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Sustainability Assessment Model in Product Development

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Abstract. Faster and more efficient development of innovative and sustainable products has become the focus for manufacturing companies in order to remain competitive in today's technologically driven world. Design concept evaluation which is the end of conceptual design is one of the most critical decision points. It relates to the final success of product development, because poor criteria assessment in design concept evaluation can rarely be compensated at the later stages. Furthermore, consumers, investors, shareholders and even competitors are basing their decisions on what to buy or invest in, from whom, and also on what company report, and sustainability is one of a critical component. In this research, a new methodology of sustainability assessment in product development for Malaysian industry has been developed using integration of green project management, new scale of "Weighting criteria" and Rough-Grey Analysis. This method will help design engineers to improve the effectiveness and objectivity of the sustainable design concept evaluation, enable them to make better-informed decisions before finalising their choice and consequently create value to the company or industry. The new framework is expected to provide an alternative to existing methods.

1. Introduction

In today's industries, product design has become the main focus in a highly competitive environment and fast-growing global market [1]. The benchmarks used to determine the competitive advantage of a manufacturing company are customer satisfaction, shorter product development time, higher quality and lower product cost [2, 3]. To meet this challenge, new and novel design methodologies that facilitate the acquisition of design knowledge and creative ideas for later reuse are much sought after. In the same context, Liu & Boyle [4] highlighted that the challenges currently faced by the engineering design industry are the need to attract and retain customers, the need to maintain and increase market share and profitability and the need to meet the requirements of diverse communities.

Concept selection or criteria assessment which is made in the early phases of design process is among the most important activities in new product development, as the consequences of a poor choice may be disastrous at worst [5]. Tools, techniques and methods are being developed that can support engineering design with an emphasis on the customer, the designer and the community [6].



Thus, a good design process should take into account the aforementioned criteria as early as possible in order to ensure the success of a product [7].

Recently, the growth in demand for the manufacturing products with the sustainability conditions are keep increasing. Most of the companies in Malaysia must extremely zealous to compete each other in producing a sustainable product without neglecting their financial side. In addition, our automotive industry is experiencing an utterly rapid improvement in the engineering phase of bringing forth a good quality goods. Nonetheless, the assessment of the sustainability requirements in the automotive sector in our country are not comprehensively covers the elements needed in the green practices.

Views from the Bursa Malaysia is clearly justified that they are strongly support the sustainability practices in our Malaysia industries. They are really devoted in creating the green environment practices in the industries all over our country. Therefore, all of the registered companies that have been patronage under the Bursa Malaysia must have the elements of the sustainability practices in their working area comprehensively [8].

In order to fulfil this current requirements, we have been motivated to apply the green project management concept (P5) as our guideline in encouraging the sustainability assessment in the concept design of the product released in the automotive industry. Hence, an exhaustive sustainability report surely can be prepared by the firms itself as required in the Bursa Malaysia.

Equally important in this topic is the sustainability assessment in the concept design evaluation phase of a product is the utmost important issue since it will measure the fulfilment of the criterions needed in the integration of the sustainability endeavours. The convergences of this process will then followed by the preparation of the sustainability reports. However, the existed sustainability practices and reports are only concern on the environment, social and financial. Thence, to overcome the dearth in the reports, the green project management concept (P5) is taken to be as a guideline in order to measure the level of the sustainability practices extensively in the design concept evaluation phase including the process and the product in the automotive industry itself. This effectual measurement tool will guide the automotive industry on how to gain a sustainability product design especially in our Malaysia context of business industry.

United Nations (UN) Global Compact is generally known as an outstanding corporate citizenship which is a very inventive towards sustainability by coordinating effectual strategies and performances. In order to sustain such a green environment company, the UN Global Compact is designed to help those companies all over the world by preparing the policy platform and guiding them with a productive practical framework. Apart from that, it will involve in promoting the advancements in a company by enacting those universal principle of human rights, labour standards, environment and anti-corruption. It is a trusted organisation that will ensure those business corporates to practice the sustainability practices by adding the values to social, planets and communities. In addition, they are guaranteeing that the implemented practices on a part will gives good implications without harming another part. The UN Global Compact is functioning by generating on the importance of sustainability and bringing it upward to summoning an event relating to the sustainability practices also helping to discover the best strategy to be best applied until our goals are achieved.

