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APPLYING AN INTERPRETIVE STRUCTURAL MODELING METHOD TO DESIGN CONSUMER 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 consumers to design consumer preference-based products. Many studies have indicated that the fulfillment of consumer needs is an important prerequisite for the development of successful products, showing the importance of developing an approach for designing a consumer preference-based product is supported. This study presents an ISM method for developing consumer 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 designing consumer preference-based products.

Keywords: *User requirements, User-centered design, Product design, ISM*

1. INTRODUCTION

In the consumerism era, user preference and product style perceptions are important requirements. However, it is a challenging task for designers to transfer the user's implicit

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preference and perceptions into specific design specifications. Accordingly, we cannot overemphasize the importance of a design approach for consumer preference-based product.

Consumer's preference refers to a real or imagined "choice" between alternatives and the possibility of rank ordering of these alternatives, based on happiness, satisfaction, gratification, enjoyment, utility they provide. This implies that a design approach which can translate consumer's choice with their satisfaction is suitable for developing a product that meets consumer's preference. Past studies [1, 2, 3, 4] have indicated that a design approach with a user-involved design concept helps to translate the users' requirements and thoughts into a product because he/she can direct a product in accordance with his/her own thoughts and preferences. Accordingly, this study will adopt a consumer-involved design concept to develop a design approach for designing a product that meets consumer's preference.

Rozenburg & Eekels [9] indicated that the nature of a product that meets consumer's preference is a structure set of consumer preferred design elements. It is architecture with hierarchy, direction and ordination characters. This implies that a design approach that can organize consumer preferred design elements into a hierarchic, directional and ordered structure model can help to build a product that meets consumer's preference.

Based on the above design concept, a design approach for designing a product that meets the consumer's preference should include the following features: (1) the approach can be operated by a consumer, and (2) it can synchronously construct a hierarchic, directional and ordered structured model of consumer preferred design elements. 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 in 1973 to analyze 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, 7, 9, 10, 11, 13]. ISM is often used to provide a fundamental understanding of a complex situation and to construct a course of action for solving this kind of problem [8, 9]. As such, ISM can (1) be operated by a consumer and (2) synchronously construct a hierarchic, directional and ordered structured model of the structured model of consumer preferred design elements. These specifications imply that ISM is suitable for developing a product that meets consumer's preference. Accordingly, the present study will adopt an Interpretive Structural Modeling (ISM) based approach (ISMBA) to develop a product that meets consumer's preference.

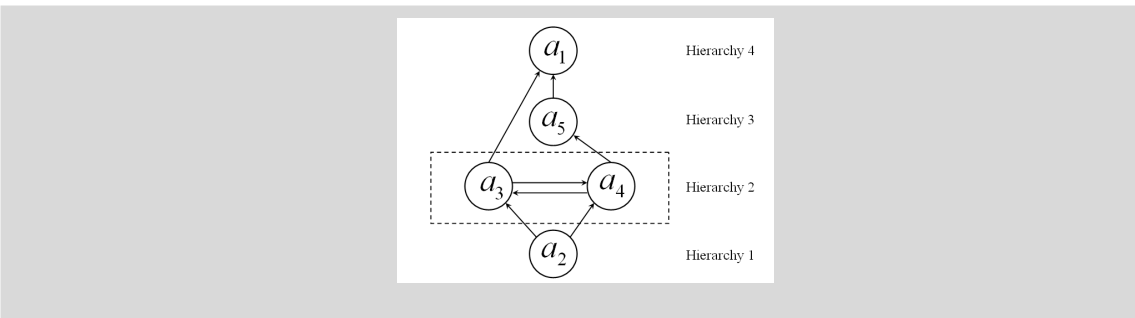


Figure 1: Diagram of structural model developed from ISM

2. METHOD

2.1. Identify Design Elements

Step1. 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 (Osgood et al., 1957; Chuang, et al. 2001). 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 and its antonym on the left. On the evaluation 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: Seventy-two consumers (42 males, 30 females in the age range 21±5), most of whom are college students in Taiwan, participated in the subjective evaluation task.

- Procedure: Each consumer was asked to evaluate 26 razors according to the image word pair in every page. The evaluations were conducted individually and each consumer was allowed to proceed at his or her own pace. To prevent the centralization of the rating scores that often occurs in such a subjective evaluation task, the consumers were told to obey the following three-step procedure:

Step 1: Classify all the razor 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".

Step 2: 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 3: The samples with the same degree of preference or image word association should be assigned the same score.

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	

Step2. Decompose design elements

Out of the 26 razor samples, 6 (**Fig. 1**) were chosen with the strongest preference scores in terms of the nine-point semantic scale. By analyzing the six representative samples, one can construct a morphological chart (**Table 2**) in terms of their global shape and features. The element categories in morphological chart service as the design elements for the implement of ISM.

ZE1 ZE 2 ZE 3 ZE 4 ZE 5 ZE 6

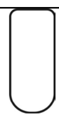
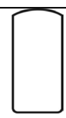
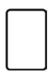
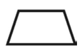
Figure 2: Top 6 razors with strong preferences.

