | (0.29)   | 0.47| -0.76| \( e^x \)  | \( S = 0.47e^x - 0.76 \) |
| Must-be                                                    |          |          |     |     |             |                      |
| Product made from green materials                          | (1.050)  | (0.71)   | 1.91| 1.20 | \( e^{-x} \)| \( S = -1.91e^{-x} + 1.2 \) |
| Product recyclability                                      | (1.040)  | (0.53)   | 1.47| 0.94 | \( e^{-x} \)| \( S = -1.47e^{-x} + 0.94 \) |
| Recyclable packaging                                       | (1.056)  | (0.75)   | 2.07| 1.32 | \( e^{-x} \)| \( S = -2.07e^{-x} + 1.32 \) |

### 4. Conclusion

When it comes down to prioritizing customer’s need and identifying product’s feature, there are no silver bullets. There are many different dimensions to be considered, and customer satisfaction probably the most important one among all. Kano’s model offers an effective approach in classifying different customer requirements into separated categories, based on their impact on customer’s satisfaction. This approach goes way beyond basic simple understanding by analyzing Kano model in a quantitative system. The relationship function between customer’s satisfaction and requirement can be determined for three main categories; performance, attractive, and must-be. Customer needs can be understand in much more accurate way. In simpler words, this model helps making difficult decisions easy.

In this research, Kano model are integrated into design activities to improve product lifecycle. A product has been chosen during this research to be a centered of improvement applied through Kano model analysis. A wide ranges of features, classify from performance, attractive, and must-be had been decided to be applied to current product design. The results will improve product lifecycle, with increases sustainability rates. A handful of features are successfully determined throughout the process, which if applied to the product design, will greatly satisfy the user while improving its sustainability. Further works will be continued to provide a better lifecycle option (increase percentage of reuse, remanufacture or recycle, whereby decrease percentage of waste) of a product using Kano model approach.

### Acknowledgement

This research is funded by Universiti Tun Hussein Onn Malaysia (UTHM) under Incentive Grant Scheme for Publication (IGSP) with Vot no. U411.

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