Over the years, various sustainability evaluation tools have been invented to fulfil the needed of solving the engineering issues in the sustainability judgements. It gives us such a hint that there are several deficiencies occurs in the measurement tools of the sustainability practices [9]. However, the existed method is not comprehensively covered those important aspects when referring to the sustainability practices in any sectors. To overcome this hurdle, we have expected to implement the green project management concept (P5) which is one of the UN Global Compacts' member. It comprises of the people, profit, planet together with the improvement addition of process and product. The green project management concept (P5) is operating to collaborates the current issues of the deterioration of our environment quality together with the economic growth alongside with the continuity of our mother of earth [10]. Apart from that, this method is ensuring the less damaged to the natural surrounding by providing the most effective guidelines towards the companies. Therefore,

when these good implications can be achieved, surely it will help the business longevity and profitability increments to be performed.

Main objective of this research is to develop sustainability assessment model to the R&D or design engineers to improve the effectiveness and objectivity of the design concept evaluation. The focus is on the automotive related product in the context of Malaysia industry.

2. Methodology

The depicted Figure 1 below shows how the general framework of the proposed approach.

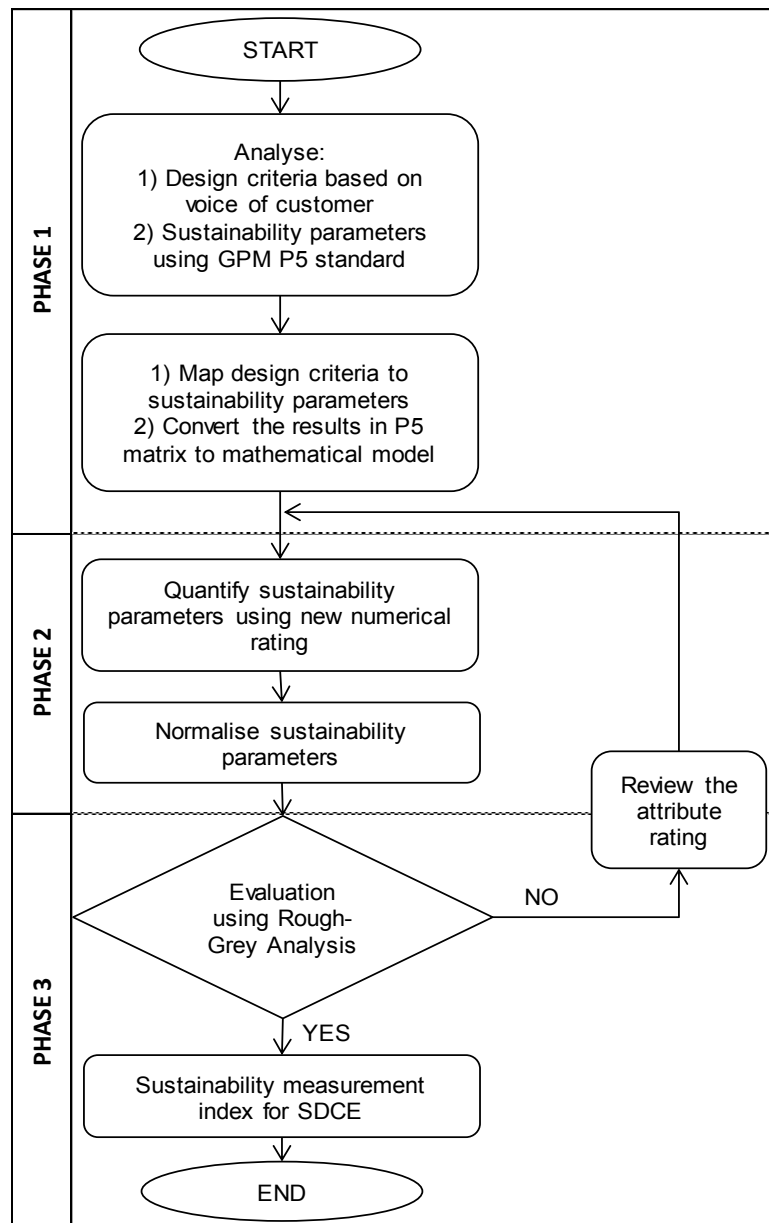


Figure 1. General framework of proposed approach

2.1. Map the design criteria to sustainability

The initial step of the model is to map the design criteria to sustainability parameters. The detail steps are described in the following paragraph [11]:

- Categorise and summarise voice of customers.

- (b) Analyse and translate voice of customers to relevant design criteria (product design specification).
- (c) Map each design criteria to relevant sustainability parameters. Mapping process will base on expert groups.

Table 1 shows the example of voice of customers and each relevant design criteria.

Table 1. Example of voice of customers and relevant criteria [1]

No.	Voice of customers	Relevant criteria
1	Product's cost/price?	Cost
2	Existing customer? Potential customer?	Customer
3	Type of materials used to produce this product?	Materials
4	Quality and reliability of the product?	Quality and reliability
5	Product's weight?	Weight
6	Total life of the product?	Product life span
7	Maintenance level in producing the product?	Maintenance
8	Does the product fulfil world's environmental standard?	Environmental
