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Integrating Green Affective Values and Material Selection in Automotive Design: A Preliminary Study

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Abstract: This paper presents a study on the integrating consumer's green affective values and material selection in the context of product design, specifically in the automotive design. Green affective values are important element in the design to understand user's emotion, need and preferences toward the green products. It is extremely important to understand user's feeling on product to avoid potential market failure. The first impression on product is captivated by the use of materials. It is pointed out that intangible issues such as perceptions and intentions of the designer should take a role in the materials selection activity in product design. However, study on the linkage between green affective values and material selection is rarely found in the literature. Therefore, the objectives of this study are to identify the significant green affective values of the consumers in Malaysia and propose a guideline for automotive designers to incorporate affective values into conceptual design and investigate its linkage on material selection. The guideline includes a technology used to translate the consumer's eco-feeling and impression of a particular component design with appropriate material selection, in this case is on car steering wheel design. Three surveys were conducted to obtain consumer's understanding on affective values and the feelings elicited when presented with visual stimuli of the material. Semantic differential scale and factor analysis were used to analyze the results. The responses obtained from the surveys were used to develop an eco-tool, which translates user's feelings and emotions into material properties and linking them to certain materials they perceived as "greener". Life Cycle Analysis (LCA) and fuzzy logic were used in developing the material scorecard with regards to environmental profile of design model. The eco-tool was validated by product design experts to understand the usefulness and operability of the guideline. It was found that the tool is easy to navigate and having great potential to help designers on integrating green affective value in design with inclusion of technical aspect and cost into the tool.

Keywords: Affective values, material feeling, conceptual design, eco-tool, material selection

1. Introduction

Kansei Engineering method is the process of linking the customers' emotional responses, also known as affective values, which includes the physical touch and psychological feelings, to the properties of a product or service. This method is significant in being the first to introduce a systematic investigation to translate customers' feelings and demands into design elements [1], [2], [3]. The Kansei approach is essential for automotive design because nowadays production that based on satisfying consumer's affective needs is the driving factor for increasing sales and profit margins [4]. If customers are having high acceptance on the product, the products will likely champion the market.

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Automotive companies that are adopting the Kansei approach in automotive design as consumers nowadays are more stringent in choosing the products based on their personal preference. However, not much progress has been made in terms of green automotive design that takes into account the affective values of the consumers because most of the research has only studied customers' affective values to the aesthetic shape features of a car [5], [6], [7], [8], [9]. Sustainable technology is less successful when it is not coupled to the affective emotion of the user, where the green design is disconnected to the user. As a result, the technology cannot be appreciated by customers and less changes of product will be successful in the market. The objectives of this study are to identify the significant green affective values of the consumers in Malaysia and propose a guideline for automotive designers to incorporate affective values into conceptual design and investigate its linkage on material selection. The study is important to understand how customers in Malaysia perceive the local automotive design and translate the affective values to select the best materials during design. By understanding and linking user emotion that encourages green behaviors into automotive design, it is more likely to improve consumer acceptance of sustainable technology used in the design and thus making sure the implemented technology is a success. This research is important for the sustainable development of local cars and will lead to a breakthrough of green affective design in Malaysia's automotive industry.

2. Literature Review

Anderson and Bourke [10] stated that affective characteristics are part of three major categories of human attributes. The first category is cognitive characteristics which relates to the typical ways of thinking while the second category, psychomotor characteristics corresponds with the ways of acting [10]. The second category is affective characteristics which corresponds with the typical ways of feeling. Thus, affective characteristics or values can be defined as the qualities that represent people's typical ways of feeling or expressing emotion. Anderson and Bourke also stated that affective values must satisfy three criteria, which is intensity, direction, and target. Intensity is basically the strength of the feeling, direction refers to the positive or negative spectrum of the feeling, and target refers to the object, idea, or behavior that the feeling is being directed at. The Fig. 1 illustrates the continuum of feelings which includes all three criteria of affective characteristics, where five targets are shown, with participant A and E having the highest feeling intensity, but on opposite directions of the spectrum [10].

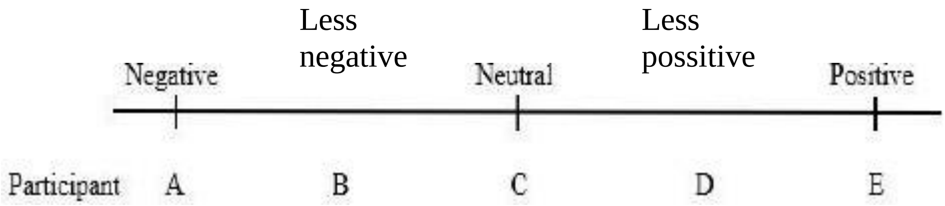

Fig. 1 - The continuum of feelings [10]

This spectrum indicates that affective values are subjective and vary among different people. Some people may feel a higher intensity towards a certain stimulus, while others may have a lower feeling intensity towards the same stimuli. Different people will also experience a different feeling direction when presented with a certain variable. For example, one participant may dislike (negative) bright-colored objects while another participant may like (positive) them. The variance in a person's affective value towards a stimulus is the sole purpose of the study of ergonomics in product design.

Kansei refers to "consumer's psychological feelings and image" towards a new product [11]. Schütte et al. [12] indicated that Kansei is the impression a person gets from a certain object, situation, or environment using all six of the human senses which includes cognition. Fan et al. [5] have established that in the current automotive market, the most important part of developing an effective marketing strategy to increase sales is not only consider customer's satisfaction into account, but also in meeting their affective demands over the appearance of the vehicles. So far, most studies have been focused in the area on how to link the affective needs of consumers to the shape features of the vehicle as aesthetic attributes are usually the key to attracting vehicle buyers. Fan et al. [5] created a prediction model for the shape design of green technology vehicles, first by collecting product samples of concept cars, then using semantic differential (SD) scale [14] to measure the participants' affective responses compiled from a questionnaire, and finally using support vector regression (SVR) to construct the prediction model.

