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THE APPLICATION OF INTERPRETIVE STRUCTURAL MODELING METHOD TO DEVELOP VERITY DESIGN SOLUTION OF CASE HOST PREFERENCE-BASED PRODUCTS: A CASE STUDY OF RAZOR

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ABSTRACT

The purpose of this study is to test the feasibility of applying an interpretive structural modeling (ISM) method for case hosts to develop verity design solution of case host preference-based products. In the early design concept stage of the product development, designers often need to create many ideas as the case of products for the main idea of what case the host wants. Hence, a conversion approach that can provide multiple design solutions meet case host's requirements is needed. This study presents an ISM method for developing verity design solution of case host preference-based products. A razor will be used as the test case. The experimental results from this study provide product designers with a new design approach for developing verity design solution of case host preference-based product.

Keywords: *User Requirements, User-Centered Design, Product Design, ISM.*

1. INTRODUCTION

In the case hostism era, user preference and product style perceptions are important requirements. However, it is a challenging task for designers to transfer the user's implicit preference and perceptions into specific design specifications. Accordingly, we cannot overemphasize the importance of a design approach for transferring their implicit preference and perceptions into specific design specifications.

The traditional conversion approach transfers case host's preference and perception into design elements. Specifically, it is an important function of traditional conversion approach to produce design solution. However, the traditional conversion approach cannot provide multiple design solutions. That is, it can not offer decision-making for the acceptance to meet the needs of the owners in practical design case. Accordingly, it is the goal of study to develop an improved conversion approach that can render multiple design solutions.

To propose an improved conversion approach, traditional conversion approach's limitation in practical design case should be further discussed. Conjoint analysis, regression analysis of Kansei Engineering [14-15]; quantification analysis of classes, product image technology and artificial neural network or fuzzy set theory are the well-known techniques of traditional conversion approach. All the techniques of traditional conversion approach adopt following major steps to produce design solutions: (1)First, MDS, factor analysis or cluster analysis classes (I) are applied to search the design elements design variables and design factors. (2)Second, using the conjoint analysis, regression analysis or quantification analysis of classes, product image technology, artificial neural network or fuzzy set theory and other techniques, the relationships between design elements and preference and perception are searched and made. Each relationship between design elements and preference and perception is unique. For example, an emotional feeling impact is only corresponding to one set of design elements. Based on the relationship as reference, a product designer can produce a design solution [2-5,9-10]. This shows that traditional conversion approach cannot offer multiple design solutions for one perception or preference. In other words, it means design solution from traditional conversion approach does not have a good diversity of design

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capability. However, in the early design concept stage of the product development, designers often need to create many ideas as the case of products for the main idea of what case the host wants. Hence, an improved conversion approach that can provide multiple design solutions meet case host's requirements is needed.

Based on the basis theory of Rozenburg & Eekels [13], design solutions are created in the way through the permutations and combinations of various design elements. If the permutation and combination rules of design elements meet case host's preferences (or sensation), it is not difficult to provide multiple design solutions to meet case host's requirements. This implies that if the improved conversion approach can provide a function of multiple design solutions meet case host's requirements, it should have the following functions: (1) analyzing design elements and design factors, (2) building variety combination rules of analyzing design elements, (3) producing design solutions in accordance with design elements combination rules. That is, advanced techniques that can converse the case host's requirements into variety design elements combination rules is request.

Interpretive Structural Modeling (ISM) is a computer-assisted process that enables people to develop a map of the complex relationships among many elements involved in a complex situation. It was first proposed by J. Warfield [16-18] in 1973 to analyze different complex socioeconomic systems. The basic idea of ISM is to rely on a user's practical experience and knowledge to decompose a complicated system into several sub-systems (elements) and construct a hierarchic, directional and ordered multi-level structural model (**Fig. 1)** [6-8,19]. ISM is often used to provide a fundamental understanding of a complex situation, one can apply his idea to construct a course of action for solving this kind of problem [8, 12]. As such, ISM can (1) construct combination rule of elements, (2) converse one's idea to structural rule of element. That is, ISM can converse case host requirements into variety design elements for considering combination rules, implied that ISM is suitable for improved conversion approach. Therefore, this study considers Interpretive Structural Modeling (ISM) as a fundamental approach (ISMBA) for a possible improved conversion technique. The ISMBA contains three major stages: (1) first, using Chuang, et al.'s approach for analyzing design elements, (2) second, using ISM to build combination rules of design elements, (3) third, producing variety design solutions in accordance with combination rules. In this study, an example of razor is used to demonstrate ISMBA operational processes.