2.2. Adopt ISM to Developing Products

Step1. Organize an ISM implementation group

To begin, a consumer group was established, and the group members were responsible for manipulating ISM. This user group consisted of fourteen subjects (8 males, 6 females in the age range 20±6), most of whom were college students in Taiwan.

Table 2: Morphological analysis of 8 razor samples

Design elements	Category 1	Category 2	Category 3	Category 4
A. Body	A_1 	A_2 	A_3 	A_4 
B. Power holder	B_1 	B_2 	B_3 	B_4 
C. Power keys	C_1 	C_2	C_3 	C_4 
D. Head	D_1 	D_2 	D_3 	D_4

Step2. Set up the input matrix ***D*** of the design elements

From the responses of the consumer 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, and due to which other factors the various risk commands might ultimately be the source of a missed objective. 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, □$_{ij}$ denotes the relationship between the ith and the jth elements, and $\boldsymbol{D}$ is the relationship matrix.

<u>Step3.</u> <u>Determine the reachability matrix $\boldsymbol{M}$ of the design elements</u>

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

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

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

$$\boldsymbol{D} = \begin{array}{c|ccccccccccccccc|} & A1 & A2 & A3 & A4 & B1 & B2 & B3 & B4 & C1 & C2 & C3 & C4 & D1 & D2 & D3 \\ \hline A1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 \\ A2 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 0 & 1 & 1 & 1 & 1 \\ A3 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 1 & 0 \\ A4 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 1 & 1 \\ B1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 0 \\ B2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 1 & 0 & 0 \\ B3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 \\ B4 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 1 & 0 & 0 \\ C1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ C2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 \\ C3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ C4 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 \\ D1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ D2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ D3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{array} \qquad (2)$$

where $\boldsymbol{I}$ is the unit matrix, k is a positive integer exponent, and $\boldsymbol{M}^*$ is the reachability matrix. Note that the reachability matrix satisfies the Boolean multiplication and addition laws (i.e. $1 \times 1 = 1$ *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:

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

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

where m_{ij} denotes the value of the *i*th row and the *j*th column.

Step4. Decompose the design elements into the leveled relationship map

According to Eq. (8), the levels and the relationships between the command items can be determined and the structure of the command items' relationships can be expressed using the graph shown in **Fig. 2**.

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

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.

Step5. Modify the new product

In accordance with the design element structure (**Fig. 2**), a product designer helps to modify the final mobile phone (**Fig. 3**).

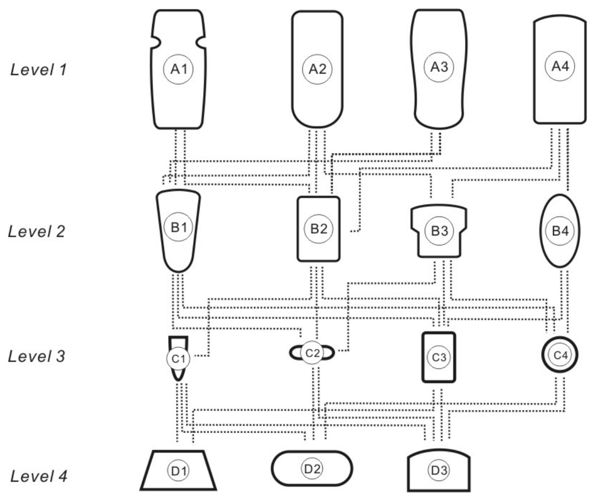


Figure 3: The design element structure developed from the reachability matrix

2.3. Satisfaction Evaluation

In this phase, another twenty-four consumers (16 males, 8 females in the age range 20±3) participated in the satisfaction evaluation task. Each consumer was asked to complete the satisfaction questionnaire (**Appendix A**) and the preference order questionnaire (**Appendix B**). In the satisfaction questionnaire, each question provided a 5-point (from 0 to 5) rating scale for the evaluation. A significance level of .05 was used to evaluate the significance of the difference in the value of a question when a participant compared both the existing products (**Fig. 1**) and the proposed products (**Fig. 3**). On other hand, a participant had to give a numerical preference order for each of the samples.

Figure 4: Several mobile phone examples developed from ISM

3.

4. RESUTLS AND DISCUSSING

3.1. The Analysis of the Consumer-preferred Mobile Phone Form

In accordance with the 6 representative samples (**Fig. 1**) and 16 design elements (**Table 2**), the following mobile phone features were identified as preferred by the users:

(1) A soft-curvature or asymmetrical body;

(2) Elliptical or rounded rectangular digital keys;

(3) An unbalanced display, function keys excluded;

The form features above indicate that consumers preferred the curved line-based shape and round shape.

On the other hand, the above speculation also can be supported by the results of the satisfaction and preference order evaluation shown in **Table 3**. **Table 3** shows that 1) consumers have different levels of satisfaction for different mobile phone samples, 2) the mobile phone samples with curved line-based shapes or round shapes got higher ratings, and 3) the mobile phone sample with curved line-based shapes or round shapes were also placed higher in the preference order than those mobile phone samples without curved line-based shapes or round shapes.