Desmet et al. [9] introduced another instrument called Product Emotion Measure (PrEmo) to access consumer's emotions elicited by car models' appearance. PrEmo is a set of product emotions that is represented visually by animations of a cartoon character and presented on a computer interface. In this study, the front view of the car model was chosen as the stimuli while the subjects were asked to express their emotional responses to the car by selecting one or more of the cartoon animations. The technique used in this method to link the relationship between the car models and the elicited emotions is by applying correspondence analysis, which explores cross-tabular data by converting such tables into graphical displays.

This study confirms that the shape features of a car model will elicit mixed emotions within and between subjects. Mixed emotions within means that the subjects experience a combination of distinct emotions as they chose more than one emotion to express how they feel when they saw the car model. Mixed emotions between subject means that different people will experience different emotions when viewing the same car model since emotional responses are personal and subjective. The advantages of the PrEmo method is that it does not ask subjects to verbalize their emotions, thus it is fast and easy to use. Besides, it also measures specific emotions instead of generalized emotional states. However, its disadvantages are that this method cannot distinguish emotions with similar scores on the same dimensional group when using this measuring approach. It is also limited to a particular stimulus which in this case is the front view of the car, as changing to a different stimulus such as the side view will give you other emotional responses.

There are other studies on the design specification of passenger car interiors based on the consumer's affective values. Jindo and Hirasago [2] studied the subjective evaluation of a car's speedometer and steering wheel by consumers. Factor analysis and SD scale are used to group the evaluation adjectives selected on two factor axes in terms of their factor loading as shown in Fig. 2.

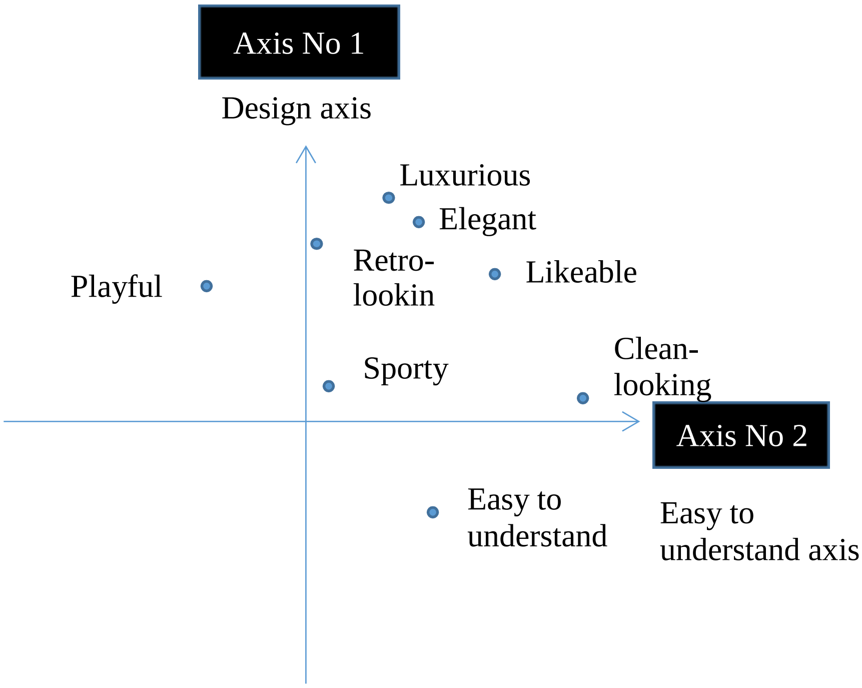

Fig. 2 - Distribution of adjectives [2]

This study managed to obtain a detailed impression data indicating the relation of the evaluation scores to its styling features because the experiment is done on small units of the passenger car interiors rather than the whole interior. However, the evaluation adjective of a certain unit cannot always be used in the same meaning for the whole interior evaluation, which gives this method a limitation. For example, an 'easy-to-understand' speedometer makes sense, but the same cannot be said for 'easy-to-understand' steering wheel. Meanwhile, Yun et al. [15] did a research on the affective evaluation for the quality of touch or feel of a surface-covering material in a vehicle interior, which is an important factor of a customer's perception of the overall product quality. While most of the other journal studies focuses on the visual input of the consumer in evaluating their affective satisfaction, Yun's study focuses instead on the touch perception when the skin makes contact with the covering materials which gives a different set of affective results. ANOVA is the tool used in this study to determine the significant design features that are related to the affective feeling elicited by surface materials. Variables that are linked to the affective feeling on specific parts of the automobile interior material are also identified. The outcome of this study is that a checklist is made which includes both the consumers and designers' perceptions on the vehicle interior materials. This checklist is a useful descriptive tool in converting consumer perception to design specification and it can be utilized in other parts of automobile design process.

From all the research areas covered above, there are little evidences that car designers incorporate consumer's green affective values into the design stages. Although Kansei Engineering is widely practiced in other countries, Malaysia's car companies have yet to adopt the approach, not to mention specifically in eco-design. Most of the research has been focused on linking the design characteristics with the exterior shape features of the car such as the curvature of the lights, bumper and other car's components.

3. Methodology

3.1 Design Specification and Variables

Designing the guideline for eco-compatible material selection involves several stages. The first stage is the data collection process. Three surveys are conducted as part of the pilot study. The objective of the survey is to evaluate the consumer's understanding of affective values, and their feeling of a car's eco-design concept, which represents their green affective values.

For the first survey, the design aspect linked to consumer's green affective values must be determined. This is the Type I application of Kansei Engineering [13]. The surface-covering material for the four main components of a car's interior, namely the steering wheel, dashboard, gear stick, and the upholstery, is chosen as the design aspect. The dependent variables for this survey are the intensity of the feeling (i.e. comfortable, satisfied) faced by the participants when presented with their choice of material, and the participant's knowledge of eco-friendly materials. The independent variables here are the list of feelings given to the participants to choose from, and the list of surface- covering materials for each of the car's interior components.