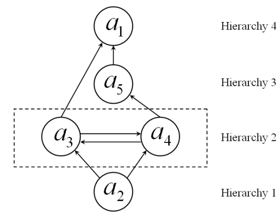

Figure 1 Diagram of structural model of ISM

2. CASE DEMONSTRATION

Phase 1 Analyzing design elements

Stage1-1 Choose the representative samples

- Materials: Twenty-six black and white razor photographs and eleven right-hand-sided image words (**Table 1**) (in Chinese) were used for the semantic differential test[1,11]. These razor samples were presented in full-scale front and side views. In the semantic differential test, the preference and image words were scored according to a nine-point scale. The attribute scale is defined by a bipolar pair of descriptive adjectives, with an image word on the right side and its antonym on the left side. On the attribute scale, a nine-point score means that the subject has a very strong preference or image impression of the razor sample, while a one-point score for a minimal preference or image impression.
- Subjects: Twelve case hosts (9 males, 3 females in the age range 45±1.3) are joined to the test. Most of them participated in the subjective evaluation task.
- Procedure: Each case host was asked to evaluate 26 razors according to the image word pair. The evaluations were conducted individually for each case host which allowed to proceed at his or her own place. To prevent the centralization of the rating scores that often occurs in a attribute evaluation task, the case hosts were told to obey the following three-step procedure:

Step a:Classify all the samples into three groups, representing low, medium, and high degrees of strength with each image word pair and preference. For example, for the preference score, there will be three piles of razors; one for "very strong preference," another for "moderate preference," and the other for "least preference".

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Table 1. The 11 image word pairs obtained from cluster analysis of the pilot test

Traditional-modern	Heavy-handy	Hard-soft	Nostalgic-avant-garde
Large-compact	Masculine-feminine	Obedient-rebellious	Hand-made-hi-tech
Coarse-delicate	Plagiaristic-creative	Rational-emotional	

Step b:Assign a score to each sample according to the strength of the preference or image word by placing a check mark along the scale. Evaluation scores should fall in the range of one to three points for the low-degree pile, four to six points for the medium pile, and seven to nine points for the high-degree pile.

Step c:The samples with the same degree of preference or image word association should be assigned the same score.

Stage1-2 Decompose design elements

Out of the 26 razor samples, 6 (**Fig. 2**) razor samples were chosen with the strongest preference scores in terms of the nine-point semantic scale. For examples, the six razor samples' score(s) are all higher than seven-point, implies that the six razor samples all meet the case hosts' requirements. Thus, the six razor samples serve as representative samples. By analyzing the six representative samples, one can construct a morphological chart (**Table 2**) in terms of their global shape and features. The element in morphological chart serves as the design elements for the implement of ISM. The procedure for building a morphological chart is as follows:

Step a:First of all, according to 6 razors common functional attributes, the study analyzes 6 razors common parts are: structure, namely, body, power holder, power keys, head (**Table 2**).

Step b:For each common part, it has been seen 6 razors all of the possible shape. The body, for example, the Fig. 2 presents each razor's body shape is depicted. Then, we can summarize them for each razor's body by the form. Later, all of these 6 razor's body shape appearances are razor's body design elements, such as Table 2 of the A1, A2, A3, A4. Thus, the principle of induction observed in this study is obtained as the design elements shown in **Table 2**.

