The Development of Sustainable Product Design Method for Sustainable and Successful New Products

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Abstract. Currently, most of the product designers have insufficient source in integrating the potential meanings when they are developing a new product. Also, it has become extremely challenging in verifying the variables of a product that could lead towards sustainable and successful products in the market. The development of a new product is not only to cater to the users' satisfactions, but additionally, it should attract more users. In this paper, the Sustainable Product Design Method (SPDM) is introduced as a process to identify and verify the variables of the users' emotional responses and perceived product quality, and element of sustainability in the early stage of the design process. The SPDM is a design guideline attempt to establish the sustainable product requirements (SPR) towards the sustainable and successful products. To prove the practicability of this method, one of the successful products was chosen as a case study. It has been found that the method built is valuable in facilitating the product designers in the early stage of product design and development process. The validation signified from this process is not only contributed towards product sustainability but also increase on its success in the market.

1. Introduction

The design of a product regulates from the user first insight and determines how it can communicate about its function. The users’ perception of a product has been influenced by the product variables. Variables of a product have significant factors that influenced the users' perceptions particularly to evaluate on its physical and aesthetics elements [13, 15, 16]. The design of product will also generate the users' interpretations regarding the attribute of the product [7, 15] and would be directly applied to product choice [14]. Users' emotions have been an essential element of product design study since that late 1980s. An emotional response is also important in product interaction that provides a strong influence between users' behaviour and product attachment. Apart from emotions, perceived quality also contributed to evaluation regarding the product superiority to meet every individual's expectations. This refers to indirect intention among product features and users' orientation during decision-making process, helping the user to receive information about the product specifications. Researchers have recognised that perceived product quality as also a cognitive response towards a product which influences the product purchase intention [11, 5], referring to the indirect intention among product features and user orientation which affected by internal or external motivations of quality of a product through some perceived quality points during decision making process [12]. Many users including the product designers and manufacturers, unintentionally only concentrated of physical appearance (visceral level) and functionality (behavioural level) of a product that are easily replenished, then on an emotional part (reflective level) to produce and maintain continuing emotions [12, 1]. The users also do not get emotionally attached to products because they are excluded from the design and manufacturing processes. As a conclusion, the product designers are still facing the difficulty to integrate a meaning in the future products because they are not simply creating products, but also the are making users to want to be responsive towards their emotions a long with designing long-lasting products. They are also struggling in integrating a potential meaning to combine users' emotional attachment with good product characteristics [16, 4]. This has caused the users...
do not being able to assess and appreciate the products as the meaning that is being communicated is not clear. Product designers need a certain guideline that may be used at the early stage of the design process or in product assessment studies. But there is no specific methodology that could be referred to that incorporate both of the users’ emotional responses and perceived quality characteristics for sustainable product as well as increase the probability its success in the market.

The purpose of this study is to develop a new sustainable product design method. The method is a design guideline for product designer and product developers, which the process of this method is incorporated the variables of emotional responses, perceived product quality and elements of sustainability in the early stage of product development. The significance of this method will be likelihood in contributing on product sustainability and successful in the market.

1.1 Sustainable and Successful New Products

The sustainable product design is not essentially about new technologies, but about reconsidering how to meet the need for growth and decreasing negative impacts at the same time. The idea of sustainable is becoming progressively important all over the world with the involvements of the incorporated approach indicators that link a community’s society, economy and environment. There are three dimensions of sustainable product development, which have connection with each other that are economic, environment and social [9]. The combination of three elements in product design could reduce the negative impact on society, economic and environment aspects. Table 1 shows the important of sustainability elements in product design.

| Element                  | Description                                                                 |
|--------------------------|----------------------------------------------------------------------------|
| Social Sustainability    | It performs specific function that includes perceptions of safety, equity, eco-prosumption and sustainable urban forms. |
| Economical Sustainability| It emphasises on the development of a higher quality product based on sustainable innovation, product durability, better price and cost, and effects on resources and environment. |
| Environmental Sustainability| It pushes manufacturers to be more responsible for the disposal and recycle of products. |