9	Disposal related to product assembly process?	Disposal
10	Product's performance?	Performance
11	Facilities used in producing the product?	Manufacturing facilities
12	Product's aesthetic?	Aesthetics, appearance and finish
13	Packing style for finished products?	Packing
14	Product's size?	Size
15	Standards and specifications of product?	Standards and specifications
16	Is the product competitive?	Competition
17	Does the product go through all required test?	Testing
18	Is the process of producing this product reliable?	Processes
19	Storage of finished products?	Shelf life (storage)
20	Quantity of each lot/batch?	Quantity
21	Product's service life?	Life in service
22	Safety level in producing the product?	Safety
23	Is there any patent conflict?	Patent, literature and product data
24	Internal constraints?	Company constraints
25	Shipment condition?	Shipment
26	Is the documentation available/completed?	Documentation
27	External constraints?	Market constraints
28	Is the process comfortable (human factors)?	Ergonomics
29	Time consuming?	Time-scales
30	Product's installation into the counter part?	Installation
31	Follow the procedure/legal aspect?	Legal
32	Any effect from political and social issue?	Political and social implications

2.2. Green project management concept integration matrix

The green project management concept (P5) integration matrix is describes in the following paragraph [10]:

- (a) Product impacts – objectives and efforts, lifespan and servicing
- (b) Process impacts – maturity and efficiency
- (c) Society (People) – labor practices and decent work, society and customers, human rights, ethical behavior
- (d) Environment (Planet) – transport, energy, water, waste

(e) Financial (Profit) – return on investment, business agility, economic simulation

2.3. Scale of “Weighting criteria”

The scale between 0 – 10 was developed to ease the respondents’ group for rating the evaluation criteria, which initially selected by the design engineers based on technical documents and the results of a prior survey. The rating value obtained from the survey then will be used to quantify the attribute ratings $\otimes v$ at later stage. Table 2 describes the scale of “Weighting criteria” in more detail.

Table 2. Scale of “Weighting criteria” [9]

Numerical rating	Description
0 – 0.4	Absolutely useless
0.5 – 1.4	Very inadequate
1.5 – 2.4	Weak
2.5 – 3.4	Tolerable
3.5 – 4.4	Adequate
4.5 – 5.4	Satisfactory
5.5 – 6.4	Good with few drawbacks
6.5 – 7.4	Good
7.5 – 8.4	Very good
8.5 – 9.4	Exceeding the requirement
9.5 – 10	Ideal

2.4. Method of quantifying the attribute ratings

The new method of quantifying the attribute ratings value, $\otimes v$ as described in the following paragraph:

(a) Develop the dummy attribute ratings chart for all criteria as shown Table 3.

