

Applying GM(0,N) in the User's Cognition of Design Research - An Example in Smart Phone Holster

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Abstract—The purpose of the study is to investigate the preference cognition of smartphone leather cases in Taiwan, and provide reference for further product design, and then promote the marketing function. In the analyzing process, we ignore the occupation of the examinees; instead, we classify the examinees into three groups according to their age and gender. The three groups are mature, middle-aged and youth. We propose the representative samples and analyze their preference based on the shape, structure, color, texture, materials, convenience, usability, quality, value, and the protective effect. The study aims to understand the preferences of smartphone leather case in different groups, and provide correct reference for further design. First, apply GM (h, N) model to analyze the weighting of influencing factors and their order structure. Second, analyze the influencing factors among the three groups. Then, the results can become a systematic application reference model to solve the uncertain issues of new product design and to provide the values of future product design application.

I. INTRODUCTION

The function of smartphone display stand is to highlight the quality and value of products, enhance the visual effects of products, and promote the product to attract the attention of consumers; thus, it can contribute to marketing opportunities [1~3]. Reviewing the previous design researches, most of them only focus on the shape, function or convenience of smartphone display stand. This paper proposes the combination of product materials and design requirement. Under the norm of beauty design, it is hoped to reach the optimal material selection method which not only promotes the design quality of products, but also achieves the function of smartphone display stand. Currently, there are diversified materials which can be used to make smartphone display stand. Under the design requirement of product quality, how to choose the appropriate material to design influences the factors of strength, rigidity, toughness, use, value, durability, productive and low cost of the product [4-7]. Hence, the paper proposes to use the above material factors as design conditions of beauty design requirements.

Manuscript received August 25, 2013.

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Evaluation method of experts' experience consensus is used to do the strategy research of material design application. Finally, it can identify the selection strategy of material factors and beauty design requirements, which can also satisfy the quality design requirements of product design.

First, the paper collects the production materials of smartphone display stand and categorize them. According to each material's attribute, 10 representative materials are proposed to be the main research data. Under the requirement of beauty design, the study on material's selection can be done. Through experts' cognitive evaluation to material's selection, the evaluation results can be compiled. Then the emphasis principles of smartphone display stand's material selection can be resolved, and the strategy of material's selection can be obtained. The data, reached from experts' evaluation, are calculated by multivariable GM(h,N) model concept in the grey system theory. Based on the weighting of factors, the order of material's selection can be calculated and the key point of smartphone display stand's material selection can be resolved. This not only avoids choosing the wrong material, but also solves the difficult problems of understanding product material design application by using research identification of experts' experience to provide actual material selection principles.

In this paper, section two introduces the math methods and weighting calculation steps. Section three is the subject introduction and research evaluation execution, including material properties correspond to the importance of beauty design requirements' evaluation and the values sorting of evaluation results. Section four includes the evaluation results and practical example analysis which uses the values in the math models to reach weighting and discussion. Finally, it is the research conclusions and recommendations.

II. MATHEMATICS METHOD

In grey system theory, the main function of GM(h,N) model is one of the methods to carry out the calculation of measurement among the discrete sequences and to compensate the shortcomings in the traditional methodology, and it divided into GM(1,N) and GM(0,N) two topics [8-11].

A. GM(1,N)

The GM(1,N) model is defined as.

$$\begin{aligned} x_1^{(0)}(k) + a_1 z_1^{(1)}(k) &= \sum_{j=2}^N b_j x_j^{(1)}(k) \\ &= b_2 x_2^{(1)}(k) + b_3 x_3^{(1)}(k) + \dots + b_N x_N^{(1)}(k) \quad (1) \end{aligned}$$

where:

i. a_1 and b_j are determined coefficients.

ii. $x_1^{(1)}(k)$: The major sequence

iii. $x_j^{(1)}(k)$: The influencing sequences.

iii. AGO $x^{(0)} = x^{(1)}$

$$= [\sum_{k=1}^1 x^{(0)}(k), \sum_{k=1}^2 x^{(0)}(k), \sum_{k=1}^3 x^{(0)}(k), \dots, \sum_{k=1}^n x^{(0)}(k)]$$

iv. $z_1^{(1)}(k) = 0.5x_1^{(1)}(k-1) + 0.5x_1^{(1)}(k)$, $k = 2, 3, 4, \dots, n$

The analytical steps are shown below.