Earlier studies have found that the best factor to distinguish the success of the new product from failure is a superior product in the eyes of the user. New product development could not be managed successfully without a clear understanding of users’ needs and wants [2, 12]. A successful product is identified as having characteristics, meeting user needs, highly visible, and provides useful benefit or attributed easily by the user [8], and required to integrates other requirements such as market needs and environmental consideration [16, 3, 2]. The collaboration of the user and product designer in this process is required to produce a good and marketable product [15, 16], and very effective source in generating a new innovative product. In the process, the characteristics of a new product could be established in the initial stage of the design process, where the new product ideas are created based on the user wants and needs, and market demand.

1.2 Product Development, Process and Method

The introduction of a new product offers the opportunity for product developers to increase its sales and enhance both competitive position and potential of surviving. In today's competitive environment, there are many product developers who want to develop shorter product time, with lower cost, high quality of product, and consequently, the signification of its [2, 4]. User satisfaction has become the source of innovation success [15, 16, 3]. In addition, users cannot only distinguish which products that works and which do not, they can often provide the answer on the ways the products do not meet the expectations. User can contribute in designing a product that satisfies the expectation, which could increase the product quality. It is important to have an understanding on the relationship between user and product that could be improved by creating
something sustainable [6]. Integrating user emotional responses and perceived quality is an important aspect of product interaction, helping users to choose and get attached with the product. Product designers should be able to understand the importance of detaining users’ emotional responses and perceived quality characteristic in the product development. Nowadays, there are no specific methodology could be referred that would incorporated both users' emotional responses and perceived product quality characteristics for sustainable products as well as increasing the probability of their success in the market. Hence, the frameworks to produce a sustainable product design should be given as a main priority for improving and have better opportunities to gain product success in the market.

The literature and empirical study implied the outcome of the users' contribution in product development and process, which is crucial to determine the sustainable product design specification. There are 28 sustainable product design specifications (SPDS) have been identified to contribute in sustainability product on 20 specifications contributed from user emotional response, where it was divided into two group, namely Emotional Aesthetics (EAs) and Emotional Function (EFe) [5]. In addition, eight perceived quality characteristics were also identified. Both aesthetic and function elements are the primary elements in the development of physical products. These elements contribute in fulfilling or becoming the sustainable product design specification, which is stimulated from the users' emotional responses and perceived quality characteristics. By integrating all these elements, the specifications of sustainable product could be fulfilled, and the probability of its success is heightened. Figure 1 shows the Sustainable Product Design Method. The SPDM is a process to identify the sustainable product design specifications. It also acts as a decision-making for verifying the priority elements of product design that would fulfill the user requirements, and which can be integrated with sustainable elements to produce a sustainable product.

Figure 1. Sustainable product design method

Formula 1 also shown an assessment process in identifying and verifying the sustainable design specification (SPDS) and ultimately, establishing the sustainable product requirements (SPR). The process is divided into two steps. The first step is set in identifying the sustainable product design specification, where both elements of emotional aesthetics (EAe) and emotional function (EFe) need to be incorporated with the product quality characteristics (PQC) to determine a sustainable product design specification (SPDS). Meanwhile, the second step is integrating the sustainable product design specification (SPDS) with the elements of sustainable product design (ESPD), and thus, it will be determined a sustainable product requirements (SPR). Towards the end, selected sustainable product requirements (SPR) should contribute to the sustainability and successful of a product.
2. Method

An investigation conducted involving of a smartphone as a case study to validate a sustainability factors that could increase the success of a product. It supposed to meet the users' recognition by using the design guideline that was introduced. The product was selected based on the product reputation and sustainable factors in the market since the product were introduced until the present day. A survey was conducted using iPhone 6 model as a focus and involving the existing users and former users for product validation. The smartphone was selected, as the investigation from statistics that shows iPhone 6 model is the most iPhone adoption until September 2017. The snowball sampling method is used to identify the population, which the exact number is unknown or limited knowledge from some iPhone 6 model users. Figure 2 show the Sustainable Product Design Method process. The sustainable product requirements are identified from a mapping of 20 product specifications and nine elements of sustainable product design, which has been recognised by the user. The requirements are sets from the high priority and low priority value.