Table 3. Dummy attribute ratings chart [12]

a_j	S_i	DM 1			...	...	DM K		
		$v_{ij Typ.}$	$v_{ij Min}$	$v_{ij Max}$	...	...	$v_{ij Typ.}$	$v_{ij Min}$	$v_{ij Max}$
a_1	S_1	V_{11}	$V_{11}-0.5$	$V_{11}+0.5$	...	..	V_{1K}	$V_{1K}-0.5$	$V_{1K}+0.5$
	S_2	V_{21}	$V_{21}-0.5$	$V_{21}+0.5$	...	...	V_{2K}	$V_{2K}-0.5$	$V_{2K}+0.5$

	S_n	V_{n1}	$V_{n1}-0.5$	$V_{n1}+0.5$	...	...	V_{nK}	$V_{nK}-0.5$	$V_{nK}+0.5$
...	
...	
a_7	S_1	V_{11}	$V_{11}-0.5$	$V_{11}+0.5$	...	..	V_{1K}	$V_{1K}-0.5$	$V_{1K}+0.5$
	S_2	V_{21}	$V_{21}-0.5$	$V_{21}+0.5$	...	...	V_{2K}	$V_{2K}-0.5$	$V_{2K}+0.5$

	S_n	V_{n1}	$V_{n1}-0.5$	$V_{n1}+0.5$	...	...	V_{nK}	$V_{nK}-0.5$	$V_{nK}+0.5$

(b) Determine the \underline{v}_{ij} and \bar{v}_{ij} using the following formula:

$$\underline{v}_{ij} = \frac{1}{K} [v_{ij}^1 Min + v_{ij}^2 Min + \dots + v_{ij}^K Min] \tag{1}$$

$$\bar{v}_{ij} = \frac{1}{K} [v_{ij}^1 Max + v_{ij}^2 Max + \dots + v_{ij}^K Max] \tag{2}$$

2.5. Procedure of the rough–grey analysis

The Rough-Grey Analysis approach is very suitable for solving the group decision-making problem in an environment of uncertainty. The attribute ratings $\otimes v$ for benefit attributes are shown in Table 4.

Table 4. The scale of attribute ratings $\otimes v$ for benefit attributes

Scale	$\otimes v$
Very poor (VP)	[0,1]
Poor (P)	[1,3]
Medium poor (MP)	[3,4]
Fair (F)	[4,5]
Medium good (MG)	[5,6]
Good (G)	[6,9]
Very good (VG)	[9,10]

The selection procedures are summarised as follows [13-15]:

- (a) Establishment of grey decision table.

Form a committee of DMs and determine attribute values of alternatives. Assume that a decision group has K persons and then the grey number value of attribute $\otimes v_{ij}$ can be calculated as:

$$\otimes v_{ij} = \frac{1}{K} [\otimes v_{ij}^1 + \otimes v_{ij}^2 + \dots + \otimes v_{ij}^K] = [\underline{v}_{ij}, \bar{v}_{ij}] \quad (3)$$

where i refers to alternatives, while j refers to different attributes; $\otimes v_{ij}^K = [\underline{v}_{ij}^K, \bar{v}_{ij}^K]$, ($i = 1, 2, \dots, m$; $j = 1, 2, \dots, n$) is the attribute rating value of the K th DM that is expressed by a grey number.

- (b) Normalisation of grey decision table.

Form a committee of DMs and determine attribute values of:

$$\otimes v_{ij}^* = \left[\frac{\underline{v}_{ij}}{v_j^{\max}}, \frac{\bar{v}_{ij}}{v_j^{\max}} \right] \quad (4)$$

where $v_j^{\max} = \max_{1 \leq i \leq m} \{\bar{v}_{ij}\}$.

