Product Design for Post-Stroke Rehabilitation Bicycle with Kansei Engineering Approach

D S Dewi¹, A Rakhmawati¹, I M L Batan² and N A Wessiani¹

¹Industrial Engineering Department, Faculty of Industrial Technology, Institut Teknologi Sepuluh Nopember (ITS), Surabaya 60111 Indonesia
²Mechanical Engineering Department, Faculty of Industrial Technology, Institut Teknologi Sepuluh Nopember (ITS), Surabaya 60111 Indonesia

dyah@ie.its.ac.id

Abstract. Stroke is one of the world’s leading diseases cause of death. However, stroke actually can be cured, through rehabilitation using post-stroke rehabilitation bicycle that actually starts in the hospital as soon as possible after they are diagnosed of stroke. The goal of stroke rehabilitation is to help the patient relearn the skills lost when a stroke affected part of their brain. Several research about the product development of the post-stroke rehabilitation bicycle has been carried out by Product Design and Development Laboratory of Mechanical Engineering Department ITS. However, the current prototypes indicates that the product is not ready to be commercialized yet. It is because the product is still under development and has not yet completed. This product development has not considered and captured the hidden needs of the customer toward the product. Therefore, certain implicit feeling & emotions of the customer should be captured in the product development process. Kansei Engineering (KE) approach is applied for this purpose.

1. Introduction
Stroke is simply defined as “brain attack”. It occurs when the blood supply is restricted or stopped, so that the brain cells begin to die. When brain cells die during a stroke, the abilities which supposed to be controlled by that area of the brain such as memory and muscle control are lost. Further, this can lead to brain injury, disability and at the worst situation, it may lead to death [1]. However, in fact, stroke can occur to anyone at any time. Based on the data of Ministry of Health Indonesia in 2014 [2], it is indicated that in 2013, there were 30,507,059 people across Indonesia which are estimated to have the prevalence of strokes. Specifically, in East Java, it is estimated that in 2013, there are 15.6% stroke prevalence multiplied by total population, 38,363,000. Therefore, in East Java it is estimated that 5,984,628 people have prevalence of stroke. Further, there are two common ways to cure stroke disease, namely with medical treatment and medical rehabilitation by exercising. The second method, which is rehabilitation, mostly are performed by either conventionally performing the patients daily activities or by an exercise using a certain tools like bicycle or treadmill to control the patient’s balance and increase their muscle strength. The type and procedure for rehabilitation vary depending on the stroke disease [3][4][5][6]. Further, according to Batan [7], rehabilitation using bicycle is easy to be performed and is included in the affordable rehabilitation programs all across Indonesia. The use of post-stroke rehabilitation bicycle delivers significant improvements in lower body muscle strength.
Based on that evidence then, since 2015, continuous research about the product development of the post-stroke rehabilitation bicycle has been carried out by Product Design and Development Laboratory of Mechanical Engineering Department ITS. However, the current prototype indicates that the product is not ready to be commercialized yet (Figure 1). It is because the product is still under development and the basis of this product development is limited only to the customer explicit needs. It is therefore, very contradictory with the findings of Bose [8], which stated that the inclusion of customers implicit needs is necessary for the product success in the market. Therefore, this product should be further developed by considering implicit needs. One of the technique strive to understand the factors that contribute to the costumer’s satisfaction in the product is Kansei Engineering (KE). Through the use of this method, certain feeling, emotions, implicit needs, and experience of the customer can be captured, embedded and reflected in the product design. KE approach especially Type 1 is a recent tool that is applied in product design for several years. It have been applied in designing various products and services, including healthcare equipment [9]. In many occasions, health care-associated products like the post-stroke rehabilitation bicycle cannot be easily commercialized because healthcare is not a typical market. Based on the evidence that stroke is on number four of the top killer diseases in Indonesia (Ministry of Health, 2018), and the fastest cure takes on average 4-5 months, it is very important to speed up the cure of stroke through the use of rehabilitation product such as the post-stroke rehabilitation bicycle. Furthermore, in order to commercialize the product, the product also need to be designed by considering other factors such as aesthetic rather than only focus on engineering aspect. Based on that fact, then this research aims to propose the design of the post-stroke rehabilitation bicycle for commercialization using Kansei Engineering (KE) approach. The design of the post-stroke rehabilitation bicycle is limited only for the outer design and packaging design and the approach used to design the post-stroke rehabilitation bicycle is Kansei Engineering type 1. This research is part of multiyear research on Product Design for Post-Stroke Rehabilitation Bicycle. While the overall research also include development of commercialization strategy, but this paper only focus on the process of Kansei Engineering implementation.