![Figure 2. Sustainable product design method process](image)

The validation process was divided into three phases; 1) Determine the users’ emotional responses regarding the aesthetics elements and function elements of the product. 2) Attempt to find the product quality characteristics based on the user requirements to the product success. 3) Find the possibility factor of product sustainability. The quantitative data was used to gain an in-depth understanding of the propose investigation. The data from empirical is analysed using SPSS software.

3. Results and discussions

Sixty (60) product users were involved in this survey. Table 2 shows users’ emotional responses of iPhone 6 model. It shows that most users show fascination (mean=3.78 point) emotion regarding the iPhone 6 model, while some of users’ experience feel anger (mean=2.25 point).
Table 2. Emotional responses of iPhone 6 model

| iPhone 6 | N  | Min | Max | Mode | Median | Mean   | Std. Deviation | Sum   |
|----------|----|-----|-----|------|--------|--------|---------------|-------|
| Fascination | 60 | 1.00| 5.00| 4.00 | 4.00   | 3.7833 | 1.13633        | 227.00|
| Joy       | 60 | 1.00| 5.00| 4.00 | 4.00   | 3.6000 | 1.18178        | 216.00|
| Happiness | 60 | 1.00| 5.00| 4.00 | 4.00   | 3.7617 | 1.18022        | 223.00|
| Admiration| 60 | 1.00| 5.00| 4.00 | 4.00   | 3.5167 | 1.15702        | 211.00|
| Pride     | 60 | 1.00| 5.00| 4.00 | 4.00   | 3.4500 | 1.12634        | 207.00|
| Satisfaction | 60 | 1.00| 5.00| 4.00 | 4.00   | 3.5333 | .98233         | 212.00|
| Desire    | 60 | 1.00| 5.00| 3.00 | 3.00   | 3.5000 | 1.19745        | 198.00|
| Disgust   | 60 | 1.00| 5.00| 2.00 | 2.00   | 2.1000 | 1.19008        | 126.00|
| Anger     | 60 | 1.00| 5.00| 1.00 | 2.00   | 2.2800 | 1.31000        | 135.00|
| Disappointment | 60 | 1.00| 5.00| 1.00 | 2.00   | 2.0000 | 1.07357        | 120.00|
| Shame     | 60 | 1.00| 5.00| 2.00 | 2.00   | 2.1333 | 1.17122        | 128.00|
| Fear      | 60 | 1.00| 5.00| 1.00 | 2.00   | 1.9833 | 1.04948        | 119.00|
| Sadness   | 60 | 1.00| 4.00| 1.00 | 2.00   | 1.9833 | .96536         | 119.00|
| Boredom   | 60 | 1.00| 4.00| 1.00 | 2.00   | 1.8500 | .89968         | 111.00|

Figure 3 presents the importance of aesthetics elements of iPhone 6 model based on the user requirements. The elements selected with the highest percentage are appearance (84.2%), color (83.3%), shape (82.9%), form (80.8%), material (72.1%), texture (66.7%), interface (64.2%), emotion and semantic (57.5%), and semiotic (52.1%).

Figure 3. Aesthetics elements on iPhone 6 model

Figure 4 displays the important of function elements of iPhone 6 model based on the user preferences. The main elements selected with the highest measurement are usability (85.4%) followed by safety (83.3%) quality (82.5%), ergonomic and technology (81.7%), reliability (80.8%), effectiveness (77.1%), lifetime (68.8%), components (66.3%) and lastly size (64.6%).
Product design elements are also considered as the specification of product. Table 3 shows the sustainable product design specification (SPDS) of successful iPhone 6 model. The very important aesthetic elements for iPhone 6 as identified are appearance, color, shape, form, meanwhile the function elements are stated as usability, safety, quality, ergonomic, technology and reliability. Meanwhile, it also shows perceived quality characteristics of the successful iPhone 6 model. The results indicated that most users preferred durability as their main priority followed by performance, features, aesthetics, perceived quality, reliability, conformance and serviceability.