The second survey aims to filter out the most popular affective values from the first one and linking them to green behaviors or practices. The dependent variables for this study are the selected 10 green affective values obtained from the first survey, as well as addition of new affective values. The independent variables are the scenarios of different environmentally-friendly practices that will elicit a green affective value in the participants of the survey.

Lastly, the purpose of the third survey is to relate a green affective value to its material or design properties. The dependent variables here are the sensory properties (i.e. Hard, Smooth, Opaque) of everyday material used in the automotive industry, where the picture of the sensory profile given as reference to the participants is adopted from [16]. The independent variables here are the 10 most popular green affective values selected from the consumer's responses in the second survey. In the later stage where the eco-tool is designed for translating the green affective values into material properties, only two affective values are presented as an example, namely "Natural" and "Elegant". Fig. 3 shows the methodology used in this research.

3.2 Participants

Three surveys were conducted involving 112 respondents. Respondents are Malaysian who own or use car for their daily activity. The participant profiles are as follow:

1. In the first survey, 40 Malaysian participants who are living in Malaysia took part in the study. Majority of the participants are males (52.4%) from the age group 18-29 years old (38.1%).
2. In the second survey, 51 Malaysian participants took part in identifying the significant green affective values. 26 of them are students, while the rest are working adults in different occupation fields. Majority of the participants are males (58.8%), and from the age group 18-29 years old (66.7%).
3. In the last survey, 21 Malaysian participants took part in the study, where their responses will be used in creating the eco-tool. 9 out of these 21 are students, while the rest are working adults. Majority of the participants are again males (52.4%), and between the ages of 18-29 (76.2%).

3.3 Procedure

Before the pilot study can be done, the domain of the study has to be determined. The surface-covering material of the steering wheel is chosen as the product domain in this research. Next, the target participant demography is chosen. All three survey questionnaires were prepared in Google Forms due to its simplicity and convenience. The purpose of each survey questionnaire was explained to the participants.

In the first survey, each participant was asked to choose their favourite surface-covering material for each interior component of a car (steering wheel, dashboard, gear stick, upholstery). Images of the components covered in that material are given as the visual stimuli. The focus was then narrowed down to just the steering wheel to avoid any discrepancies in affective values from each participant because different components of a car will elicit a different feeling from the user. Then, the participants were asked to evaluate the intensity of their feeling when visualizing the touch and texture of the material using SD scale.

For the second survey, each participant was asked to give an affective value that resonates most with them when they visualize each of the 10 scenarios of environmentally friendly practices given to them. They are to choose from a list of the most popular responses from the first survey or write down their own adjective that comes to mind. From this survey, a list of more than 10 green affective values was obtained.