1. Building the original sequences

$$x_1^{(0)} = (x_1^{(0)}(1), x_1^{(0)}(2), \dots, x_1^{(0)}(k))$$

$$x_2^{(0)} = (x_2^{(0)}(1), x_2^{(0)}(2), \dots, x_2^{(0)}(k))$$

$$x_3^{(0)} = (x_3^{(0)}(1), x_3^{(0)}(2), \dots, x_3^{(0)}(k)) \quad , \quad k = 1, 2, 3, \dots, n \quad (2)$$

.....

$$x_N^{(0)} = (x_N^{(0)}(1), x_N^{(0)}(2), \dots, x_N^{(0)}(k))$$

2. Building the AGO sequences: According to the AGO formula, we have

$$x_1^{(1)} = (x_1^{(1)}(1), x_1^{(1)}(2), \dots, x_1^{(1)}(k))$$

$$x_2^{(1)} = (x_2^{(1)}(1), x_2^{(1)}(2), \dots, x_2^{(1)}(k))$$

$$x_3^{(1)} = (x_3^{(1)}(1), x_3^{(1)}(2), \dots, x_3^{(1)}(k)) \quad , \quad k = 1, 2, 3, \dots, n \quad (3)$$

.....

$$x_N^{(1)} = (x_N^{(1)}(1), x_N^{(1)}(2), \dots, x_N^{(1)}(k))$$

3. Combining the AGO sequences with the major sequence

$$x_1^{(0)}(k) + az_1^{(1)}(k) = \sum_{j=2}^N b_j x_j^{(1)}(k) \quad (4)$$

$$\text{where: } z_1^{(1)}(k) = 0.5x_1^{(1)}(k) + 0.5x_1^{(1)}(k-1), k \geq 2$$

4. Substituting all AGO values into equation (4), we have

$$x_1^{(0)}(2) + az_1^{(1)}(2) = b_2 x_2^{(1)}(2) + \dots + b_N x_N^{(1)}(2)$$

$$x_1^{(0)}(3) + az_1^{(1)}(3) = b_2 x_2^{(1)}(3) + \dots + b_N x_N^{(1)}(3) \quad (5)$$

.....

$$x_1^{(0)}(n) + az_1^{(1)}(n) = b_2 x_2^{(1)}(n) + \dots + b_N x_N^{(1)}(n)$$

Then transform the equation into matrix form, then Eq. would become:

$$\begin{bmatrix} x_1^{(0)}(2) \\ x_1^{(0)}(3) \\ \vdots \\ x_1^{(0)}(n) \end{bmatrix} = \begin{bmatrix} -z_1^{(1)}(2) & x_2^{(1)}(2) & \dots & x_N^{(1)}(2) \\ -z_1^{(1)}(3) & x_2^{(1)}(3) & \dots & x_N^{(1)}(3) \\ \vdots & \vdots & \dots & \vdots \\ -z_1^{(1)}(n) & x_2^{(1)}(n) & \dots & x_N^{(1)}(n) \end{bmatrix} \begin{bmatrix} a \\ b_2 \\ \vdots \\ b_N \end{bmatrix} \quad (6)$$

5. Find the parameters

By using the inverse and matrix method to find the values of b_N , the method is $\hat{a} = (B^T B)^{-1} B^T Y_N$,

$$\text{where: } B = \begin{bmatrix} -z_1^{(1)}(2) & x_2^{(1)}(2) & \dots & x_N^{(1)}(2) \\ -z_1^{(1)}(3) & x_2^{(1)}(3) & \dots & x_N^{(1)}(3) \\ \vdots & \vdots & \dots & \vdots \\ -z_1^{(1)}(n) & x_2^{(1)}(n) & \dots & x_N^{(1)}(n) \end{bmatrix},$$

$$Y_N = \begin{bmatrix} x_1^{(0)}(2) \\ x_1^{(0)}(3) \\ \vdots \\ x_1^{(0)}(n) \end{bmatrix}, \quad \hat{a} = \begin{bmatrix} a \\ b_2 \\ \vdots \\ b_N \end{bmatrix}$$

Hence, the relationship between the major sequence and the influencing sequences can be found by comparing the value of b_N .