Figure 1. Post-Stroke Rehabilitation Bicycle Alpha Prototype [10]

2. Research Methodology
The research was conducted through several stages which describes in the following sections.

The first step to conduct this research is done through observing the existing condition of the design of post-stroke rehabilitation bicycle as the main object of this research. It is currently displayed in the Product Design and Development Laboratory of Mechanical Engineering ITS. Not only that, several interview is carried out toward the laboratory assistant about the current condition of the prototype, the prototypes generation, the prototype design, the previous research that associated with the product development and the other related information. An interview is also carried out toward a neurologist and
medic rehabilitation specialist to gather the expert judgment about stroke and its rehabilitation program. Those information will be used as the basis in developing the preliminary design of the post-stroke rehabilitation bicycle. As an addition, literature study is carried out to discover the theories, concepts, and knowledge from the literature used as the basis to support this research.

The next step is determining the market segmentation and target means that the market is divided into distinct groups of buyers who have distinct needs, characteristics, or behavior. By determining the market segmentation, target, and position, it will provide the depth explanation of distinct group of buyer [10]. Therefore, the segmentation, target, and positioning should be specified.

After the segmentation, target, and positioning of the product is identified, then product preliminary designs are made based on the interview and literature study result. The product preliminary designs will be made and placed in the questionnaire to capture the customer responses through the use of Kansei words. This product design is a preliminary design and will be further analyzed and revised based on the Kansei responses of the respondents. Then, a questionnaire is developed to assess the implicit needs of the customer about the product design through the use of Kansei words. There are two statistical methods used to process the selected Kansei words, which are factor analysis and partial least square. The Kansei words responses which are obtained previously will processed using factor analysis. By performing factor analysis, the number of variables which are the Kansei words will be reduced, as the redundant data is eliminated. The Kansei words which has similar characteristic will also be grouped together. After the redundant data is reduced, then by using partial least square, the influence of Kansei words with the product design will be identified. The variables which has the greatest impact toward the product design also can be determined.

3. Data gathering & processing
For product design purpose, data was gathered by mainly using Kansei Engineering questionnaire and then processed by using statistical analysis. The description of the process are presented as follows:

3.1. Kansei Words Development
Based on initial study, there are four product attributes which become the focus of design, which are brand font, the overall packaging post stroke rehabilitation bicycle, palms’ feature, and feet’s feature. For the brand feature, the aspect which will be discussed will be limited to the types of font. While for the overall post-stroke rehabilitation bicycle, the aspect which will be discussed are the bicycle color, and the seat color. Then, for the palms’ feature, the aspect which will be discussed are the material, color, and its form. Lastly, for the feet’s feature, the aspect which will be discussed are its color, its material, and its form.

Further, to be able to identify the implicit needs of the customer toward those four product attributes, Kansei words are developed so that the implicit needs, feelings, and emotions of the customer toward the product design can be identified. In general, there are two common ways to develop Kansei words, whether develop the Kansei words based on the expectation and expressions from the user who has been tried the previous product prototype and based on the literature study. For the first way, which is identification of Kansei words from the user who has been tried the product prototype, several interviews are conducted toward several post-stroke patients who have used the previous generation of the post-stroke rehabilitation bicycle across Surabaya to assess their expectation and needs toward the preliminary product design. This approach is commonly known as Feedback Captured after Task (FCAT) which is a way to develop Kansei words is by performing usability testing to customers who use the product. To find the post stroke patients that are willing to involve in the survey, indeed, quite challenging. The respondents that involve in this research mainly because the access provided by the doctor or hospital. From the interview, then several important words that express their expectation toward the product are noted and listed in the following Table 1.
Table 1. Kansei Words Translation from customer expectation