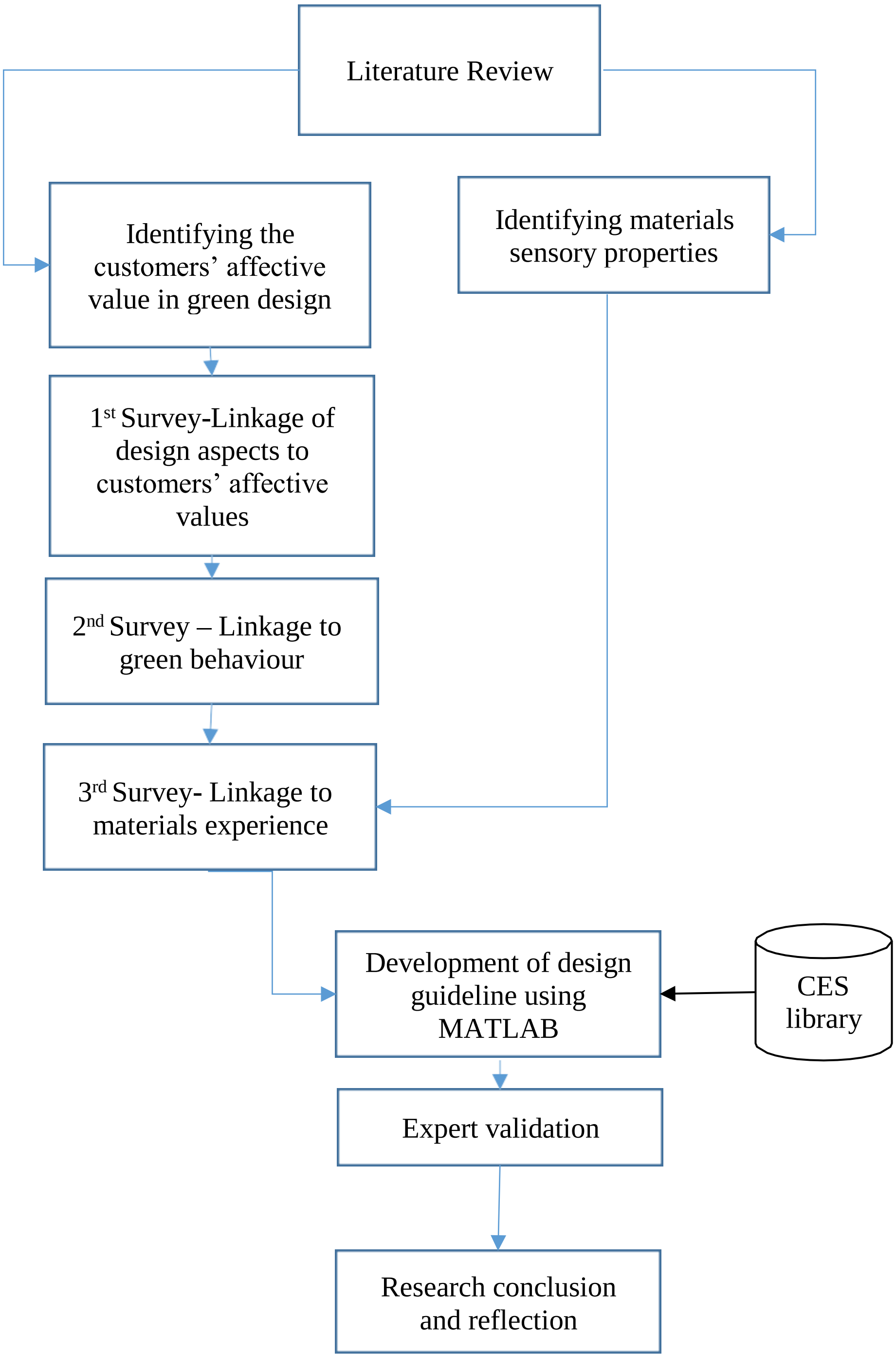

Fig. 3 - Research methodology

Rate the magnitude of material properties that you think an ELEGANT steering wheel cover has from visual aspects.					
	Highly X	Moderately X	Neutral	Moderately Y	Highly Y
Hard (X) – Soft (Y)	○	○	○	○	○

Fig. 4 - Magnitude scale of material properties

Lastly in the third survey, the participants were asked to rate the sensory properties (i.e. Soft, Smooth, Warm) of each material that they think best associate with a particular green affective value on a magnitude scale, as shown in the example in Fig. 4.

3.4 Guideline Development

3.4.1 Designing the Eco-tool

The purpose of the Eco-tool is to link each green affective value to the material properties and suggest suitable materials to be used on the steering wheel for car designers to choose from. This step represents the Type II Kansei Engineering System where a computer engine and database system is designed to aid the Kansei process [17]. This tool was created with MATLAB, which automatically generates object-oriented codes that specifies the application design and layout.

The application interface was divided into three sections and was designed to be as straightforward for car designers as possible. In the first section, a dropdown menu with the list of green affective values obtained from the the survey was created as shown in Fig. 6 and 7.

The second section is the sensory properties of materials called "Material Description". This section created to translate the affective value into the feeling that describe a material. Once the green affective value has been selected in the material descriptor, only the sensory properties that are related to the affective value will be enabled for selection. The dropdown menu will also be disabled in this stage to avoid overwriting of the coding and to lock in the car designer's choice. The coding for this link between the two sections was based on the consumer's responses from the third survey. To give the car designers a rough idea of the visual and tactile aspect of the sensory properties, a sensory profile diagram adopted from [17] in Fig. 5 was provided in the guideline to be used together with the eco-tool.

The third section of the tool is the "Material List", where only the materials that satisfy the sensory properties selected by the car designers will appear in the system.

For each material, a custom-made profile sheet was prepared and coded to pop-up as a separate window when their button is clicked. This profile sheet consists of a complete set of specific information about the material's environmental and sensory performance, obtained from CES EduPack 2017. Each profile sheet will have a CREO model of the car steering wheel covered in the material of selection. Only selected information was extracted based on the material selection guidelines for eco-design of long-term products, which is adapted from [16] and will be explained further in next section.

3.4.2 Eco-Compatibility and Material Selection Scorecard

Life Cycle Analysis (LCA) plays an important role in the development of a material database, which considers the environmental impact of each material from cradle-to-grave [16]. Since LCA is an integral part of the methodological approach in identifying the most important environmental impacts of a material, it was used to design the material selection guideline for an eco-compatible product. In the automotive industry, car designers usually adopt all guidelines that cater to a long-term product because the average life expectancy of a car based on Nationwide's 2017 infographic is 11.4 years old [18]. In this guideline, three strategy subsets were produced from the results of LCA and these subsets each represent a different purpose in the product life cycle.

The first subset is the "Use of Material with Low Environmental Impacts", which is aimed at optimizing resource consumption and minimize emissions along the product life cycle. For long-term products like a car, the short distribution chain guideline in the subset was neglected because a reduction in distribution impact on the environment is not the primary concern for car designers. Instead, automotive companies emphasize on the eco-efficiency of the material, and usually opt for renewable and non-toxic materials.

Meanwhile, the second subset is the "Material Lifetime Extension", which deals with the end of life phase of a material and is aimed at extending the life cycle of a product as well as postpone the time of waste disposal. This strategy is included because it is generally adhered to in the automotive industry, since every company's objective is to reduce resource consumption and emissions by delaying the use of new natural resources in manufacturing new material. The biodegradability and landfill disposal guidelines were not complied with during material selection because for a long-term product, it is essential to choose durable materials instead of adopting biodegradable or recycled ones as suggested in [16] illustrated in Fig 8.