Phase 2 Building Combination Rules of Design Elements

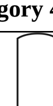
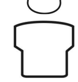
Stage2-1 Organize an ISM implementation group

ZE1	ZE 2	ZE 3	ZE 4	ZE 5	ZE 6
7.8*	7.5*	7.2*	7.8*	8.2*	8.4*

*score of attribute scale

Figure 2. Top 6 razors with strong preferences.

Table 2. Morphological analysis of 6 razor samples

Design elements	Category 1		Category 2		Category 3		Category 4	
A. Body	A1		A2		A3		A4	
B. Power holder	B1		B2		B3		B4	

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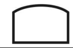
C. Power keys	C1		C2		C3		C4	
D. Head	D1		D2		D3		D4	

To begin, a case host group was established, and the group members were responsible for manipulating ISM. This user group consisted of fourteen subjects (8 males, 6 females), most of whom were college students in Taiwan.

Stage2-2 Set up the input matrix ***D*** of the design elements

From the responses of the case host group, the directed relationships among the design elements (**Table 2**) were hypothesized as the matrix ***D***. This matrix provides an initial impression of how, in what order the risk design element might ultimately be correlated. It is constructed by asking questions like "Do you prefer the design element e_i to the design element e_j?" If the answer is "Yes" then $\pi_{ij}=1$; otherwise $\pi_{ij}=0$. The general form of the relation matrix can be written as follows:

$$D=\begin{array}{c} \\ e_1 \\ e_2 \\ \vdots \\ e_n \end{array}\begin{array}{c} \begin{array}{cccc} e_1 & e_2 & \cdots & e_n \end{array} \\ \begin{bmatrix} 0 & \pi_{12} & \cdots & \pi_{1n} \\ \pi_{21} & 0 & \cdots & \pi_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \pi_{n1} & \pi_{n2} & \cdots & 0 \end{bmatrix} \end{array}, \qquad (1)$$

where e_i is the ith element in the system, π_{ij} denotes the relationship between the ith and the jth elements, and ***D*** is the relationship matrix.

Stage2-3 Determine the reachability matrix ***M*** of the design elements

After constructing the relationship matrix, we can calculate the reachability matrix using Eqs. (3) and (4) as follows:

$$M = D + I\,, \qquad (3)$$

$$M^{*} = M^{k} = M^{k+1}, \quad k > 1, \qquad (4)$$

where ***I*** is the unit matrix, k is a positive integer exponent, and ***M**** is the reachability matrix. Note that the reachability matrix satisfies the Boolean multiplication and addition laws (i.e. $1\times1=1$ *and* $1+1=1$). For example,

$$M=\begin{bmatrix}1 & 0\\ 1 & 1\end{bmatrix},\quad M^{2}=\begin{bmatrix}1 & 0\\ 1 & 1\end{bmatrix}. \qquad (5)$$

Next we can calculate the reachability set and the priority set based on Eqs. (6) and (7), respectively, as per the following equations:

$$R(t_i)=\{e_i \mid m^{*}_{ji}=1\}\,, \qquad (6)$$

$$A(t_i)=\{e_i \mid m^{*}_{ij}=1\}, \qquad (7)$$

where m_{ij} denotes the value of the ith row and the jth column.

Stage2-4 Decompose the design elements into the leveled relationship map

The levels and the relationships between the command items can be formulated as:

$$R(t_i)\bigcap A(t_i)=R(t_i) \qquad (8)$$

The structure of the command items' relationships can be expressed using the graph shown in **Fig. 2**. This is an algorithm-based process that groups the command items into different levels depending upon their relationships. This provides a multilevel interpretive structural model in which the relationships among the design elements are clarified.

Phase 3 Producing Varity Design Solutions

In accordance with the design element structure (**Fig. 3**), a product designer helps to modify the final razor design solutions (**Fig. 4**). The following description of the use of design element structure (**Fig. 4**) produces a variety of design methods and steps razor.