For cost attributes, its normalised grey number value $\otimes v_{ij}^*$ is expressed as:

$$\otimes v_{ij}^* = \left[\frac{v_j^{\min}}{v_{ij}}, \frac{v_j^{\min}}{\underline{v}_{ij}} \right] \quad (5)$$

where $v_j^{\min} = \min_{1 \leq i \leq m} \{v_{ij}\}$.

The normalisation method mentioned above is to preserve the attribute that the ranges of normalised grey numbers belong to $[0, 1]$.

- (c) Determination of the suitable alternatives.

- (d) In order to reduce unnecessary information and maintain the determining rules, we determine the suitable alternatives by a grey-based rough set with lower approximation. The lower approximation of suitable alternatives S^* are determined by:

$$\underline{RS}^* = \{S_i \in U \mid [S_i]_R \subseteq S^*\} \quad (6)$$

where $S^* = \{S_i \mid d_i = \text{yes}\}$.

- (e) Making the ideal alternative for reference.

According to \underline{RS}^* obtained from equation (6), we determinate the ideal alternative S^{\max} for reference by:

$$S^{\max} = S_0 = \left\{ \begin{array}{l} \left[\max_{\forall i} v_{i1}^*, \max_{\forall i} v_{i1}^- \right] \\ \left[\max_{\forall i} v_{i2}^*, \max_{\forall i} v_{i2}^- \right] \\ \dots, \left[\max_{\forall i} v_{im}^*, \max_{\forall i} v_{im}^- \right] \end{array} \right\} \quad (7)$$

- (f) Selection the most suitable alternative.

The grey relational coefficient (GRC) of $\otimes x_i$ with respect to $\otimes x_0$ at the k th attribute, is calculated as [16]:

$$\gamma(\otimes x_0(k), \otimes x_i(k)) = \frac{\Delta \min + \rho \Delta \max}{\Delta_{0i}(k) + \rho \Delta \max} \quad (8)$$

where

$$\Delta \max = \max_{\forall i, \forall k} L(\otimes x_0(k), \otimes x_i(k)) \quad (9)$$

$$\Delta \min = \min_{\forall i, \forall k} L(\otimes x_0(k), \otimes x_i(k)) \quad (10)$$

$$\Delta_{0i}(k) = L(\otimes x_0(k), \otimes x_i(k)) \quad (11)$$

$L(\otimes x_0(k), \otimes x_i(k))$ is the Euclidean space distance of $\otimes x_0(k)$ and $\otimes x_i(k)$ which is calculated by equation below:

$$L(\otimes x_1, \otimes x_2) = \sqrt{(\underline{x}_1 - \underline{x}_2)^2 + (\bar{x}_1 - \bar{x}_2)^2} \quad (12)$$

ρ is the distinguishing coefficient, $\rho=[0, 1]$. The grey relational grade (GRG) between each comparative sequence $\otimes x_i$ and the reference sequence $\otimes x_0$ can be derived from the average of GRC, which is denoted as:

$$\Gamma_{0i} = \sum_{k=1}^n \frac{1}{n} \gamma(\otimes x_0(k), \otimes x_i(k)) \quad (13)$$

where Γ_{0i} represents the degree of relation between each comparative sequence and the reference sequence. Through the calculation of GRG between comparative sequences RS^* with reference sequence S^{\max} , the alternative corresponding to the maximum value of GRG can be considered as the most suitable alternative.

3. Conclusion

This sustainability assessment model in product development is expected to benefit design engineers or project managers in the Malaysia context in producing sustainability reporting, strengthening brand equity, progressing vision and strategy, reducing compliance costs and advantage in competition. Furthermore, it enables the designers to make a better-informed decision which incorporated with sustainability assessment result before finalising the best design concept. This model will also help both private sector and the government which associated with decision-making process.

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