Kano model and weighted rating evaluation method for product lifecycle improvement

To cite this article: M F Hassan et al 2019 J. Phys.: Conf. Ser. 1150 012027

View the article online for updates and enhancements.

You may also like

- Effect of recycled course aggregate from concrete debris on the strength of concrete
  V S Lesovik, R V Lesovik and W S Albo Ali
- (Invited) Electrochemical Recycling of Used Nuclear Fuel
  Mark Williamson
- Preliminary Study on Kano Model in the Conceptual Design Activities for Product Lifecycle Improvement
  Mohd Fahrul Hassan, M.R.A. Rahman, A.M.T. Ariffin et al.

Recent citations

- Material selection in design for deconstruction using Kano model, fuzzy-AHP and TOPSIS methodology
  Milad Zoghi et al.
Kano model and weighted rating evaluation method for product lifecycle improvement

M F Hassan¹, K H Mazalan¹, M N A Rahman¹, A E Ismail¹, M R Ibrahim¹, M Z Rahim¹ and M F Ahmad²

¹Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia
²Faculty of Technology Management, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia

Abstract: Product end-of-life is a stage in the life cycle, whereby it has inspired all form of markets in today’s modern era. Manufacturer and companies are adhering to each of the available resources into seeing how to enhance and lower the natural effects of their product end-of-life. On the other side, various products have been produced without the concern of their product end-of-life, which have cause the increasing in waste products. Landfill dumps demonstrate of the way that squanders these issues to a further extend, as solid waste transfer by means of landfilling is becoming more difficult because most of the landfills are approaching its threshold or had exceeded its maximum limit of capacity. Also, lack of product recovery knowledges and recyclability features may lead to the increasing value of waste. Thus, sustainable awareness aspects must be implemented into designs, as the percentages of disposal and materials waste can be reduced significantly. Additionally, the implementation through the combination methods of Kano Model and weighted rating evaluation is one of the ways that aid consumers or manufacturers to increase the level of recycling activities. Subsequently, these combinations can also be used as a basis for consumers and manufacturers to determine on which of the products to be produced are of a good quality as well as an excellent recycling property. Therefore, this research emphasizes on the portable household fan, which has been chosen as the case study in evaluating the product end-of-life cycle.

1. Introduction
A product is the thing that offered available to be purchased. It can be a service or an item. A product can be physical or in virtual or digital frame. Each item is made at a cost and each is sold at a cost. Every product has a valuable life after which it needs substitution, and an existence cycle after which it must be re-created [1]. Basically, a product that made with open-loop system is started with a raw material, proceed into manufacturing process, and lastly into user’s hand [1, 2]. Open-loop manufacturing had prompt to the significant issue, decreasing rapidly available of landfill disposal space. In 2000, Malaysia generate about 15,000 tons of solid waste each day and the value increased every year [3]. According to the statistic, nearly 80 percent of the total solid waste collected. However, the percent of solid waste increased every year. Malaysians produce an average of 30,000 tons of waste every day. Only 5 percent of it is recycled [1]. Nowadays, many products have been produced without concerning their product end-of-life which many cause increasing waste product. Landfill dumps are demonstration of the way that squanders issue is wild [4]. Lack of product recovery knowledges and recyclability features lead to increasing value of waste.
From literature, many studies have been done in the product lifecycle improvement in terms of fundamental theories and concepts behind the scenes. Smith et al. (2012) used a method of mass customization for life cycle product in order to create individually customized products with considering mass production volume, cost and efficiency [5]. Xiao et al. (2015) presented a lifecycle assessment of household refrigerators as a cradle-to-grave lifecycle assessment of a direct-cooling double-door household refrigerator [6]. Andriankaja et al. (2015) applied Product Lifecycle Management (PLM) approach for Eco-design product geared to operate within a PLM system [7]. However, sustainable awareness aspects not be implemented into designs, as the percentages of disposal and materials waste can be reduced significantly. Additionally, this strategy can be one of the ways that aid consumers or manufacturers to increase the level of recycling activities and can also be used as a basis for them to determine on which of the products to be produced are of a good quality as well as an excellent recycling property. Due to those limitations, Hassan et al. (2017) proposed a new assessment tool, named ProSET to assess the sustainability level of a product at the design stage that taking into consideration various factors required for ensuring sustainability using weighted decision matrix as the platform and neural network to compute the sustainability index [8]. Wherefore, this paper proposes a systematic approach that integrating Kano model and weighted rating evaluation method in the conceptual design for product life cycle improvement.

