

PAPER • OPEN ACCESS

Evaluation and its Method of Green Design of Industrial Products from the Perspective of Symbiosis

To cite this article: Zhijin Xu and Yankui Song 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **573** 012098

View the [article online](#) for updates and enhancements.

Evaluation and its Method of Green Design of Industrial Products from the Perspective of Symbiosis

Zhijin Xu¹ and Yankui Song^{2*}

¹ School of Management, Capital Normal University, Beijing, 100056, China

² College English Department, Capital Normal University, Beijing, 100048, China

* Corresponding author's e-mail: sylviasong@163.com

Abstract. Green design of industrial products is an important part of the core competitiveness of enterprises. On the basis of symbiosis theory, this paper analyzes systematically the evaluation index system and the corresponding evaluation method of green design of industrial products from the research perspective of symbiotic relationship among the factors of human-machine-environment-society system. The author holds that the symbiotic relationship among products, human, technology, resources, economy, society, environment and others, which are mutual coordination, mutual integration, mutual restriction and mutual benefit, is the fundamental analysis framework and research perspective of green design evaluation of industrial products. It is the premise and foundation in the research of green design evaluation and is of important strategic significance to determine the reasonable research perspective and analysis framework. From the perspective of symbiotic relationship, the green design evaluation is a problem of multi-factor, multi-level and fuzzy comprehensive evaluation. Its evaluation index system, composed of a relatively independent set of indicators, can describe and represent the attributes and their symbiotic relationship among technology, resources, economy, society and environment. It is reasonable, feasible and has special advantages to select and apply the fuzzy comprehensive evaluation method in the green design evaluation.

1. Introduction

Green design of industrial products is the core of product development and market extension, constitutes an important part of enterprises' competitiveness and is receiving increasing attention. At present, scholars at home and abroad have achieved a lot of findings on the evaluation and its method of green design, but each has its own characteristics, showing different emphasis. Domestic scholars often focus on the interpretation of evaluation theory and the construction of evaluation model, establish the evaluation index system of green design from multi-dimension and multi-level, and emphasize rational analysis, logical proof and sufficient data, but they often have little relevance with users or pay insufficient attention to them. Expert opinions and suggestions are taken as the starting point and basis of evaluation[1-3]. While foreign scholars pay more attention to the evaluation of design process, construct the evaluation index system of green design from the perspective of the relationship among consumers, markets and products, emphasize perceptual judgment and experience summary, and take psychological experiments and users' feedback information as the starting point of evaluation and the basis of analysis so as to reflect users' personalized real feelings[4-5]. These diverse findings also embody the differences of green design in different national conditions and cultures.



This paper attempts to analyze and construct the evaluation criteria and the corresponding evaluation index system of green design of industrial products based on symbiosis theory, taking the human-machine-environment-society system and the *symbiotic relationship*[6] among products, human, technology, resources, economy, society and environment as an analysis framework and research perspective. Furthermore, Fuzzy Comprehensive Evaluation method (FCE)[7-8] is applied to the evaluation of green design and its scientific, effective and feasible evaluation method is drawn.

2. New research perspective of evaluation of green design

It is an important premise and foundation of research on the green design of industrial products to select and determine a reasonable research perspective and analysis framework. Considering that the green design of industrial products involves many factors, it is appropriate to evaluate it in the big system of human-machine-environment-society. Green design evaluation should not focus on the advantages and disadvantages of individual factors of human, machine, environment and society, but should treat products, human, environment and society as a system. It analyzes the characteristics of human, product, environment, society and etc. and their relationship among interaction, mutual coordination, mutual restriction and mutual benefit to achieve the optimization of the overall function through adjusting the system structure. In fact, a well-designed product must be compatible with human, technology, economy, society environment and others.

The relationship of coordination, ingenious integration and mutual benefit among various factors in human-machine-environment-society system constitutes a kind of symbiotic relationship. *Symbiosis* was originally a biological concept, first proposed in 1879 by Anton de Bary, a German mycologist. He defined it as “living together of different species”[6], that is to live together, being a permanent material connection among organisms to some extent. American biologist Lynn Margulis (1981) formally put forward the endosymbiosis theory in his book *Symbiosis in Cell Evolution* which gradually formed the general symbiosis theory. Since the end of the 20th century, symbiosis theory has been gradually expanded from biology to economics, management, pedagogy and other disciplines and many important findings have been achieved. So it has received more and more attention and recognition.