Table 3. Sustainable product design specification (SPDS) of successful iPhone 6 model

Table 4 displays the elements of sustainable product design (ESPD) of iPhone 6 model. Users decide that accessibility as their top priority followed by performance, material, resource, reuse, value, cost, and equity.
Table 4. The elements of sustainable product design (ESPD) of the successful iPhone 6 model

| Element of Sustainability (ES) | Accessibility | Performance | Material | Resource | Development | Reuse | Value | Cost | Equity |
|--------------------------------|---------------|-------------|----------|----------|-------------|-------|-------|------|--------|

The introduction of new design guideline attempts to assist the product designer to produce a good product. The development of design guideline or known as Sustainable Product Design Method (SPDM) is essential in the early concept development stage, which will enable the product designer to determine and establish the sustainable product requirements for a new product. This design guideline attempts to provide a framework to assist the product designer during the development of a new product. A new design guideline could help in verifying and establishing the sustainable product requirements (SPR) in the market. It also can help to improve the effectiveness in creating product ideas and quality in design process. Therefore, the systematic process is designated as a new decision-making tool for product designer during the development of a new product in the early stage of product development process. Meanwhile, the factors influencing the production for great products are not only contributed from the elements of aesthetics and function, but other aspects also needed to be recognised such as emotions, perceived quality and elements of sustainability. All the elements need to incorporate and integrate with a systematic process.

The validation results of the product sustainability and success of iPhone 6 model have found that there are four (4) elements of product design from aesthetic (EAe) and six (6) function (EFe), followed by eight (8) perceived quality characteristics (POC) and nine (9) elements of sustainability (ESPD) as indicated as the Sustainable Product Specification (SPR). Figure 5 shows sustainable and successful product elements of iPhone 6 model. Three important elements from aesthetic (appearance, shape, and, form) and function elements, (usability, safety, quality, ergonomics, technology, and reliability) are identified as product design specification assessed from iPhone 6 model. Most of the users show fascination level regarding the iPhone 6 model appraisals. Regarding the product quality characteristics, most users prefer iPhone 6 model choose durability as the main priority followed by performance, features, aesthetics, perceived quality, reliability, conformance, and serviceability. The highest priority of sustainability of iPhone 6 products is accessibility followed by performance, material, resource, development, reuse, value, cost, and equity.
In addition, the formula below also indicated that the specification for iPhone 6 model for its sustainability and its successful product. The equations of the product sustainable and successful of iPhone 6 model are stated as below:

\[
[E_{Ae03} + E_{Ae02} + E_{Ae01} + E_{Ae04}] + [E_{Fe01} + E_{Fe02} + E_{Fe04} + E_{Fe03} + E_{Fe05} + E_{Fe06}] + [P_{QC01} + P_{QC02} + P_{QC03} + P_{QC04} + P_{QC05} + P_{QC06} + P_{QC07} + P_{QC08}] + [S_{e02} + S_{e01} + S_{e03} + S_{e04} + S_{e06} + S_{e05} + S_{e08} + S_{e09}] = SPR
\]

4. Conclusion
The development of a new design guideline acknowledged as Sustainable Product Design Method (SPDM) is successful implemented. The method is a process that incorporated the variables of emotional responses, perceived product quality, and the elements of sustainability, which is an attempt to increase the product sustainability and success in the market. Through this method, the product designer and product developer can easily verify and establish the sustainable product requirements in the early stage of the product development process. The findings for sustainable and successful products in the market was valid through the results from the data gathering using the iPhone 6 model as subject, using the SPDM. All the elements found have contributed to the product sustainability and as well as was increased its success in the market. As a conclusion, users’ emotional responses and perceived product quality has significant of product design sustainability.

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