2. Methodology
Development of an integrated approach helps in planning guidelines and structured the pace through every process and steps throughout the project. The planned process is intended to overcome any upcoming potential problems, while optimizing the results of this project. In this study, Kano model approaches is used to identify the suitable product used to be improved during its end-of-life cycle, and provide the best recovery options, which to be implemented.

The combination of Kano model and weighted rating evaluation is one of the ways that help consumers or manufacturers increase the level of recycling. Figure 1 shows the flow process to understanding the development of an integrated approach. Input is a product that will be used as an experimental material for the study of choosing a household portable fan as a product to be studied and output is the result that will be obtained after using Kano model and weighted rating evaluation to increase the level of the recycled product. Indirectly, this combination can also be used as a basis for consumers or manufacturers to determine which products to produce are of good quality as well as excellent recycling levels.

3. Case study
In this section, a case study on a product is conducted to illustrate the proposed approach. A table fan was identified as the product. All calculations by this approach are not fully presented in this paper, yet it is only shows the results. The results were collected based on the sustainable verification from SolidWorks software.
In the first stage, it focused on translating the customer’s satisfaction on improving the product life cycle into functional requirement. These obtained requirements were applied to the product to improve its life cycle and amplify customer’s satisfaction significantly.

The common household table fan as in figure 2 runs on simple basic processes to circulate wind to breeze the user. The portable fan comprises of a turning game plan of vanes or sharp edges, which circulate the liquid. The turning gathering of edges and center-point is known as an impeller, a rotor, or a sprinter. In depth, it is composed of lodging or case, as this may coordinate the wind current or increment wellbeing by keeping objects from reaching the fan sharp edges. Also, most fans are powered by electric motor. The table fan was disassembled into four main components which is consists of Casing, Switch, Blade and Motor. The components of the table fan were redrawn using SolidWorks software as shown in figure 3.

![Figure 2. Common household table fan.](image1)

![Figure 3: The 3D modelling of table fan.](image2)

Based on the Kano model, three major categories: Attractive, Performance and Must-be were applied in the next stage. The Attractive and Performance will bring delight and satisfaction to the user, meanwhile Must-be is compulsory for the features to be included into product design [9]. This stage discusses and elaborates each customer requirement alteration and modification that is needed to the current product design.

- **Must-be**

  1) *Product made from green material*
  
  Any material made or composed of renewable resources are considered as green material. There are many criteria to be considered in recognizing green material. Among these criteria are, product must be made from recycle material, product capability to be salvaged, remanufactured, refurbished or reuse, and lastly locally available or ease to find material.

  2) *Product recyclability*
  
  As mentioned earlier, most of the materials used in the market modern electrical fan are highly recyclable. Since it is a must-be features, failed to deliver this demand will cause serious users dissatisfaction.

- **Performance**

  1) *Product made from current materials*
  
  Current material is used in manufacturing product to achieve the customer satisfaction. Most of the portable fan available in the current market are made from various material include polymer. Almost in market nowadays, the fans are made from polymer because the material is cheap as well as light weight. Maintaining the current material will continue satisfaction of the user other than improving its life cycles, since most of the material use is recycle.
2) **Multiple disposal option**
There are two most common disposal options that anyone can think of: either the product goes to landfill or being recycled. There is another option that has stood out in the sustainable society, a law called Electronic waste recycling Act of 2003. It was first introduced in California, as the law called upon any associated companies to collect and recycling E-waste. E-waste describes as any discarded electrical or electronic devices, which electrical desk fan belong to. The law mainly focused on salvaging any useful components and refurbished them for a new product.

3) **Product capability to be turned to other products**
Practically, any disposal product can be repurposed into any new functional object, and desk fan also included. There are numerous of books and tutorial on the net, describing detail step-by-step guide on turning any disposal materials into other products.