In this paper, it is a new choice in the research perspective to study green design evaluation of industrial products under the analysis framework of human-machine-environment-society system, starting from this symbiotic relationship of coordination, ingenious integration and mutual benefit. It is not only necessary, but also significant to take the symbiotic relationship among products, human, environment and society as a new perspective of the evaluation of green design and thus to research systematically on the evaluation criteria and methods of green design in line with the needs of sustainable development of human beings.

3. Index system construction of evaluation of green design

It is a process of abstracting, generalizing and describing the green design of industrial products, and transforming the abstract concept into a real measurable variable or carrier to establish its evaluation index system. This is a cognitive process from concrete to abstract, and then from abstract to concrete, which unifies subjectivity and objectivity.

From the new research perspective of symbiotic relationship in the human-machine-environment-society system mentioned above, an evaluation index system of green design of industrial products (see Table 1) is preliminarily constructed, which consists of 25 relatively independent indicators through extensive document research and expert consultation[9-13]. This evaluation index system can better describe, characterize and represent the multiple evaluation criteria and requirements of green design. It reflects and embodies the symbiotic relationship among products, technology, resources, economy, society, human and environment and the goal of sustainable development. Due to space limitation, there is no further explanation about the specific connotation of the indicators in the above.

Table 1. Evaluation index system of green design of industrial products.

Objects evaluated	Evaluation factors (First level indicators)	Evaluation indicators (Second level indicators)
Evaluation index system of green design of industrial products	Technical attributes (U_1)	<i>Quality reliability (u_{11})</i>
		<i>Functional effectiveness (u_{12})</i>
		<i>Operational security (u_{13})</i>
		<i>Maintenance convenience (u_{14})</i>
		<i>Species diversity (u_{15})</i>
	Resource attributes (U_2)	<i>Material type (u_{21})</i>
		<i>Unit product resource consumption (u_{22})</i>
		<i>Utilization rate of resources (u_{23})</i>
		<i>Resource renewability (u_{24})</i>
	Economic attributes (U_3)	<i>Cost (u_{31})</i>
		<i>Product added value (u_{32})</i>
		<i>Profit benefit (u_{33})</i>
		<i>Industrialization degree (u_{34})</i>
		<i>Market share (u_{35})</i>
	Social attributes (U_4)	<i>Maintenance of social security (u_{41})</i>
		<i>Improvement of quality of life (u_{42})</i>
		<i>Permissibility of law and policy (u_{43})</i>
		<i>Social public satisfaction (u_{44})</i>
	Humanistic attributes (U_5)	<i>Human-computer interaction (u_{51})</i>
		<i>Aesthetics of Modelling (u_{52})</i>
		<i>Cultural integration (u_{53})</i>
	Environmental attributes (U_6)	<i>Water pollution degree (u_{61})</i>
		<i>Air pollution degree (u_{62})</i>
		<i>Noise pollution degree (u_{63})</i>
		<i>Waste Pollution degree (u_{64})</i>

4. Method selection of evaluation of green design

In order to evaluate the green design of industrial products scientifically and reasonably, we must also select the evaluation method on the basis of determining reasonably its constituent factors and evaluation index system. Among all kinds of evaluation methods, we think that it is more appropriate to select FCE in green design evaluation for which is essentially a multi-object, multi-factor, multi-level and fuzzy comprehensive evaluation problem.

The evaluation indicators are various in the problem of multi-object, multi-factor and multi-level comprehensive evaluation. Some are quantifiable and others are difficult to quantify. Traditional evaluation methods are effective for quantifiable indicators, but they often encounter great difficulties for non-quantifiable ones. When both indicators coexist in an evaluation index system, the traditional methods have great limitations. We must select new more reasonable and effective evaluation methods. FCE is the suitable one among them. By abstracting, generalizing and describing the various attributes of the evaluated objects, it can well deal with the relationship between quantifiable and non-quantifiable indicators with fuzzy operation and weight distribution. Finally, it reaches scientific and reasonable comprehensive evaluation results that can both reflect the subjective value judgment of the evaluator and can be measured in practice.