Step a:First, choose one of the shapes through the body level, such as A1. Next, one of

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***D*=**

	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2	D3
A1	0	0	0	0	1	0	0	0	1	0	1	0	1	0	1
A2	0	0	0	0	0	1	1	0	0	1	0	1	1	1	1
A3	0	0	0	0	1	1	0	0	1	1	1	0	0	1	0
A4	0	0	0	0	0	1	0	0	1	1	0	1	0	1	1
B1	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0
B2	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0
B3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
B4	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0
C1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
C2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
C3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
C4	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
D1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

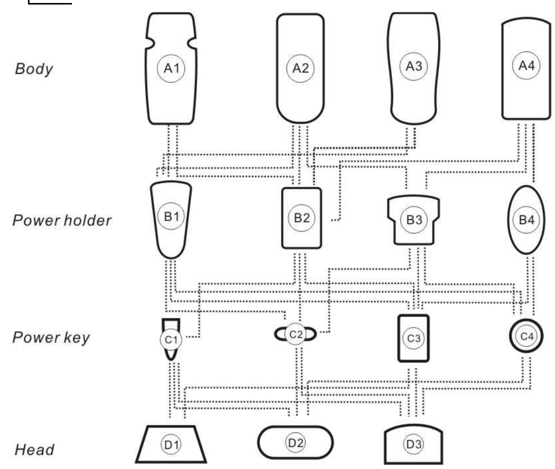

Figure 3. The design element structure developed from the reachability matrix

NZ1 NZ2 NZ3 NZ4 NZ5 NZ6

Figure 4. Several razor examples developed from ISMBA

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the power holder form elements that are associated A1, such as B1, was chosen from the power holder level. Then, the above selections can be combined.

Step b:Later, then continue down to power key level, designer can chose one of power key shapes that are connected to B1, such as C1 and C2. Select one of them (such as C2), and then it can be combined.

Step c:Following the previous steps, then, from the head level to select a form connected with the C2 elements, such as D2, the final combined into a complete one razor. NZ1 is case A1-B1-C2-D2 combination of the results.

Step d:Meanwhile, if the designers want to get various other razor design solution, he can follow the Step 1 to Step 3 of the above-mentioned method, according to different routes with different design elements considering form elements. Hence, the razor can have different designs. In **Fig. 4**, NZ1, NZ2, NZ3, NZ4, NZ5, and NZ6 are created from the **Fig. 3** of the design element structure choice of 6 different kinds of design elements considering the path of the razor constructed 6 different designs. **Fig. 4** displays the use of ISMBA to generate variety design solution in possible design elements.

3. DISCUSSION

3.1. The Analysis of the Case host-preferred Razor Form

In accordance with the 6 representative samples (**Fig. 2**) and 15 design elements (**Table 2**), the following razor features were identified as preferred by the users: a soft-curvature, elliptical or rounded rectangular design element. The form features indicate that case host preferred the curved line-based shape and round shape. The design element structure (**Fig. 3**) can explain the above speculation. **Fig. 3** shows that the connecting rules of design elements are divided into a few groups. For instance, the following design elements for curved-line design elements are grouped together: the design elements A1, A3, B3, B4, C1, C3 and D3. The following design elements for round shapes are grouped together: the design elements A2, A4, B1, B2, C2, C4, D1 and D4. These design element structure analyses show that there seems to be a relationship among the curved line–based shape group and the round shape group. This explains why case hosts preferred the curved line-based shape and round shape.

3.2. The Feasibility of Applying ISMBA to Produce Variety Design Solutions

Finally, the variety design solutions of case host-preferred products are also shown in **Fig. 4.** This product variety was due to the hierarchy of design element interactions within a product (**Fig. 3**). This approach represents related design constraints within a product using a structural graph. It can help designers to create variant resolutions in a series of design product for case host requests.

4. SUGGESTIONS

To win the competition in design market, the issues regarding providing various product solutions for designer to meet case host needs are more and more important. From this viewpoint, we cannot overemphasize a design approach that can modify variety design solutions. This study tested the feasibility of applying the ISMBA method for developing variety design solutions. Based on the experimental results, several suggestions can be made as:

- First, we suggest that the product designer should use curved line-based and round shapes in designing a razor. This should improve the case host satisfaction with a razor.
- Second, this study suggests that the product designer could adopt ISMBA to develop various products so as to satisfy the individually requirements of case hosts.