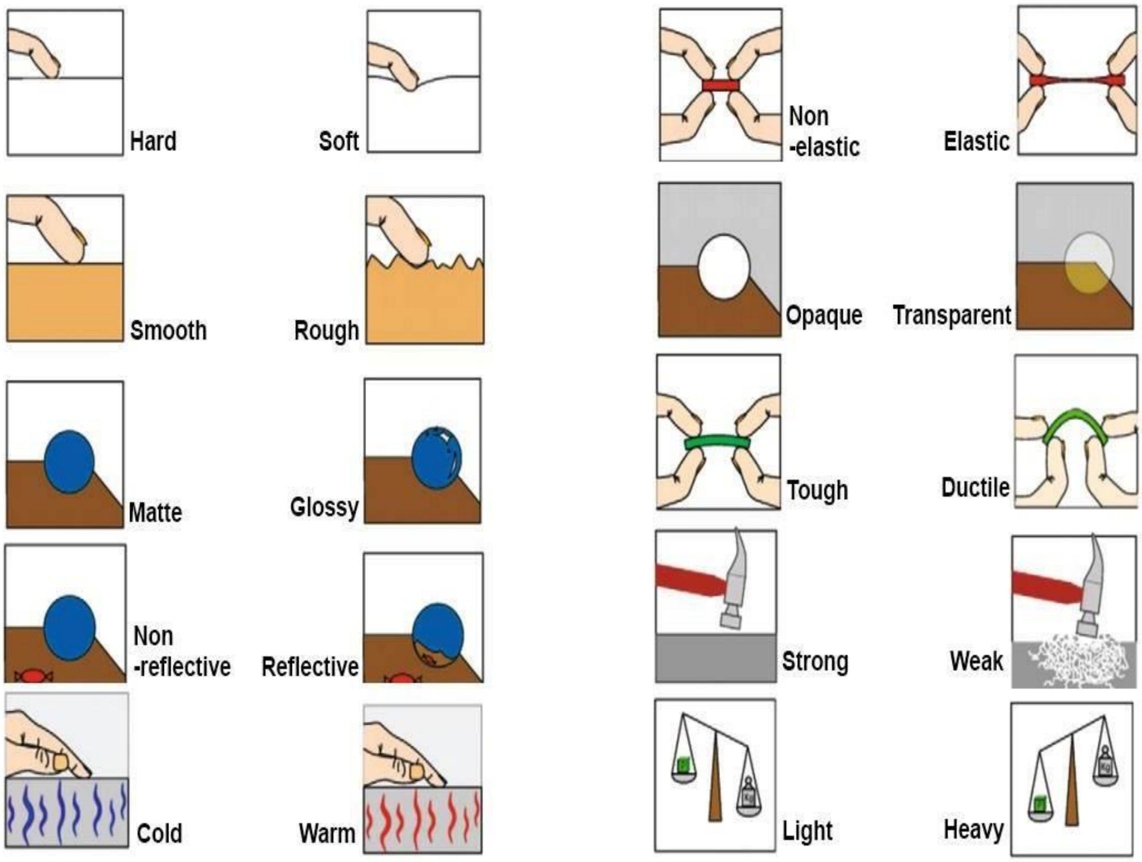

Fig. 5 - Sensory profile diagram [17]