In fact, FCE has specific advantages, which is accepted and applied widely in many fields. It is a correct choice to apply FCE into the evaluation of green design, which is of great strategic significance for the sustainable development of an enterprise, an industry and even a country.

5. Models of comprehensive evaluation method of green design

The theoretical basis of comprehensive evaluation method of the green design of industrial products is the FCE models provided by fuzzy mathematics.

According to FCE[7], set $U=\{u_1, u_2, \dots, u_n\}$, u_i ($i=1, 2, \dots, n$) as the evaluation factor set; $V=\{v_1, v_2, \dots, v_m\}$, v_j ($j=1, 2, \dots, m$) as the comment set; and $A=(a_1, a_2, \dots, a_n)$, a_i ($0 \leq a_i \leq 1$) as the weight allocation; where $R=(r_{ij})=(r_{i1}, r_{i2}, \dots, r_{im})$, r_{ij} ($0 \leq r_{ij} \leq 1$, $i=1, 2, \dots, n$, $j=1, 2, \dots, m$) as the single factor evaluation. Thus, a comprehensive evaluation model of multiple operators $M(\overset{\bullet}{\star}, \overset{+}{\star})$ is given:

$$AoR = B = (b_1 b_2 \dots b_m) \quad (1)$$

Where,

$$b_j = (a_1 r_{1j})(a_2 r_{2j}) \dots (a_n r_{nj}) \quad (j=1, 2, \dots, m)$$

Let \circ be operators of fuzzy compound operation. They are the generalized operators $\overset{\bullet}{\star}$ (fuzzy *and* operations) and $\overset{+}{\star}$ (fuzzy *or* operations). In theory, there are various generalized fuzzy operations, but only five specific models have been proposed up to now[8]. Operators of different fuzzy compound operations have different attributes and characteristics, play different roles and embody different comprehensive evaluation ideas and purposes. Therefore, the selection of operators of fuzzy compound operations is of important guiding significance.

To divide the factor sets into different levels, the above model can be applied to multi-level factors, and the evaluation results of each level are the input of the upper level evaluation in sequence until to the top level. Thus, the final fuzzy comprehensive evaluation results can be obtained.

Specifically, the general process of comprehensive evaluation of green design with the FCE models includes the following steps.

Firstly, establish an evaluation index system to determine the corresponding evaluation factor set U . According to Table 1, the evaluation factor set of the green design of industrial products $U=\{U_1, U_2, U_3, U_4, U_5, U_6\}=\{\text{technical attributes, resource attributes, economic attributes, social attributes, humanistic attributes, environmental attributes}\}$.

Secondly, determine the evaluation grades and criteria so as to establish the comment set V . Generally, an evaluation group consisting of several experts (usually 9-13) of different categories will conduct peer reviews, and establish a corresponding comment set for evaluating green design of industrial products $V=\{v_k\}=\{v_1, v_2, v_3, v_4, v_5\}=\{\text{Excellent, Good, Medium, Qualified, Unqualified}\}$ ($k_{\max}=5$).

Thirdly, determine the weight $A=\{a_i\}$ of evaluation indicators. It is an important link and soul in the comprehensive evaluation of green design of industrial products. There are many methods to determine the weights. Some emphasize the subjective experience, simple and easy to implement, but with poor objectivity; while others are objective, but complicated in their analysis and calculation. Therefore, they should be selected according to the actual situation.

Fourthly, evaluate the single factors and obtain the single factor fuzzy comprehensive evaluation matrix $R=\{R_i\}$. Single factor fuzzy evaluation evaluates each indicator u_{ij} separately in subset U_i , and that is, each secondary indicator u_{ij} in the factor U_i can be evaluated as the subordinate degree r_{ij} of every grade v_k .

Fifthly, determine the fuzzy comprehensive evaluation model $M(\overset{\bullet}{\star}, \overset{+}{\star})$. When weight A and single factor fuzzy comprehensive evaluation matrix R are known, the comprehensive evaluation can be carried out by the compound operation of fuzzy matrix, and the evaluation model of fuzzy comprehensive evaluation can be obtained.

Sixthly, obtain finally the results B of fuzzy comprehensive evaluation. When matrices R_i and weights a_i of index u_{ij} are known by the single factor fuzzy comprehensive evaluation, the results $B_i=a_i \circ R_i$ of single factor fuzzy evaluation can be obtained through fuzzy compound operations (1).

On the basis of single factor fuzzy evaluation, a higher level of fuzzy comprehensive evaluation can be continued. That is, take the results B_i ($i=1, 2, \dots, m$) of single factor fuzzy evaluation as the matrix $R=\{B_i\}$ ($i=1, 2, \dots, m$) of higher level fuzzy comprehensive evaluation, combine with weight A of single factor U_i by the fuzzy compound operation (1), and then obtain a higher level of fuzzy comprehensive evaluation results $B=A \circ R$. Finally, continue the steps until the result B of the fuzzy comprehensive evaluation of green design is obtained:

$$B=A \circ R=[a_1, a_2, a_3, a_4, a_5] \circ [B_1, B_2, B_3, B_4, B_5]^T \quad (2)$$

In this way, according to the principle of maximum subordination, we can obtain and determine the comprehensive evaluation value of green design of industrial products and its results of technical, resource, economic, social, humanistic and environmental attributes which belong to different grades of excellent, good, medium, qualified and unqualified by Formula (2).

Due to space limitation, only the general process of comprehensive evaluation of green design of industrial products is shown by FCE without specific case analysis.

6. Conclusion

The evaluation of green design of industrial products is essentially a fuzzy comprehensive problem of multi-object, multi-factor and multi-level. The premise and foundation of solving this problem are to select and determine a reasonable research perspective and analysis framework. Its key is to construct the evaluation criteria and apply the evaluation method correctly. The widely applied FCE method is effective and advantageous in solving and dealing with the comprehensive problem. With this method we can better judge and evaluate whether an industrial product design is good or bad and whether it can support and meet the needs of sustainable development of human beings. It is of great important, decisive and guiding significance to allocate indicator weights and to select compound operators rationally.

In a word, the research on the evaluation and its method of green design of industrial products is important and still needs to be explored continuously for the further optimization of human-machine-environment-society system and the symbiotic development of products, human, technology, resources, economy, society and environment.

Acknowledgments

The paper is funded by the soft science project from the Talent Centre of the Ministry of Science and Technology (2017-2019).

References

- [1] Ke, S.J., Liu, H.J. (2010) Research on product modelling evaluation technology based on brand image. *Packaging Engineering*, 18: 21–24.
- [2] Liu, T.J. (2016) Application of green design in industrial product. *China Packaging Industry*, 02: 11–14.
- [3] Pan, P., Yang, S.X. (2013) Evaluation system and evaluation method of products style design. *Mechanical Design and Research*, 10: 19–22.
- [4] Li, Y., Chen, H. (2005) *Green Design Methodology for Industrial Products*. Tsinghua University Press, Beijing.
- [5] Wang, L.L., et al. (2018) Application of green design in industrial product. *Grass-roots Construction*, 02: 17–18.
- [6] Yuan, C.Q. (1998) *Symbiosis Theory and Small Economy*. Economic Science Publishing House, Beijing.
- [7] Wang, P.Z. (1980) Introduction to fuzzy mathematics. *Practice and Understanding of Mathematics*, 02-03: 5–12.
- [8] Liu, Y.Y., et al. (1983) Mathematical model of comprehensive evaluation. *Fuzzy Mathematics*, 1: 23–26.
- [9] Xie, J.P., Chen, R.Q. (2003) Three-dimensional fuzzy evaluation model for green design of industrial products. *Journal of Huazhong University of Science and Technology (Natural Science Edition)*, 06: 15–18.
- [10] Wang, C.P. (2009) Constructing the evaluation index system of green design. *Packaging Engineering*, 12: 8–11.
- [11] Liang, C.W., et al. (2013) Construction of evaluation index system for green design of industrial products in Foshan. *Modern Economic Information*, 11: 25–28.

- [12] Wan, L. (2015) Application of green design in industrial product. *Industrial Design*, 08: 17–20.
- [13] Xing, P.H. (2017) On the application of green design in industrial product. *Design*, 13: 9–12.