B. GM(0I, N)

The GM(0, N) model is the special topic in GM(h, N), and the mathematics model is shown below.

$$az_1^{(1)}(k) = \sum_{j=2}^N b_j x_j^{(1)}(k) = b_2 x_2^{(1)}(k) + b_3 x_3^{(1)}(k) + \dots + b_N x_N^{(1)}(k) \quad (7)$$

where: $z_1^{(1)}(k) = 0.5x_1^{(1)}(k-1) + 0.5x_1^{(1)}(k)$, $k = 2, 3, 4, \dots, n$, and the analysis steps are

1. Substituting all AGO values into equation (7), we have

$$a_1 z_1^{(1)}(2) = b_2 x_2^{(1)}(2) + \dots + b_N x_N^{(1)}(2)$$

$$a_1 z_1^{(1)}(3) = b_2 x_2^{(1)}(3) + \dots + b_N x_N^{(1)}(3)$$

$$a_1 z_1^{(1)}(4) = b_2 x_2^{(1)}(4) + \dots + b_N x_N^{(1)}(4) \quad (8)$$

.....

$$a_1 z_1^{(1)}(n) = b_2 x_2^{(1)}(n) + \dots + b_N x_N^{(1)}(n)$$

2. Dividing a_1 in both sides: Translate into matrix form

$$\begin{bmatrix} 0.5x_1^{(1)}(1) + 0.5x_1^{(1)}(2) \\ 0.5x_1^{(1)}(2) + 0.5x_1^{(1)}(3) \\ \vdots \\ 0.5x_1^{(1)}(n-1) + 0.5x_1^{(1)}(n) \end{bmatrix} = \begin{bmatrix} x_2^{(1)}(2) & \dots & x_N^{(1)}(2) \\ x_2^{(1)}(3) & \dots & x_N^{(1)}(3) \\ \vdots & \dots & \vdots \\ x_2^{(1)}(n) & \dots & x_N^{(1)}(n) \end{bmatrix} \begin{bmatrix} \frac{b_2}{a_1} \\ \frac{b_3}{a_1} \\ \frac{b_4}{a_1} \\ \vdots \\ \frac{b_N}{a_1} \end{bmatrix} \quad (9)$$

And assume $\frac{b_j}{a_1} = \hat{b}_m$, where $m = 2, 3, 4, \dots, N$, then

equation (9) can be rearranged into

$$\begin{bmatrix} 0.5x_1^{(1)}(1) + 0.5x_1^{(1)}(2) \\ 0.5x_1^{(1)}(2) + 0.5x_1^{(1)}(3) \\ \vdots \\ 0.5x_1^{(1)}(n-1) + 0.5x_1^{(1)}(n) \end{bmatrix} = \begin{bmatrix} x_2^{(1)}(2) & \dots & x_N^{(1)}(2) \\ x_2^{(1)}(3) & \dots & x_N^{(1)}(3) \\ \vdots & \dots & \vdots \\ x_2^{(1)}(n) & \dots & x_N^{(1)}(n) \end{bmatrix} \begin{bmatrix} \hat{b}_2 \\ \hat{b}_3 \\ \hat{b}_4 \\ \vdots \\ \hat{b}_N \end{bmatrix} \quad (10)$$

C. Find the Parameters

Use $\hat{B} = (Y^T Y)^{-1} Y^T X$ to solve the values of \hat{b}_m , the relationship between the major sequence and the influencing sequences can be found by comparing the values of \hat{b}_m .