| Customer Expectation                                                                 | Kansei Words Translation          |
|---------------------------------------------------------------------------------------|-----------------------------------|
| The appearance/the outer of the bicycle should not be embarrassing toward others       | Glamorous-Dull Casual-Attractive   |
| “Jangan sampai bentuk sepedanya malah membuat penggunanya malu”                       |                                   |
| The bicycle features should be proven to be safe for the user                         | Robust-Fragile                    |
| “Fitur sepeda harus benar aman untuk pengguna”                                        |                                   |
| The bicycle features should not complicate the user                                   | Easy to use-Difficult             |
| “Fitur sepeda justru jangan sampai menyulitkan penggunanya”                           | Flexible-Rigid                    |
| The bicycle’s appearance should be normal, as usual as it can be, so that it will not | Ordinary- Remarkable              |
| attract others attention.                                                             |                                   |
| “Tampilan sepeda yang normal-normal saja, agar tidak menarik perhatian orang banyak” |                                   |
| The bicycle’s appearance should be soft and calm, rather than conspicuous             | Calm-Aggressive                   |
| “Sepeda jangan mencolok, justru harusnya yang kalem saja”                              | Minimalist-stylish                |
| The bicycle appearance and features no need to be unique. In the opposite, it should  |                                   |
| be kept as simple as it can, because its main function is for health.                 |                                   |
| “Tidak perlu yang aneh-aneh, yang simple saja berhubung itu untuk kesehatan”          |                                   |
| The bicycles features should not endanger the user                                    | Safe-dangerous                    |
| “Fitur sepeda jangan malah membahayakan keselamatan pasien”                           | Easy to use-difficult             |
| The bicycle features should be easy to use and comfortable for the user              | Comfortable-uncomfortable         |
| “Fitur sepeda harus mudah dan nyaman dipakai untuk orang stroke”                     |                                   |

Further, based on the literature study, several suitable Kansei words for the post-stroke rehabilitation bicycle are identified. The final kansei words is normally selected based on the most common words that used by the customers or users. In this sense, adequate number of data is require since it will affect the result. Data mining may be useful for this purpose. Unfortunately, there are limited source was discuss about the better ways to select the final kansei words. Since post stroke rehabilitation bicycle is not really a common product use by the current customers (post stroke patients) so the data is limited. Therefore, as the post-stroke rehabilitation bicycle attributes observed in this research limited to four attributes, so then all of the Kansei words constructed in this research will be classified based on the discussion with the product developer, according to which component the words will most likely suitable to assess. Overall, those selected Kansei words will assess different product perspectives from the customer point of view, and automatically will enrich and broaden the identification of the customer implicit needs.

3.2. Kansei Survey

Understanding customer preferences is very important in developing the post-stroke rehabilitation bicycle. It is because, customer are the determiners whether they will purchase the product or not. Further, customer will also determine how successful a product becomes in the market, because after all, the profits will eventually come from the customers. Therefore, the opinion of the customers matter a lot, especially for this post-stroke rehabilitation bicycle. Most people will rely on their friends, relatives and colleagues to tell them which bicycle that delivers the most significant improvement toward the patient’s condition. Therefore, the negative experience of a single customer may send away tons of other...
potential customers. That is why, it is very essential to identify the customer needs and expectation deeply, so that the product developed will be able to fulfil and satisfy their needs. Further, the more the customer’s needs, preferences, and expectation are identified, the more successful its sales strategies will be, as understanding about what they need, what they value and what their expectations are may increase the effectiveness of its marketing strategies.

However, in this research, the customer implicit needs identification for the post-stroke rehabilitation bicycle are performed by carrying out survey toward certain respondents. The survey are carried out by showing questionnaire that contained several figures of the product features, font types for the brand name, the color for each product features & the font types. In the following figures below, the Kansei questionnaire to assess the customer implicit needs will be shown. There are three part of the questionnaire, the first part of the Kansei questionnaire show several design and color of the palms’ feature. Further, this palms’ feature itself is developed because most of the post-stroke patients still have abnormalities in their motoric aspect, especially palm, so that even if they have been able to use their hands without others help, the stiffness of the patients’ palm will remain. Therefore, in order to keep the patient palm and fingers stays on the steer, this feature is developed. Because it is one of the crucial elements of the post-stroke rehabilitation bicycle, which may affect the purchase decision of the customer, then the customer implicit needs about this feature should be assessed further. Next, the second part show the feet’s feature toward the bicycle pedal. Then, the third part and forth part, are, the overall post-stroke rehabilitation bicycle and brand name. As the example, Figure 2 show part 3 of the questionnaire. All of the design shown in Figure 2 is developed based on the existing product which are widely available in the market. As to prove that this design are feasible to be used for the post-stroke rehabilitation bicycle, discussion with the product developer is also performed.

Kansei survey is conducted by using 5-scales semantic differential scales (Table 2). The assessment is performed toward respondents consist of patients’ family & relatives by giving the appropriate value of each Kansei words for each of the design. Then, the average of the Kansei response will be calculated and used in the next data processing.