- **Attractive**
  1) **Modular design**
  To improve and ease product maintenance and repair, modular design should be implicated. Modular features help in improving product life cycle by allowing simple replacing over the broken components to be replaced by any available component from different models. This multifunctional component helps manufacturer reduces fabricating resources and storage consumption, thus lead to sustainable environment.

2) **Product remanufacturing**
   A key that is important in the product remanufacturing is its capability to dissemble. A product with inability to be dissembled would generally not capable for manufacturing. Thus, implying ease product dissemble features into design will greatly please the users and improve its capability in remanufacturing.

3) **Extendable life cycle upgrade**
   Product capability for an upgrade, to extent life cycle that are much more related to the modular design. Modular design allows swapping out broken modular component and replacing it with new ones or new parts. The process extends product life to a certain period, until another modular component is out of order, and the process repeats. Respondent perceive this feature quite an attractive, besides providing better life cycle improvement to the product.

4) **Number of part recovered**
The attractiveness of a product depends on the number parts, which can be recovered for recycle. Product with higher recycling parts mean better sustainable rate or high rate of sustainable. Almost all materials involved in manufacturing modern household fan or desk fan are recycle material because almost of these materials are from polymer, which is highly recyclable.

   Alternative concepts are deferred primarily in physical or in abstract embodiment. This can be listed up the sub functions in a column of a matrix and the alternative concepts for each function in adjacent rows. This approach is called a morphological matrix. Additionally, to simulate alternative combinations, selection can made by one concepts from any column, for each function. The alternatives that have been made in the market for table fan can help in developing for more alternative concepts design. The step of elaborating the concepts design is shows in table 1.
Table 1. Morphological matrix.

|                | Alternative Concepts |
|----------------|----------------------|
| Material product | Aluminum  Steel  Polymer |
| Energy sources   | Electric  Solar  Battery |

From the morphological matrix analysis, it was identified that there are nine alternatives combinations. The next process is to Analyzing Alternative Concepts. There are several methods can be used in evaluating alternative concepts for example Pugh and Weighted rating evaluation method. The weighted rating evaluation method had been chosen for case study. Every function fractions will be analyzed so that in the end, the best alternative concepts are determined.

The best five combinations have been chosen to be evaluated using the weighted rating method. There are five main criteria were identified in weighted rating method in this study. The criteria were function, price, design ergonomic, and sustainability. By using weighted rating method, marks between values 1 to 5 are being given according to criteria that had been selected in the previous stage. From the weighted rating evaluating concept, the highest score was selected from five combinations of weighted decision matrix evaluation concepts table. The selected combination (table 2) has been chosen as the main concepts of this study.

Table 2. The selected combination for table fan.

| Product material | Energy sources |
|------------------|---------------|
| Polymer          | Electric      |

a. Verification Analysis
SolidWorks Sustainability gives noteworthy ecological outcomes by measuring the natural effects of individual outlines over the item life cycle including the impacts of material, assembling, gathering, and transportation.

Before improvement result, the material used is PE- High density- Film. The example of products from this material is boats, bottle caps, plastic bag and more. The value of carbon footprint, total energy consumed, air acidification, and water eutrophication. The carbon footprint shows the number for material that has been exposed to the carbon footprint is 12 kg CO$_2$e. Next, the value of total energy consumed, air acidification, and water eutrophication is 300 MJ, 0.030 kg SO$_2$e, and 5.3E $-$ 3 kg PO$_{2e}$ respectively.