$$\text{where: } X = \begin{bmatrix} 0.5x_1^{(1)}(1) + 0.5x_1^{(1)}(2) \\ 0.5x_1^{(1)}(2) + 0.5x_1^{(1)}(3) \\ \vdots \\ 0.5x_1^{(1)}(n-1) + 0.5x_1^{(1)}(n) \end{bmatrix},$$

$$Y = \begin{bmatrix} x_2^{(1)}(2) & \cdots & x_N^{(1)}(2) \\ x_2^{(1)}(3) & \cdots & x_N^{(1)}(3) \\ \vdots & \cdots & \vdots \\ x_2^{(1)}(n) & \cdots & x_N^{(1)}(n) \end{bmatrix}, \hat{B} = \begin{bmatrix} \hat{b}_2 \\ \hat{b}_3 \\ \hat{b}_4 \\ \vdots \\ \hat{b}_N \end{bmatrix}$$

III. REAL EXAMPLE

A. Subjects

The sample population of the present study, which is age-oriented, includes three age groups: 1) mid-high age group, 2) middle age group, and 3) mid-low age group. The present study does not take respondents' job specifications into consideration. Mid-high age group is coded as X; middle age group, Y; mid-low age group, Z. Each group consists of 15 male and 15 female respondents, as is shown in Table 1. Age differentiation, which is the main consideration of the study, may provide insight into the correlation between respondents of different ages and their choices of I-phone leather covers. Designers of I-phone leather covers may also avail themselves of the finding for better design.

TABLE I
AGE AND GENDER DISTRIBUTION OF SUBJECT

(X)	Age	46-50	51-60	61 and above
Mid-high age	Male	7	4	4
	Female	6	6	3
(Y)	Age	31-35	36-40	41-45
Middle age	Male	6	4	5
	Female	5	5	5
(Z)	Age	15-20	21-25	26-30
Mid-low age	Male	4	6	5
	Female	4	7	4

B. Sample Collection

To obtain sufficient data for analysis, the researcher first target I-phone shops, I-phone product catalogs and commercial websites as sources of samples. By referring to the three sources, the researcher first from the Internet and magazines pick out a total of 57 samples (leather covers), which are different from each other in material, construction, style and/or use. After close observation, 18 samples are excluded for being similar in material, color and/or appearance. The remaining 39 samples are then subject to classification in terms 10 preference factors, including appearance, construction, color, texture, material, convenience, use, quality, cost, and protection effect. Finally, 10 surveyed respondents are invited to pick up 10 from among the 38 samples. The 10 representative samples, which respectively assume letters (A) through (J), form the basis for another data analysis, as is shown in Fig. 1.



Fig. 1. The data of sample

C. Preference Factors and Coding

The 10 preference factors postulated by the researcher include *appearance, construction, color, texture, material, convenience, use, quality, cost, and protection effect*. Each of them is assigned an English letter starting from (A) to (J). The ten distinctive preference factors serve as the evaluation basis for data analysis of this study, which is shown in Table 2.

D. Evaluation of Degree of Importance

The age-classified respondents are asked to evaluate the degree of importance of the 10 preference factors. The 10 samples, (A) through (J), were sequentially positioned in the leftist line spaces of the column, while the 10 preference factors, (a) through (j), were horizontally positioned in the top row spaces. A decision matrix consisting of 10 row ($i=1,2,3,\dots,10$) and 10 lines ($j=1,2,3,\dots,10$) is therefore provided. To conduct the evaluation, the researcher use five-scale type to evaluate the degree of importance of each factor. Each factor is considered to be either "extremely important," (5 points) "very important," (4 points) "important," (3 points), "not important," (2 points) or "very unimportant," (1 point) The respondents are asked to fill the numbers deemed appropriate in the 10 by10 column spaces. Respondents are also asked to evaluate, on the basis of the 10

samples from (A) to (J), the aesthetic appeal of the samples. The score of each sample was designated to range between 0 and 10. The scores are respectively filled into corresponding column spaces of the decision matrix. Finally, the average evaluation values of the three age groups may be obtained. (See Tables 3, Table 4 and Table 5) The evaluation result may then be subject to differentiation and analysis.

IV. RESULTS AND ANALYSIS

Tables 3, Table 4 and Table 5 respectively show the average evaluation values of the three age groups. The average evaluation values of each group are then subject to calculation via the two models, namely GM(1,N) and GM(0,N). In the principle of multiple variables, calculate the 0 hierarchy and one hierarchy study compared results

A. Calculation and Analysis of the Mid-high Age Group(X)

First, the derived average values of the expert evaluation decision are

$$x_1 = (6.9, 6.5, 6.1, 6.3, 6.7, 7.5, 7.9, 7.2, 8.3, 8.6)$$

while appearance to protection effect are the input series.

$$x_2 = \text{Appearance} = (2.68, 3, 3.24, 3.24, 3.04, 3.3, 3.25, 3.3, 3.28, 3.51)$$

$$x_3 = \text{Construction} = (2.1, 2.24, 2.72, 2.52, 2.82, 2.78, 2.73, 2.74, 2.83, 2.96)$$

$$x_4 = \text{Color} = (1.06, 1.86, 1.58, 1.7, 1.98, 1.68, 1.57, 1.73, 1.21, 1.86)$$

$$x_5 = \text{Texture} = (1.12, 1.8, 2, 1.92, 2.9, 1.59, 1.83, 1.88, 1.91, 2.01)$$

$$x_6 = \text{Material} = (2.5, 2.76, 3, 2.8, 3.1, 3.15, 2.99, 3.02, 3.13, 3.2)$$

$$x_7 = \text{Convenience} = (3.32, 3.28, 3.65, 3.6, 3.92, 3.81, 3.69, 3.71, 3.87, 3.9)$$

$$x_8 = \text{Use} = (3.25, 3.62, 4.06, 4, 3.95, 4, 3.83, 3.98, 4.11, 4.02)$$

$$x_9 = \text{Quality} = (3, 3.22, 3.6, 3.78, 4.12, 3.62, 3.59, 3.61, 3.71, 3.82)$$

$$x_{10} = \text{Cost} = (3.82, 4.05, 4.23, 4.4, 4.31, 4.5, 4.43, 4.47, 4.52, 4.63)$$

$$x_{11} = \text{Protection effect} = (4, 4.1, 4.2, 4.35, 4.2, 4.68, 4.5, 4.54, 4.83, 4.78)$$

Afterward, the values of each series are introduced to equations (6) and equation (10) to obtain the weight of each factor. Table 6 shows the result.

B. Calculation and Analysis of the Mid Age Group(Y)

First, the derived average values of the expert evaluation decision are

$$x_1 = (6.6, 8.1, 7.3, 8.2, 7.6, 6.3, 6.5, 7.2, 8.8, 8.3)$$

while appearance to protection effect are the input series.

$$x_2 = \text{Appearance} = (1.82, 2, 2.32, 2.29, 1.75, 2.3, 2.28, 2.32, 2.24, 2.5)$$

$$x_3 = \text{Construction} = (3.48, 3, 3.65, 3.78, 3.2, 3.85, 3.82, 3.82, 3.78, 3.96)$$

$$x_4 = \text{Color} = (2.02, 1.86, 2.3, 2.5, 2.05, 2.85, 2.5, 2.54, 2.42, 2.65)$$

$$x_5 = \text{Texture} = (3.56, 3.85, 4.1, 4.12, 3.62, 4, 4.4, 4.05, 4, 4.12)$$

$$x_6 = \text{Material} = (3.22, 3.35, 3.52, 3.4, 3, 3.6, 3.7, 3.9, 3.5, 3.84)$$

$$x_7 = \text{Convenience} = (1.68, 1.84, 1.96, 2, 1.78, 2.02, 2.16, 2.17, 2, 2.22)$$

$$x_8 = \text{Use} = (2.54, 1.76, 2, 2.2, 1.75, 2.5, 2.42, 2.28, 2.16, 2.36)$$

$$x_9 = \text{Quality} = (2, 2.02, 2.3, 2.4, 2, 2.74, 2.68, 2.5, 2.42, 2.6)$$

$$x_{10} = \text{Cost} = (4, 4.24, 4.26, 4.44, 4, 4.24, 4.62, 4.6, 4.35, 4.6)$$

$$x_{11} = \text{Protection effect} = (3.9, 3.98, 4.2, 4.35, 3.96, 4, 4.5, 4.62, 4.4, 4.48)$$

Afterward, the values of each series are introduced to equations (6) and equation (10) to obtain the weight of each factor. Table 7 shows the result.

C. Calculation and Analysis of the Mid-low Age Group(Z)

First, the derived average values of the expert evaluation decision are

$$x_1 = (8, 6.1, 7.6, 8.2, 6.6, 6.8, 7.2, 7.8, 8.3, 8.5)$$

while appearance to protection effect are the input series.

$$x_2 = \text{Appearance} = (3.85, 3.38, 4, 3.69, 3.72, 4.33, 4, 3.9, 4.1, 4.26)$$

$$x_3 = \text{Construction} = (2.1, 1.75, 2.04, 1.76, 2, 2.47, 2.06, 2, 2.48, 2.32)$$

$$x_4 = \text{Color} = (3.62, 3.09, 3.62, 3.26, 3.3, 3.5, 3.58, 3.5, 3.75, 3.82)$$

$$x_5 = \text{Texture} = (4, 3.49, 4.1, 4.55, 3.85, 4, 4.1, 4, 4.36, 4.32)$$

$$x_6 = \text{Material} = (2.2, 2.43, 2.21, 1.98, 2.2, 2.74, 2.42, 2.34, 2.62, 2.5)$$

$$x_7 = \text{Convenience} = (3, 2.68, 2.82, 2.51, 2.68, 3.12, 2.74, 2.72, 2.95, 3.02)$$

$$x_8 = \text{Use} = (3.26, 3.14, 3.41, 3.19, 3.21, 3.78, 3.28, 3.4, 3.52, 3.65)$$

$$x_9 = \text{Quality} = (3.8, 3.52, 3.68, 3.67, 3.52, 4.12, 4.06, 3.62, 4.1, 4)$$

$$x_{10} = \text{Cost} = (4.29, 4.05, 4.2, 3.82, 4, 4.48, 4.15, 4.2, 4.62, 4.5)$$

$$x_{11} = \text{Protection effect} = (4.33, 3.98, 4.4, 4, 4.17, 4.62, 4.26, 4.34, 4.72, 4.55)$$

Afterward, the values of each series are substitute into equations (6) and equation (10) to obtain the weight of each factor. Table 8 shows the result. Meanwhile, we may obtain evaluation analysis by using toolbox [9,10].

D. The Results and Analysis

Based on the result derived from mathematical calculation, the researcher assigns, from each of the three Tables (Tables 6, 7 and 8), the top three respondents for comparison analysis (please see Table 9). The three age groups, namely X, Y and Z, are found to have different evaluation results. When calculated via GM(1,N) and GM(0,N), X group has convenience (f) ranking as No.1 in both calculations, followed by construction (b) and value (i). Therefore, both construction and cost form a group, which implies mid-high aged people are mature in thought. The result of evaluation achieves a high degree of consensus.

When calculated via GM(1,N) and GM(0,N), Y group has use (g) and value (i) ranking as No.1 respectively. However, Y group has value (i) and quality (h) ranking respectively as the 2nd and 3rd place when calculated via GM(1,N), while it has construction (b) and use (g) ranking respectively as the 2nd and 3rd place when calculated via GM(0,N). This suggests that middle-aged people, who are undergoing age transition, have developed multiple-thought mindsets. As a result, different evaluation results are derived.

When calculated via GM(1,N) and GM(0,N) respectively, Z group has value (i) ranking as No.1 in both calculations. When calculated via GM(1,N), it has convenience (f) and material (e) ranking as the 2nd and 3rd place respectively. However, when calculated via GM(0,N), it has material (e) and configuration (a) ranking as the 2nd and 3rd respectively. The result points to the fact that mid-low aged people, who are less experienced socially, tend to take value (i) into their primary consideration, followed by material (e).