Table 3 The evaluation of satisfaction and preference order

	exiting product						proposed product					
	ZE1	ZE2	ZE3	ZE4	ZE5	ZE6	NZ1	NZ2	NZ3	NZ4	NZ5	NZ6
satisfaction	2.8	2.2	2.1	3.3	1.8	3.8	4.1	3.4	3.9	3.1	3.0	2.5
preference order	8	10	11	5	12	3	1	4	2	6	7	9

*: $p < 0.05$

The design element structure (**Fig. 2**) can explain the above speculation. **Fig. 2** shows that the design elements are divided into a few groups in the design element structure. For instance, the following design elements related to curved-line shapes are grouped together: the design elements A1, A3, B3, B4, C1, C3 and D3. The following design elements related to round shapes are grouped together: the design elements A2, A4, B1, B2, C2, C4, D1 and D4. In addition, the design elements within each group are meaningfully ordered. For instance, the design elements are organized in the following order in the design element structure: body, digital key, function key and display. 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. That is, the design element structure in the new product looks like a preference (experience, knowledge) from the user's perspective. As a result, the users are more satisfied with the proposed product. This explains why the product developed from ISM is preferred by the users over the exiting product.

3.2. The Feasibility of Applying ISM Approach

Table 3 also shows the results of satisfaction and preference order evaluation for both the existing and proposed mobile phones (**Table 3**). It shows that 1) consumers have different rating scales for different mobile phone samples, 2) Mobile phones developed from ISM got higher ratings than existing mobile phones, and 3) Mobile phones developed from ISM were ranked higher in the preference order than exiting mobile phones. These results indicated that consumers are more satisfied with the proposed mobile phones than with the existing mobile phones. This thus supports the feasibility of applying the ISM method for consumer preference-based product design.

3.3. The Variety of Consumer-preferred Products

Finally, the variety of consumer-preferred products is also shown in **Fig. 3** and **Fig. 2.** This product variety was due to the hierarchy of design element interactions within a product. This approach represents the design priority and related design constraints within a product using a structural graph, helping designers to create variant design solutions in a product family for different market requests.

5.

6. CONCLUSION AND FUTGURE STUDY

Due to the increasing of competition among the products in market, the issue regarding designing a product that meets consumer needs has been gotten more and more important. From this viewpoint, we cannot overemphasize a design approach that can efficiently modify a consumer preference-based product. This study tested the feasibility of applying the ISM method for designing consumer preference-based product. Based on the experimental results, several conclusions can be drawn and suggestions can be made.

- First, we suggest that the product designer should use curved line-based and round shapes in designing a mobile phone. This should improve the user satisfaction with the mobile phone.

- Second, this study suggests that the product designer could adopt ISM to develop a product so as to increase the user satisfaction with the product.

- Third, this study suggests that the product designer could adopt ISM to develop various products so as to satisfy the individually customized requirements of consumers.

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Appendix A: the questionnaire on the degrees of satisfaction

How satisfied did you feel with the given mobile phone?			
Exiting product	ZE 1	very satisfied(5)-satisfied(4)-equal(3)-less satisfied(2)-much less satisfied(1)	Ans:___
	ZE 2	very satisfied(5)-satisfied(4)-equal(3)-less satisfied(2)-much less satisfied(1)	Ans:___
	ZE 3	very satisfied(5)-satisfied(4)-equal(3)-less satisfied(2)-much less satisfied(1)	Ans:___
	ZE 4	very satisfied(5)-satisfied(4)-equal(3)-less satisfied(2)-much less satisfied(1)	Ans:___
	ZE 5	very satisfied(5)-satisfied(4)-equal(3)-less satisfied(2)-much less satisfied(1)	Ans:___
	ZE 6	very satisfied(5)-satisfied(4)-equal(3)-less satisfied(2)-much less satisfied(1)	Ans:___
Proposed product	NZ 1	very satisfied(5)-satisfied(4)-equal(3)-less satisfied(2)-much less satisfied(1)	Ans:___
	NZ 2	very satisfied(5)-satisfied(4)-equal(3)-less satisfied(2)-much less satisfied(1)	Ans:___
	NZ 3	very satisfied(5)-satisfied(4)-equal(3)-less satisfied(2)-much less satisfied(1)	Ans:___
	NZ 4	very satisfied(5)-satisfied(4)-equal(3)-less satisfied(2)-much less satisfied(1)	Ans:___
	NZ 5	very satisfied(5)-satisfied(4)-equal(3)-less satisfied(2)-much less satisfied(1)	Ans:___
	NZ 6	very satisfied(5)-satisfied(4)-equal(3)-less satisfied(2)-much less satisfied(1)	Ans:___

Appendix B: the questionnaire on preference order

What is the order of your preferences among the mobile phones?												
samples	ZE 1	ZE 2	ZE 3	ZE 4	ZE 5	ZE 6	NZ 1	NZ 2	NZ 3	NZ 4	NZ 5	NZ 6
Ans:	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )