IOP Conference Series: Materials Science and Engineering

PAPER • **OPEN ACCESS**

The Application Research of Fuzzy Mathematics in Design Quality Evaluation of Industrial Product

To cite this article: Wenming Liu and Jiajun Leng 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **573** 012015

IOP Conf. Series: Materials Science and Engineering **573** (2019) 012015 doi:10.1088/1757-899X/573/1/012015

The Application Research of Fuzzy Mathematics in Design Quality Evaluation of Industrial Product

Wenming Liu [1*], Jiajun Leng [1]

[1] School of Design and Art, Shenyang Jianzhu University, Shenyang, LiaoNing, ,110168, China

[*]Corresponding author's e-mail: 83373734@qq.com

Abstract. The applying of Fuzzy Mathematics theory of evaluation and decision method is applied to single or comprehensive evaluation of design quality of industrial products by using scientific mathematical model and the formula model which can be applied directly is given by examples. It solves the problem that there is no scientific, accurate and comprehensive evaluation on the fuzzy concept of industrial product design quality. Introducing one scientific evaluation method which can evaluate design quality of industrial products by using Fuzzy Mathematics for relevant people who are engaged in judging design quality. It also provides relatively direct and specific reference basis and direction for industrial design practitioners to improve design quality.

1. Preface

With the rising steadily of the industrial design in China, industrial capability in China has also increased all these years, new industrial design products have also emerged, but the quality of some of these new products are only common level. How to make a scientific and comprehensive evaluation of the quality of industrial products design, what kind of industrial products are good products? This issue has been raised.According to the commonly used evaluation method, the experts of the relevant professional disciplines score the product design quality, and take the average value after removing the highest and lowest scores for all the scores.The evaluation of the design quality of industrial products by this method can only obtain a specific value.But the evaluation results are not objective and comprehensive.If we use the evaluation method in fuzzy mathematics theory, the product design quality can be evaluated more scientifically, which can make the evaluation reasonable, more scientific and comprehensive.

The industrial product design quality evaluation elements usually have the following aspects:

① Functional elements:

Function refers to the utility or function of the product, and the ability to be accepted. The product needs to have a certain function to be able to produce and sell. Therefore, the product is essentially the carrier of the function, and the realization of the function is the ultimate goal of the product design.

②Structural elements:

If the product function is the external connection between the system and the environment, then the structure is the connection of the elements within the product system.The structure is the bearer of the product function, structure determines the realization of the product function. The structure is both the bearer of the function and the product form.

③Human factors:

Human factors are related to people which can be extended to human factors engineering. It covers a wide range of factors including ergonomics, psychological, sociological elements and aesthetic elements.

④ Formal elements:

Form generally refers to the form of things under certain conditions. Form is the external manifestation of the internal structure of a product in design terms. There are many factors related to morphology, the formal aesthetic law lays the foundation for the evaluation factor selection.

⑤color elements:

Color is one of the most sensitive form factors that can infect people's aesthetic emotions, color can also cause people's aesthetic pleasure. Colors, like the form, have similar language functions and can convey semantic meaning. In the color design, the association is often generated by color, on the other hand, color and form are regarded as symbols together, and the color symbol suggestion function is utilized to convey the intention.

⑥ Environmental elements:

Environmental factors must be considered in product design because products causing environmental problems at every stage of the life cycle.

2. Single evaluation and comprehensive evaluation.

A certain factor or part of an object or category is evaluated according to certain criteria, called a single evaluation. Obtaining an overall evaluation of an object or categories of objects from a multitude of individual evaluations is called a comprehensive evaluation. The purpose of comprehensive evaluation is usually to hope that several objects can be sorted according to a certain meaning, pick the best or the worst objects from these objects. called the decision process. Comprehensive evaluation is also a type of decision-making process.

3. Evaluation method:

3.1. the traditional method:

3.1.1. the total score method:

Set ‘n’ factors for one object, we evaluate a sore ‘S_i’ for every factor, find sum.

$$s = \sum_{i=1}^{n} s_i$$

‘S’ is the evaluate standard of the object. For example, the results of the pentathletes, the college entrance examination qualifying line, etc., are all adopted

3.1.2. weighted average method:

Set ‘n’ factors for one object, we evaluate a sore ‘S_i’ for every factor,Given the different emphasis on each factor, factors can be assigned different weights $a_i = (i = 1,2,...,n)$, It represents the percentage of the ‘i’ factor in the judgement. Available sum

$$s = \sum_{i=1}^{n} a_i \bullet s_i \qquad (\sum_{i=1}^{n} a_i = 1)$$

As the standard for judgement, such as in job determination, grading usually use this method.

3.2. Fuzzy method:

With the traditional method of evaluation, the result is always single, that is, the evaluation result is expressed with a numerical value, but sometimes that is not comprehensive and accurate.In particular, the evaluation of industrial product design quality is a factors always be influenced, and the factors involved in the object to be evaluated are often fuzzy. The traditional evaluation method is obviously not scientific, comprehensive or accurate enough. Therefore, we can adopt the method of fuzzy comprehensive evaluation for the design quality of industrial products.

To scientifically, correctly and comprehensively evaluate a specific object, it is necessary to give appropriate comments on several aspects of the object (called elements), and then make a comprehensive evaluation. For example, to evaluate the design quality of an industrial product, the product's "functional elements", "structural elements", "human factors", "morphological elements", "color elements", "environmental elements" and so on should be evaluated first, and then integrated.

It is always denoted $U=\{u_1,u_2,\cdots,u_m\}$ as the evaluation factor set. Like evaluate the industrial product, we can use $U=\{u_1,u_2,\cdots,u_m\}$, $u_1,u_2,\cdots,u_m$ respectively express functional elements, structural elements and human factors, etc.

'V' represent the comment set. 'V' can be a finite set, for example V=(A,B,C,D,E), or V=(level 1, level 2,…,level n), we usually can call that V＝(v_1, v_2,…,v_n), 'V' could also be the interval on the real axis, for example V=(0, 1), or V=(0, 100) etc. For the case where V is a finite set, we can also take v_1, v_2, …v_n quantitative. As a subset of [0,1] or [0,100](for example, if a product is scored on a percentage scale, then V = {1,2...), 100}).

Set the fuzzy vector that has been given

$$A=(a_1,a_2,\cdots,a_n)$$

And fuzzy matrix

$$R=\begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{pmatrix}_{n\times m}$$

The fuzzy synthesis operation is defined as

$$AOR=B=(b_1,b_2,\cdots,b_m)$$

Among them

$$b_j=(a_1*r_{1j})*(a_2*r_{2j})*\cdots*(a_n*a_{nj}) \qquad (j=1,2,\cdots,m)$$

Operator $M(*,*)$ is a symbol of operation. Two algorithms are introduced here.

(1)"Dominant factor type"

According to the law of Max - min, the box "Sunday afternoon" instead of ", "use" ∨ "instead of " ".

$$b_j=\overset{n}{\underset{i=1}{\vee}}(a_j\wedge r_{ij}) \qquad (j=1,2,\cdots,m) \tag{1}$$

Or

$$b_j=\max\{\min(a_1,r_{ij}),\cdots,\min(a_n,r_{nj})\tag{2}$$

(2)"Weighted average"

By the ordinary matrix multiplication symbol, that is, " ' instead of' , '+', ' instead of ' ".

$$b_j=\sum_{i=1}^{n}a_i r_{ij} \qquad (j=1,2,\cdots,m) \tag{3}$$

For example: The product appraisal department identifies an industrial product. From the perspective of design, we must consider the three elements of form, color and human factors. Take the domain 'U'.

$$U=\{u_1(\text{form}),\ u_2(\text{color}),\ u_3(\text{human factors})\}$$

The evaluation is divided into four levels, that is, take the comment set as 'V'

$$V=\{v_1(\text{very good}),\ v_2(\text{better}),\ v_3(\text{average}),\ v_4(\text{bad})\}$$

When it comes to form evaluation, 50% of people think it is "very good", 40% think it is "better", 10% think it is "average" and no one thinks it is "bad"

（0.5， 0.4， 0.1， 0）

Similarly, the evaluation of color is

（0.4， 0.3， 0.2， 0.1）

The evaluation of human factors is

（0， 0.1， 0.3， 0.6）

In this way, an evaluation fuzzy matrix is obtained

$$R=\begin{pmatrix}0.5 & 0.4 & 0.1 & 0\\ 0.4 & 0.3 & 0.2 & 0.1\\ 0 & 0.1 & 0.3 & 0.6\end{pmatrix}$$

The following is the weight of the three factors in the evaluation of the product, which can be obtained by two methods:

(1) The simplest method, directly by the experts to agree;

(2) through the statistical experts to determine the score

The experts participating in the evaluation believe that the main requirements for the product are: shape elements and human factors, color elements are ranked in the least important position, so the weight vector can be

$$A=(0.5,0.2,0.3)$$

The following two algorithms are used to calculate the comprehensive evaluation of the product.

The principal factor prominence algorithm is first used, which can be obtained from the previous formula (1) or (2)

$$B=AOR=(0.5\quad 0.2\quad 0.3)\begin{pmatrix}0.5 & 0.4 & 0.1 & 0\\ 0.4 & 0.3 & 0.2 & 0.1\\ 0 & 0.1 & 0.3 & 0.6\end{pmatrix}=((0.5\wedge 0.5)\vee(0.2\wedge 0.4)\vee(0.3\wedge 0),$$

$$(0.5\wedge 0.4)\vee(0.2\wedge 0.3)\vee(0.3\wedge 0.1),(0.5\wedge 0.1)\vee(0.2\wedge 0.2)\vee(0.3\wedge 0.3),$$

$$(0.5\wedge 0)\vee(0.2\wedge 0.1)\vee(0.3\wedge 0.6))=(0.5,0.4,0.3,0.3)$$

But because of

0.5+0.4+0.3+0.3=1.5

Than normalize it, Divide each item by 1.5 times, and the final comprehensive evaluation result is

$$(0.33(\text{very good}),0.27(\text{better}),0.20(\text{average}),0.20(\text{bad}))$$

Using weighted average algorithm, which can be obtained from the previous formula (3)

$$B=AOR=(0.5\quad 0.2\quad 0.3)\begin{pmatrix}0.5 & 0.4 & 0.1 & 0\\ 0.4 & 0.3 & 0.2 & 0.1\\ 0 & 0.1 & 0.3 & 0.6\end{pmatrix}=((0.5\times 0.5)+(0.2\times 0.4)+(0.3\times 0),$$

$$(0.5\times 0.4)+(0.2\times 0.3)+(0.3\times 0.1),(0.5\times 0.1)+(0.2\times 0.2)+(0.3\times 0.3),$$

$$(0.5\times 0)+(0.2\times 0.1)+(0.3\times 0.6))=(0.33,0.29,0.18,0.20)$$

Because of

0.33+0.29+0.18+0.20=1.0

Has been normalization, so the final comprehensive evaluation result is

$$(0.33(\text{very good}),0.29(\text{better}),0.18(\text{average}),0.20(\text{bad}))$$

According to the above two algorithms, when morphological elements, color elements and human factors are taken into consideration for this industrial product at the same time, there is a large proportion of the comprehensive evaluation results, which are respectively 60% and 62%.

As can be seen from the above example, the comprehensive evaluation should be carried out in the following steps:

(1)Select the factor set 'U' and comment set 'V'. The principle is to be comprehensive while addressing the principal contradiction. In this way, we can better simulate people's thinking and avoid some unnecessary troubles.

(2)Single factor evaluation vector is determined through survey statistics. The number of respondents should be enough and representative, and then the evaluation fuzzy matrix 'R' can be obtained from each single factor evaluation vector.

(3)Determine the weight vector 'A'. One method is by authoritative experts and representative people according to the importance of the factors to determine the degree.

(4)Select the appropriate algorithm. Two algorithms are commonly used: weighted average and principal factor prominence.

In general, the results of the two algorithms are much the same. Note the characteristics of these two algorithms:

Weighted average algorithm is often used in the case of many factor sets, it can avoid information loss;

The principal factor prominence algorithm is used to avoid the situation that the data in the fuzzy matrix is very different

One of the "naughty" data interference.

In addition, a large number of statistical calculations show that the number of factor sets cannot be greatly different from the number of comment sets when the dominant factor type is used; otherwise, the weight value will be too small and the single-factor evaluation data will be "overwhelmed".

4.Research conclusions

Fuzzy mathematics is a relatively scientific, accurate and comprehensive method to evaluate the design quality of industrial products. The fuzzy mathematics method can make the expression of the evaluation result more concrete and comprehensive, and make the evaluation of the fuzzy concept of product design quality clear. This method is simple and easy to use, and can directly use the mathematical formula template enumerated in this paper to set different evaluation factor sets and comment sets for different products, and then determine the single factor vector and weight vector, and select one of the weighted average or dominant prominence algorithm for calculation according to the need. In this way, a relatively scientific, accurate and comprehensive evaluation conclusion can be drawn. The evaluation conclusion can reflect the design quality of a product in the specific factors on which the performance of good or poor. This not only provides a scientific evaluation method for professionals engaged in product design, but also provides relatively direct and specific reference basis and direction for product designers to improve design and improve design quality.

References

[1] Wu,X.(1993) Product System Design.China Light Industry Press,Beijing.
[2] Peng,Z.(2003) Fuzzy sets and applications.Wuhan University Press,Wuhan.
[3] Wang,F.(1988)Fuzzy mathematics and engineering science.Harbin Institute of Shipbuilding Engineering Press,Harbin.
[4] He,Z.(1983)The application of fuzzy.Tianjin Science and Technology Press,Tianjin.
[5] Chen,S.(2004)Cyclical iteration model and unified theory of fuzzy cluster, recognition and optimum decision.Journal of Dalian University of Technology,Dalian.
[6] Duan,B.(2004)Interval number-based multiple fuzzy optimization model.Journal of Hohai University,Nanjing.
[7] Zhang,X.(2003)Advance in fuzzy comprehensive evaluation methods theory and application.Journal of Shandong university of architecture and engineering,Shandong.