Because GM(1,N) contains dynamic data, while GM(0,N) is characterized by quasi calculation data. Where different sorting orders are found to result from the analysis, it suggests that refer to the calculation result from GM(0,N).

V. RESULTS AND ANALYSIS

The research is done by using the material selection of smartphone display stand. Based on the beauty requirement, the professionals are chosen as subjects. The overall research uses transparent data to show the results which convey the consensus opinions of experts and solve the problem of selection product materials. Especially, by using the GM(h,N) model in soft-computing calculation and according to the impact factor's weighting, we can calculate the structural order of material selection elements, analyze the thinking problems of material selection and present the research results in an objective way. All in all, the paper has done the

analysis of associated problems of material type, material quality and product design requirement, and it has the following contributions.

1. It can clearly identify the problem of selecting materials and provide the key principles of product material selection.
2. According to the requirements of product design, it can provide the focus of material selection which promotes the validity.
3. By using the experts' experiences, the evaluation can provide correct information and promote the research results to be credible.
4. The proposed method can be used to single material or multi-material's selections which provides a new research direction.

Moreover, the GM(h,N) method used in this paper is just one of the soft-calculation methods; therefore, it is suggested to add other impact factors to be analyzed in the future researches. Besides, other soft-calculation methods, like the fuzzy theory, the neural theory and the rough set theory can be combined to do holistic analysis in the future, and it is believed to reach better results.

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TABLE II CODING OF PREFERENCE FACTORS

(a) Appearance	(b) Construction	(c) Color	(d) Texture	(e) Material
(f) Convenience	(g) Use	(h) Quality	(i) Cost	(j) Protection effect

TABLE III AVERAGE EVALUATION VALUES OF THE MID-HIGH AGE GROUP (X)

	a	b	c	d	e	f	g	h	i	j	The average point (0 ~ 10)
(A)	2.68	2.10	1.06	1.12	2.50	3.32	3.25	3	3.82	4	6.9
(B)	3	2.24	1.86	1.80	2.76	3.28	3.62	3.22	4.05	4.10	6.5
(C)	3.24	2.72	1.58	2	3	3.65	4.06	3.60	4.23	4.2	6.1
(D)	3.24	2.52	1.70	1.92	2.80	3.6	4	3.78	4.40	4.35	6.3
(E)	3.04	2.82	1.98	2.90	3.1	3.92	3.95	4.12	4.31	4.20	6.7
(F)	3.30	2.78	1.68	1.59	3.15	3.81	4	3.62	4.50	4.68	7.5
(G)	3.25	2.73	1.57	1.83	2.99	3.69	3.83	3.59	4.43	4.50	7.9
(H)	3.30	2.74	1.73	1.88	3.02	3.71	3.98	3.61	4.47	4.54	7.2
(I)	3.28	2.83	1.21	1.91	3.13	3.87	4.11	3.71	4.52	4.83	8.3
(J)	3.51	2.96	1.86	2.01	3.20	3.90	4.02	3.82	4.63	4.78	8.6

TABLE IV AVERAGE EVALUATION VALUES OF THE MID AGE GROUP (Y)

	a	b	c	d	e	f	g	h	i	j	The average point (0 ~ 10)
(A)	1.82	3.48	2.02	3.56	3.22	1.68	2.54	2	4	3.90	6.6
(B)	2	3	1.86	3.85	3.35	1.84	1.76	2.02	4.24	3.98	8.1
(C)	2.32	3.65	2.30	4.10	3.52	1.96	2	2.30	4.26	4.20	7.3
(D)	2.29	3.78	2.50	4.12	3.40	2	2.20	2.40	4.44	4.35	8.2
(E)	1.75	3.20	2.05	3.62	3	1.78	1.75	2	4	3.96	7.6
(F)	2.3	3.85	2.85	4	3.60	2.02	2.50	2.74	4.24	4	6.3
(G)	2.28	3.82	2.50	4.40	3.7	2.16	2.42	2.68	4.62	4.5	6.5
(H)	2.32	3.82	2.54	4.05	3.90	2.17	2.28	2.50	4.60	4.62	7.2
(I)	2.24	3.78	2.42	4	3.5	2	2.16	2.42	4.35	4.40	8.8
(J)	2.50	3.96	2.65	4.12	3.84	2.22	2.36	2.60	4.60	4.48	8.3