**Figure 2.** Customer Preferences Questionnaire (part 3)
Table 2. Kansei Words Assessment using Semantic Differential Scale

| No. | Kansei Words | Semantic Differential Scale | Kansei Words |
|-----|--------------|----------------------------|--------------|
| 1   | Heavy        | Light                      | Light        |
| 2   | Hard         | Soft                       | Robust       |
| 3   | Fragile      | Casual                     | Calm         |
| 4   | Serious      | Joyful                     | Glamorous    |
| 5   | Dull         | Attractive                 | Comfortable  |
| 6   | Attractive   | Uncomfortable              | Comfortable  |
| 7   | Aggressive   | Difficult                  | Easy to use  |
| 8   | Rigid        | Minimalist                 | Stylish      |
| 9   | Complex      | Rigid                      | Flexible     |
| 10  | Remarkable   | Complex                    | Simple       |
| 11  | Dirty        | Dangerous                  | Ordinary     |
| 12  | Dirty        | Dangerous                  | Simple       |
| 13  | Opposed      | Opposed                    | Colorful     |
| 14  | Retro        | Retro                      | Modern       |

3.3. Factor analysis

Factor analysis is used as Kansei words reduction technique, identification of the most important Kansei words, and group those Kansei words based on their correlation. Further, factor analysis is performed in SPSS 24 software and will generate the outputs in form of descriptive statistics, correlation matrix, KMO and Bartlett’ test, anti-image matrices, communalities, total variance explained, scree plot, and component matrix. As for example; the factor analysis result indicates that for the palms’ feature, two components are formed. Which named as “Visual Attractiveness” and “Comfort”. For the overall post-stroke rehabilitation bicycle, two component are formed and named as “Sense” and “Bold.

3.4. Identification of influential design element

The associated design element which will be best to represent the selected Kansei words, will be identified based on the discussion with the product developer and expert judgment. For example, for the palms’ feature, several forms of palms’ feature are the best representation of the words safe, simple, easy to use and robust. While for the words glamorous and attractive, the element associated with them is the color of the palms’ feature. And, for the word soft and robust, it is associated with the material of the palms’ feature. Whereas for the overall post-stroke rehabilitation bicycle, the best design element to represent Kansei words harmonious, joyful, glamorous, clean, colorful, glamorous, aggressive, attractive and colorful are grey, yellow, white, black, navy blue, and more than one colors.

3.5. Partial least square regression

PLS is used to identify the most influenced items which has been identified previously. This PLS is performed in XLSTAT. Then, the most influenced design items can be identified through the highest relationship score in the PLS output. Based on this result then the final product design is created. Before further process the data by using PLS, the influential design element should be weighted through few
discussion with the product developer and expert judgment. Later on, this weighting result together with the Kansei responses will be used as the input to perform partial least square and the most influenced items can be identified through the highest score in PLS output. The following Table 3 present the example of the PLS regression run on XLSTAT for the palms’ feature.

Table 3. PLS Result on Palms’ Feature

| Item  | Category | \( u_1 \) | \( u_2 \) | \( t_1 \) | \( t_2 \) | Average |
|-------|----------|-----------|-----------|-----------|-----------|---------|
| Material | Silicone | -1.380 | -0.406 | -0.531 | -0.531 | -0.712 |
|        | Lycra | 1.083 | 0.319 | 0.831 | 0.831 | 0.766 |
| Color  | Grey | -1.380 | -0.406 | -1.081 | -1.081 | -0.987 |
|        | Yellow | 1.498 | 0.441 | 1.124 | 1.124 | 1.047 |
|        | A | -1.156 | -0.340 | -1.642 | -1.642 | -1.195 |
| Model  | B | -0.356 | -0.105 | -1.293 | -1.293 | -0.762 |
|        | C | 1.691 | 0.498 | 2.592 | 2.592 | 1.843 |

As can be seen from Table 3, palms’ feature made of lycra with yellow color and model C is selected for the final design.

4. Result & conclusion
Using Kansei Engineering approach, the implicit needs of the customer can be identified and translated into the suitable product design. Since the main aim of this research more to the aesthetic aspect rather than on engineering aspect therefore only four product design attributes become the focus of design which are brand font, the overall packaging post stroke rehabilitation bicycle, palms’ feature, and feet’s feature. Considering very limited publication was found on post stroke rehabilitation bicycle, this research could contribute to the research area by introducing the use of KE approach to design the packaging or aesthetic aspect of the bicycle to be ready to the commercialization stage. This is become the It is indicated that the most influence item for the brand font is modern font, while for the overall post-stroke rehabilitation bicycle, the grey color is chosen as the overall color of the bicycle and more than one color is chosen as the most influence seat color. Meanwhile, for the palms features, lycra with yellow color and model C is selected for the final design. While for the feet’s feature, the semi-permanent mechanism, grey color, and model B is selected for the final product design. Figure show the proposed design for post stroke bicycle feature design.

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