REFRENCES:

[1] M. Chuang, and Ma, Y., “Expressing the expected product images in product design”, *International Journal of Industrial Ergonomics*, Vol.27, No.2, 2001, pp.233-245.
[2] K. Fukushima, H. Kawata, Y. Fujiwara, and H. Genno, “Human sensory perception oriented image processing in a color system”, *International Journal of Industrial Ergonomics*, Vol.15, No.2, 1995, pp.63-74.
[3] T. Jindo, and K. Hirasago, “Application studies to car interior of Kansei engineering”,

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International Journal of Industrial Ergonomics, Vol.19, No.2, 1997, pp.105-114.

[4] M. Nagamachi, "Kansei engineering: A new ergonomic consumer-oriented technology for product development", *International Journal of Industrial Ergonomics*, Vol.15, No.1, 1995, pp.3-11.

[5] M. Nagamachi, "Implication of Kansei engineering and its application to automotive design consultation", *Proceedings of the 3rd Pan-Pacific Conference on Occupational Ergonomics*, 1996, pp. 171-175.

[6] M. Nagai, D. Yamaguchi, and G. Li, "Grey Structural Modeling," *Journal of Grey System*, Vol.8, No.2, 2005, pp. 119-130.

[7] M. Nagai, and D. Yamaguchi, *Elements on Grey System Theory and Applications*, Kyoritsu Shuppan, Tokyo, 2004.

[8] W. R. Nelson, L. N. Haney, L. T. Ostrom, and R. E. Richards, "Structured methods for identifying and correcting potential human errors in space operations," *Acta Astronautic*a, Vol.43, No.3, pp. 211-222, 1998.

[9] T. Nishino, M. Nagamachi, T. Tsuchiya, Y. Matsubara, and D. Cooper, "A genetics-based approach to automated design based on Kansei engineering", *Proceedings of the 3rd Pan-Pacific Conference on Occupational Ergonomics*, 1996, pp. 162-166.

[10] K. Nishikawa, Y. Hirasawa, and M. Nagamachi, "Evaluation of thermal environment based on Kansei engineering", *The Japanese Journal of Ergonomics*, Vol.33, No.5, 1997, pp.289-296.

[11] C. E. Osgood, and C. J. Suci, *The Measurement of Meaning*. University of Illinois Press, Urbana, 1957.

[12] H. M. N. Raafat, and A. H. Abdouni, "Development of an expert system for human reliability analysis", *Journal of Occupational Accidents*, Vol.9, No.2, 1987, pp. 137-152.

[13] N. F. M. Rozenburg, and J. Eekels, *Product Design: Fundamentals and Method*, Delft University of Technology, The Netherlands, 1991.

[14] S. Chung, and M. Nagamachi, "A study of prediction of design trend scene in terms of Kansei engineering", *Proceedings of the 3rd Pan-Pacific Conference on Occupational Ergonomics*, 1996, pp. 157-161.

[15] C. Tanoue, K. Ishizaka, and M. Nagamachi, "Kansei engineering: a study on perception of vehicle interior image", *International Journal of Industrial Ergonomics*, Vol.19, No.1, 1997, pp.115-128.

[16] J. Warfield, "Developing interconnection matrices in structural modeling," *IEEE Trans. on Systems, Man & Cybernetics*, Vol.4, No.1, 1974, pp.81-87.

[17] J. Warfield, "Toward interpretation of complex structural models," *IEEE Trans. on Systems, Man & Cybernetics*, Vol.4, No.5, pp. 405-417, 1974.

[18] J. Warfield, *Societal Systems: Planning, Policy and Complexity.* John Wiley & Sons, Inc., New York, NY, 1976.

[19] D. Li. Yamaguchi, G. K. Mizutani, T. Akabane, M. Nagai, and M. Kitaoka, "A realization algorithm of grey structural modeling," *Journal of Grey System*, Vol.10, No.1, pp. 33-40, 2007.

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