Additionally, for an improvement result, the material has been changed, which is is Polyphenyl ether (PPE) to acquire better result. The example of products are structural parts, household component, automotive items that depend on high heat resistance and more. The value of the carbon footprint, total energy consumed, air acidification, and water eutrophication. The carbon footprint shows the number for material that has been exposed to the carbon footprint is 25 kg CO$_2$e. Next, the value of total energy consumed, air acidification, and water eutrophication is 490 MJ, 0.046 kg SO$_2$e, and 8.1E $-$ 3 kg PO$_{2e}$ respectively. Table 3 shows the comparison between before and after improvement.
### Table 3. Before and after improvement.

| Before Improvement | After Improvement |
|-------------------|-------------------|
| ● Material: PE-High density-Film | ● Material: Polyphenyl ether (PPE) |
| ● Transportation distance: 1900km | ● Transportation distance: 1900km |
| ● Life time use: 2 years | ● Life time use: 2 years |
| ● Recycled percent: 63% | ● Recycled percent: 81% |
| ● Landfill percent: 32% | ● Landfill percent: 14% |
| ● Example product: boats, bottle caps, plastic bag and more | ● Example product: household component, automotive items and more. |

In conclusion, the two types of material for recycle purposes used in this study are PE-High Density-Film and Polyphenyl ether (PPE). The two selections are suitable material for recycling and ease to find or commonly used in Asian. The value of carbon footprint, total energy consumed, air acidification, and water eutrophication, the value shows the different value quite similar because the two materials that have been used are suitable for recycling purposes. The recycle value for PE-High Density-Film and PPE show in figure 4 and 5.

![Figure 4](image1.png) **Figure 4.** The recycled value for material PE-High-Density.

![Figure 5](image2.png) **Figure 5.** The recycled value for material PPE.

### 4. Conclusion

There are many different dimensions to be considered, and customer satisfaction probably is the most important one among all. Kano Model’s offers an effective approach in classifying different customer requirements into separate categories, based on their impact customer’s satisfaction. This approach goes beyond the basic simple of understanding and analyzing in Kano model in a quantitative system. Next, the Weighted rating evaluation method also offers the effective method to helps improving the life-cycle of the product. On the other side, there are ways to other methods that can help by improving the product in design. Also, weighted rating evaluation can easily be used for design selection and can help in selecting the suitable material for improvement purpose, as well.

For this research, Kano model and weighted rating evaluation are integrated into design activities to improve the product life cycle. The product has been selected during this research to be centered for improvement through the Kano model and weighted rating evaluation. A wide range of features classify from performance, attractive, and must-be had been decided to be applied to current product design. The result will then improve on the product lifecycle, with an increase in the sustainability rate. A handful features are successfully determined throughout the process, which if applied to the product design, will greatly satisfy user while improving its sustainability.

### 5. References

[1] Y C Moh and L A Manaf 2014 Overview of household solid waste recycling policy status and challenges in Malaysia *Resources, Conservation and Recycling* 82 (2014) 50–61

[2] M C Chiu and C H Chu 2012 Review of sustainable product design from life cycle perspectives *International Journal of Precision Engineering and Manufacturing* 13(7) 1259–1272

[3] S T Wee 2004 Pengurusan Sisa Pepejal Di Malaysia *Jurnal Sains Sosial* Jilid 2B 9 – 25

[4] M F Hassan, M Z M Saman and S Sharif 2016 ProSET: A decision support system for
sustainability performance evaluation Proceedings of the 2016 International Conference on Industrial Engineering and Operations Management, Kuala Lumpur, Malaysia, 2016

[5] S Smith, G C Smith, R Jiao and C H Chu 2013 Mass customization in the product life cycle J Intell Manuf 24 877–885

[6] R Xiao, Y Zhang, X Liu and Z Yuan 2015 A life-cycle assessment of household refrigerators in China Journal of Cleaner Production 95 301–310

[7] H Andriankaja, F Vallet, J L Duigou and B Eynard 2015 A method to ecodesign structural parts in the transport sector based on Product Life cycle Management Journal of Cleaner Production 94 165-176

[8] M F Hassan, S Mahmood, M Z M Saman, S Sharif and S Z Sapuan 2017 Application of product sustainability evaluation tool (ProSET) on car seat design configuration International Journal of Mechanical & Mechatronics Engineering 17(3) 88-97

[9] Q Xu, R J Jiao, X Yang, M Helander, H M Khalid and A Opperud 2009 An analytical Kano model for customer need analysis Design Studies 30(1) 87–110

6. Acknowledgements
The authors wish to thank the Universiti Tun Hussein Onn Malaysia (UTHM) for the financial support for this work.