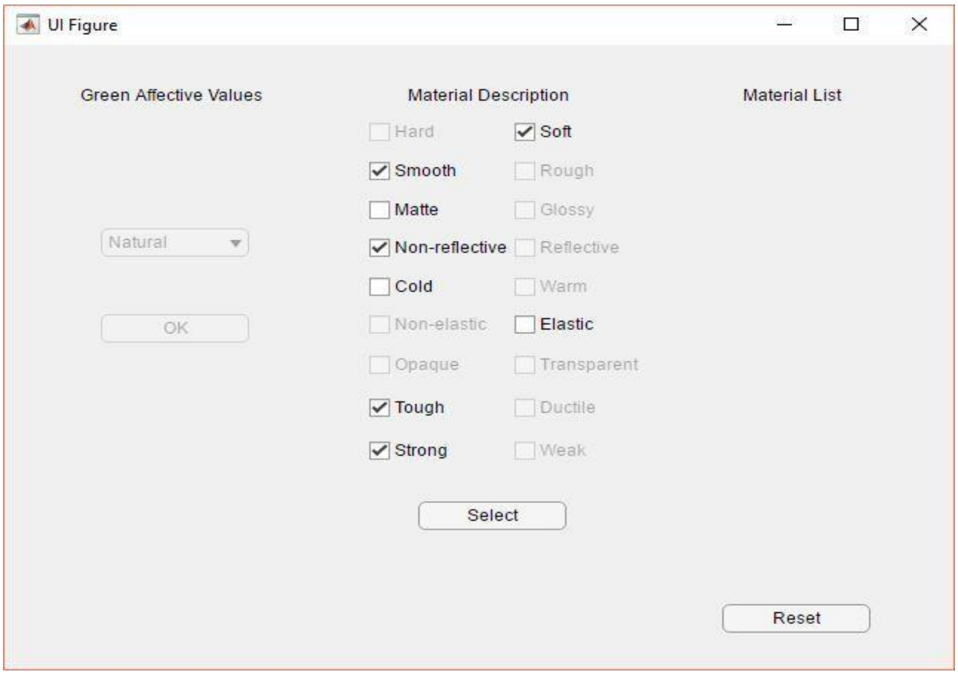

Fig. 6 - Choosing material description in Eco-tool

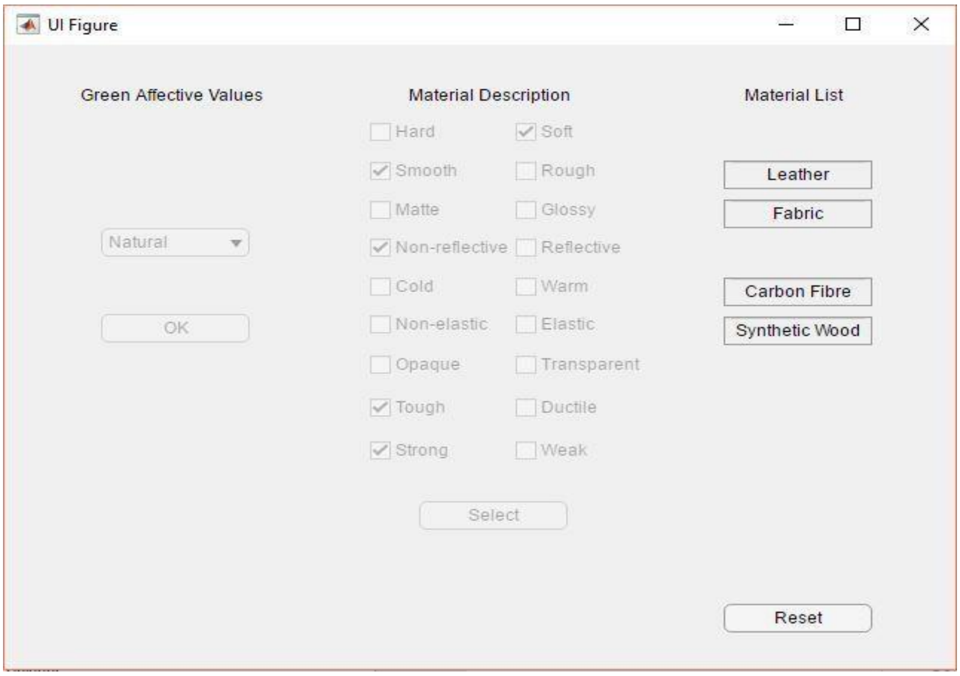

Fig 7 - Material list according to material descriptor

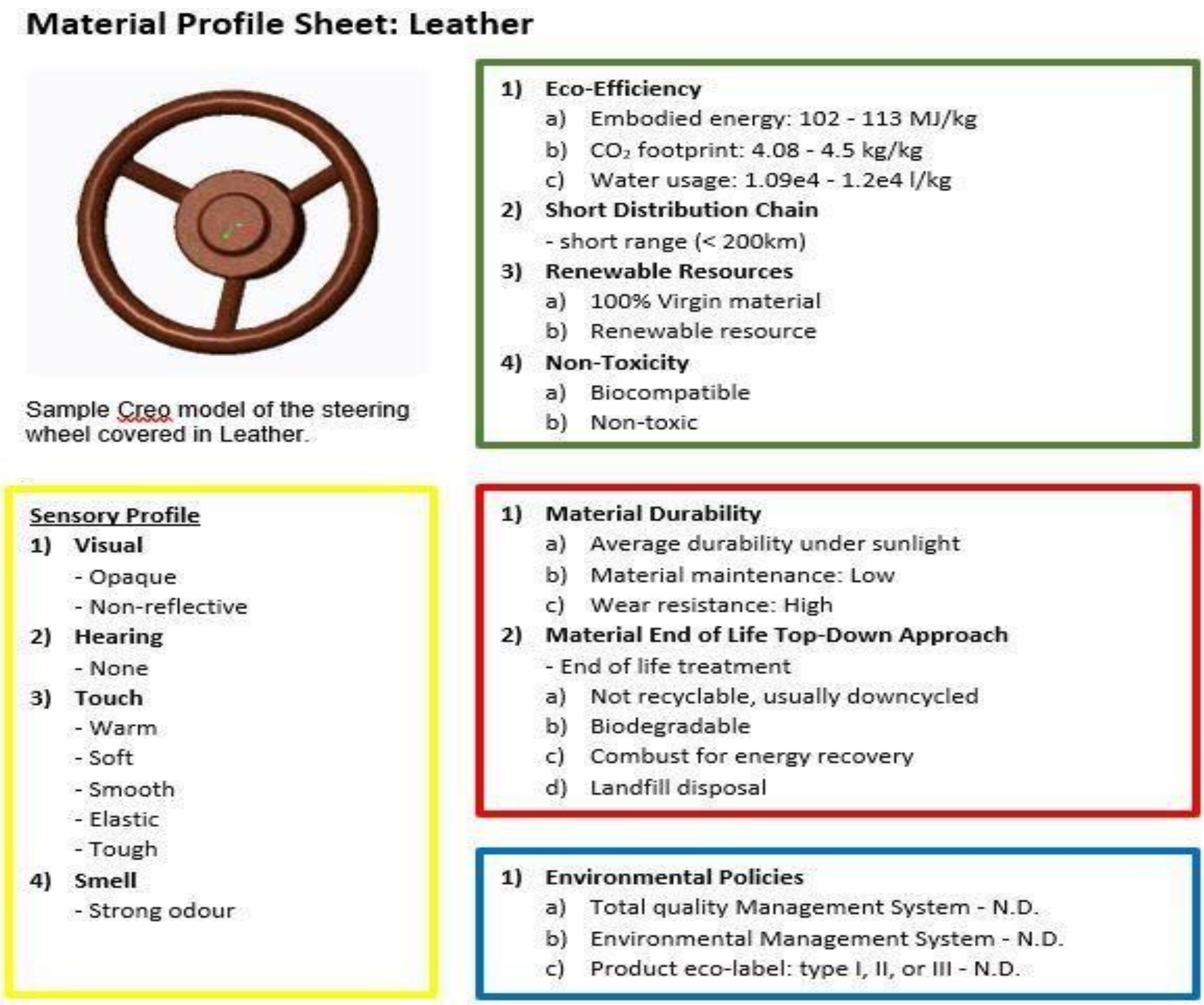

Fig. 8 - Long term product strategy and guidelines for material selection [16]

The third subset, “Ethics”, relates to the material manufacturer’s ethics and policies. This guideline must be complied by the material manufacturer and is a reference for car designers to gauge the manufacturer’s responsibility and behaviour towards the environment. Each manufacturer must be able to produce a certification for its manufacturing processes of the material in conjunction with their company’s environmental mission.

These resulting guidelines were the basis of the development of a material selection scorecard for a car steering wheel. The quantitative method used here to calculate how many material properties that satisfy the selected guidelines for a car was based on a combination of cold logic, which takes on the constraints-objectives-documentation format [19], and fuzzy logic for the scoring system [20]. Under each guideline that must be complied with, there were multiple constraints found from a quick search on the net. For example, there is a limit to the embodied energy (<100MJ/kg) of a steering wheel material under the eco-efficiency guideline. Fuzzy logic is used here, so if the material properties satisfy this requirement, the truth value will be 1, and 0 for vice versa. For some constraints like UV durability, the truth value may be any number in between 0 and 1. The scores of all four materials were then totaled up for each constraint and the material with the highest score will be the best selection for this case, as shown in Table 1.