TABLE V AVERAGE EVALUATION VALUES OF THE MID-LOW AGE GROUP (Z)

	a	b	c	d	e	f	g	h	i	j	The average point (0 ~ 10)
(A)	3.85	2.10	3.62	4	2.20	3	3.26	3.80	4.29	4.33	8.0
(B)	3.38	1.75	3.09	3.49	2.43	2.68	3.14	3.52	4.05	3.98	6.1
(C)	4	2.04	3.62	4.10	2.21	2.82	3.41	3.68	4.20	4.40	7.6
(D)	3.69	1.76	3.26	4.55	1.98	2.51	3.19	3.67	3.82	4	8.2
(E)	3.72	2	3.30	3.85	2.20	2.68	3.21	3.52	4	4.17	6.6
(F)	4.33	2.47	3.50	4	2.74	3.12	3.78	4.12	4.48	4.62	6.8
(G)	4	2.06	3.58	4.1	2.42	2.74	3.28	4.06	4.15	4.26	7.2
(H)	3.90	2	3.50	4	2.34	2.72	3.40	3.62	4.20	4.34	7.8
(I)	4.10	2.48	3.75	4.36	2.62	2.95	3.52	4.10	4.62	4.72	8.3
(J)	4.26	2.32	3.82	4.32	2.50	3.02	3.65	4	4.50	4.55	8.5

TABLE VI THE WEIGHTING FOR EACH FACTOR IN MID-HIGH AGE GROUP (X)

	a	b	c	d	e	f	g	h	i	j
GM(1,N)	10.4675	20.9846	2.3478	2.8545	3.0449	24.0433	4.9856	3.6585	13.1627	2.5145
Rank	IV	II	X	VIII	VII	I	V	VI	III	IX
GM(0,N)	0.8579	3.5045	0.8497	1.7076	2.9143	13.5872	2.2883	0.3172	4.1917	2.3927
Rank	VIII	III	IX	VII	IV	I	VI	X	II	V

TABLE VII THE WEIGHTING FOR EACH FACTOR IN MID AGE GROUP (Y)

	a	b	c	d	e	f	g	h	i	j
GM(1,N)	0.3995	3.7997	2.8501	1.5839	2.6882	1.5743	17.3199	13.6469	14.3822	0.3995
Rank	VIII	IV	V	VII	VI	IX	I	III	II	X
GM(0,N)	2.0192	14.5563	8.287	9.4044	1.1235	5.8755	14.2492	11.7178	17.811	2.0192
Rank	VIII	II	VI	V	X	VII	III	IV	I	IX

TABLE VIII THE WEIGHTING FOR EACH FACTOR IN MID-LOW AGE GROUP (Z)

	a	b	c	d	e	f	g	h	i	j
GM(1,N)	3.175	1.5351	0.7971	3.2953	6.1418	13.5416	4.0927	2.1924	21.1471	3.175
Rank	VI	IX	X	V	III	II	IV	VIII	I	VII
GM(0,N)	88.9646	15.3684	86.2468	22.9146	89.4028	52.094	39.3716	21.0844	156.0524	88.9646
Rank	III	X	IV	VIII	II	VI	VII	IX	I	III

TABLE IX COMPARISON OF THE TOP THREE

		First	Second	Third
(X) Group	GM(1,N)	(f) Convenience	(b) Construction	(i) Cost
	GM(0,N)	(f) Convenience	(i) Cost	(b) Construction
(Y) Group	GM(1,N)	(g) Use	(i) Cost	(h) Quality
	GM(0,N)	(i) Cost	(b) Construction	(g) Use
(Z) Group	GM(1,N)	(i) Cost	(f) Convenience	(e) Material
	GM(0,N)	(i) Cost	(e) Material	(a) Appearance