Table 1 - Material selection scorecard for a “Natural” steering wheel

Guideline \ Material	Leather	Polyester	Synthetic Wood	Carbon Fibre
Use of Materials with Low Environmental Impact				
1. Eco-Efficiency	**1**	**3**	**3**	**0**
i. Embodied energy below 100 MJ/kg	0	1	1	0
ii. CO2 footprint below 5.0 kg/kg	1	1	1	0
iii. Water usage below 1000 l/kg	0	1	1	0
2. Renewable Resources	**1**	**0.5**	**1**	**0**
i. Percentage recycled to virgin material (0 = 0%, 1 = 100%)	0	0.5	0.5	0
ii. Renewable resource	1	0	0.5	0
3. Non-Toxicity	**2**	**1**	**2**	**2**
i. Biocompatible	1	1	1	1
ii. Non-Toxic	1	0	1	1
Material Lifetime Extension				
4. Material Durability	**2.5**	**1.5**	**3**	**3**
i. Durability under sunlight (0 for poor, 1 for good)	0.5	1	1	1
ii. Material maintenance (0 for high, 1 for low)	1	0.5	1	1
iii. Wear resistance (0 for low, 1 for high)	1	0	1	1
5. Material End of Life Top-Down Approach	**1**	**2**	**2**	**1**
i. Recyclable	0	1	1	0
iii. Combustible for energy recovery	1	1	1	1
Ethics				
6. Environmental Policies	**3**	**3**	**3**	**3**
i. Total quality Management System	1	1	1	1
ii. Environmental Management System	1	1	1	1
iii. Product eco-label: type I, II, or III	1	1	1	1
TOTAL	**10.5**	**11**	**14**	**9**

The purpose of this scorecard is to make a trade-off on the material selection process as different sections of a car design will have different criterion importance or objectives to be met. In Table 1, when consumers want a “Natural” feel to their steering wheel as well as a specific combination of sensory properties, the Eco-tool suggested four materials which were Leather, Polyester, Synthetic Wood, and Carbon Fibre.

4. Results and Discussion

From the first survey, five most commonly used materials were selected by participants for steering wheel that are Synthetic Wood, Polyurethane, Leather, Carbon Fibre, and ABS Plastic, Leather was the most popular among the participants, with 28 out of 42 of them choosing it as their preference. About 10 participants suggested and chose another material that was not included on the list, which was Polyester. When asked to rate the intensity of their feeling elicited from their choice of material, “Comfortable”, “Natural”, and “Clean-looking” were selected as the strongest affective values. In the second survey, the lowest scoring affective values from the first survey like “Youthful”, “Eco- friendly”, and “Proud” were removed and replaced with new affective values like “Pleasant”, “Elegant”, and “Vital” which obtained from journal articles [4] [8]. When the 51 participants are presented with visual stimuli in the form of 10 pictures portraying environmentally friendly practices, the two adjectives that appeared most often were “Natural”, and “Elegant” in descending order. For the third survey, according to the responses of 21 participants, the sensory properties that relate best to a “Natural” material feel were Soft, Smooth, Matte, Non-reflective, Cold, Elastic, Tough, and Strong. This data was used to code the link between the green affective value and its sensory properties in the Eco- tool, shown in Fig. 6. As for an “Elegant” material feel, the results obtained were Hard, Smooth, Matte, Non-reflective, Opaque, Tough, and Strong. Table 2 below summarized the affective values from second and third surveys.

Table 2 - Summary of affective values chosen from the survey

	Number of participants	Chosen Affective Values	Material’s feeling
Second survey	51	Natural	-
		Elegant	-
Third survey – relation of affective values to material’s feeling	21	Natural	Soft, Smooth, Matte, Non-reflective, Cold, Elastic, Tough, and Strong
		Elegant	Hard, Smooth, Matte, Non-reflective, Opaque, Tough, and Strong

The result from the survey showed that for each choosen affective value is linked to the feeling on material. This agrees well with research carried out by [21] that material used in a product relate to affective values and evoke emotions of the user. It is imperative to incorporate material experience in design stage knowing that user will interact with product and greater material experience will increase product likeability. Therefore, the proposed method can assist designer in translating the user feeling towards product into actual design. As a result, this method will increase user’s confident and pleasant experience of using the product.

In affective design, the consumer expectations are treated as target feeling. For example, the target feeling may be specified as ‘‘Natural’’, and the design translated this meaning into material feeling that is soft, smooth, matte, non reflective, cold, elastic and strong as indicated in the survey result. This approach enables the development of a product to incorporate user preferences.

Integration of green affective value with material selection is done using material scorecard as depicted in Table 1. After getting material list from eco-tool, material selection will be carried out using material scorecard. In this stage, material will be evaluated based on its ecological compatibility. Ecological profile of material is generated from the database and score for each material is obtained. The designer can gather all of these information to select the best material with greater eco compatibility. This can be used as a guideline for product designer to evaluate the eco compatibility of their design while conducting material selection activity, thus it will shorten design time. In design, material selection is very critical that can influence budgetary decision of product development [22] and also how users will experience of using those products [23]. From Table 1, synthetic wood had the highest score among the four of materials because it satisfied most of the constraints under all three guidelines and was the most eco-compatible material to be used on the steering wheel for that particular green affective value. Synthetic wood is an artificial wood products made of composite and are widely accepted as a durable alternative to natural wood. Its environmental impact is depending on the composition of renewable and non renewable materials. It has high durability, eco efficiency as well as more recyclable compared to other materials that listed in Table 1. Although it has impressive environmental profile, designer need to further examine of the material cost aspects. This is to ensure comprehensive material selection analysis has been carried out and best material for this particular design can be obtained.

From the result, it is evident that designers can have greater material analysis with regards of environmental profile as well as the linkage with user’s view before selecting materials. The current approach also offers advantages in developing an affective design. First, the proposed design approach is suitable for the designers to modify existing products in order to expand the targeted user groups.

5. Validation

Validation is conducted by getting feedback from the experts on the Eco-tool and material scorecard. Two product designers and one automotive expert are involved in the validation stage. The validation is conducted in two stages firstly, a briefing is conducted to present the proposed tool. Secondly, a discussion is carried to obtain the feedback. From the feedback, it is found that the tool is quite easy to understand and navigate thus help them to incorporate the affective value into the design. Some areas of improvement are also identified by experts as follows:

1. The sample size and database of the affective values must be expanded to give car designers a variety of choices.
2. It was suggested that for the material selection study, the participants must be given a sample of the material to touch and feel the texture so that give a more accurate affective value and material sensory properties in the results.
3. Inclusion of cost and technical aspects in the scorecard will add benefit for designer’s decision making.

6. Conclusion

From this study it is evident that affective values can be incorporated into many aspects of automotive design. Linkage with the material selection has presented in the case study of car's interior components showed a systematic approach to obtain materials preference using the scorecard. It was also found that by choosing specific feelings elicited by consumers when they visualize the texture and feel of their preferred material on a particular component such as a steering wheel, the designers able to link customers' feeling into the material's eco-properties which will indirectly benefit the environment. The Eco-tool and custom scorecard were designed with two research keys namely environmental and perceptual aspects to assist the designer in the material selection process using the trade-off method. This proposed design guideline also covered the research area of a car's aesthetic eco-design, which was less studied in the literature. By following the proper guidelines, it is possible to select the most suitable materials in the effort of developing a greener and more sustainable car in the future without sacrificing user satisfaction. Further study is required in other parts of car design, the material and affective value database have to be expanded, and other factors like cost need to be included in the trade-off method during the material selection process. By tweaking the methodology to suit the usage context, this guideline can also be used for other product eco-design in a multitude of industries.

References

[1] Hsiao, S. W., & Chen, C. H. (1997). A semantic and shape grammar based approach for product design. Design Studies, 18(3), 275-296.

[2] Jindo, T., & Hirasago, K. (1997). Application studies to car interior of Kansei engineering. International Journal of Industrial Ergonomics, 19(2), 105-114.

[3] Moulson, T., & Sproles, G. (2000). Styling strategy. Business Horizons, 43(5), 45-52.

[4] Nagamachi, M. (1995). Kansei Engineering: A new ergonomic consumer-oriented technology for product development. International Journal of Industrial Ergonomics, 15(1), 3-11.

[5] Fan, K. K., Chiu, C. H., & Yang, C. C. (2014). Green technology automotive shape design based on neural networks and support vector regression. Engineering Computations, 31, 1732-1745.

[6] Seva, R. (2017). B5-1 Integrating Affective Requirements in Car Design Methodologies. The Japanese Journal of Ergonomics, 53, S540-S543.

[7] Lai, H. H., Chang, Y. M., & Chang, H.-C. (2005). A robust design approach for enhancing the feeling quality of a product: a car profile case study. International Journal of Industrial Ergonomics, 35(5), 445-460.

[8] Kim, S., Cho, Y., Niki, K., & Yamanaka, T. (2016). Integrating affective values to sustainable behaviour focused on Kansei engineering. International Journal of Sustainable Engineering, 9(6), 378-389.

[9] Desmet, P., Hekkert, P., & Jacobs, J. (2000). When a car makes you smile: Development and application of an instrument to measure product emotions. Advances in Consumer Research, 27, 111-117.

[10] Anderson, L. W., & Bourke, S. F. (2013). Assessing affective characteristics in the schools. Hoboken: Taylor and Francis.

[11] Nagamachi, M. (1997). Kansei engineering: the framework and methods. In Kansei Engineering 1 (pp. 1-9): Kaibundo Publishing co. Ltd.

[12] Schütte, S. T. W., Eklund, J., Axelsson, J. R. C., & Nagamachi, M. (2004). Concepts, methods and tools in Kansei engineering. Theoretical Issues in Ergonomics Science, 5(3), 214-231

[13] Nagamachi, M. (1999). Kansei Engineering and its Applications in Automotive Design.

[14] Osgood, C. E., Suci, G. J., & Tannenbaum, P. H. (1957). The measurement of meaning. Oxford, England: Univer. Illinois Press.

[15] Yun, M. H., You, H., Geum, W., & Kong, D. (2004). Affective Evaluation of Vehicle Interior Craftsmanship: Systematic Checklists for Touch/Feel Quality of Surface-Covering Material. Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 48(6), 971-975.

[16] Karana, E., Hekkert, P., & Kandachar, P. (2009). Meanings of materials through sensorial properties and manufacturing processes. Materials & Design, 30(7), 2778-2784.

[17] M., N. (2001). Workshop 2 on Kansei Engineering. Paper presented at the Proceedings of International Conference on Affective Human Factors Design, Singapore.

[18] Allione, C., De Giorgi, C., Lerma, B., & Petruccelli, L. (2012). From ecodesign products guidelines to materials guidelines for a sustainable product. Qualitative and quantitative multicriteria environmental profile of a material. Energy, 39(1), 90-99.

[19] Nationwide. (2017, 10 June). How long do cars last? How you can maximize your car's life expectancy [Infographic]. Retrieved from https://blog.nationwide.com/how-long-cars-last-infographic/

[20] Abulifa, A. A., Che Soh, A., Hassan, M. K., Raja Ahmad, R. M. K., & Mohd Radzi, M. A. (2019). Energy Management System in Battery Electric Vehicle Based on Fuzzy Logic Control to Optimize the Energy Consumption in HVAC System. International Journal of Integrated Engineering, 11(4).
[21] Ashby, M. F. (2013). Material selection strategies. In M. F. Ashby (Ed.), Materials and the Environment (Second Edition) (pp. 227-273). Boston: Butterworth-Heinemann.
[22] Ludden, G.D.S., Schifferstein, H.N.J., Hekkert, P., (2008). Surprise as a design strategy. Design Issues 24 (2), 28-38.
[23] Karana, E., Pedgley, O and Rognoli, V. (2014). Material Experience: Fundamentals of Materials and Design. Butterworth-Heinemann.