A Study of the Product Styling Design Evaluation System for Handheld Transceivers and its Applications

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Abstract—**It is critical for an enterprise to make quick, effective, and reasonable decisions when evaluating and screening out a large number of product styling design schemes for handheld transceivers. This study is based on the fundamental contents and program of product styling designs. Embodied individual properties of handheld transceiver products and styling design experiences were integrated into the investigation. Via detailed questionnaire investigations and data analyses, the contents of evaluating handheld transceiver product design schemes can be verified and confirmed. This approach follows both fundamental quantitative and qualitative principles including comprehensiveness, systematicness, and flexibility. An evaluation model for the product styling of handheld transceivers has been built along and subjective factors, neutral factors, and objective factors serve as the factors of the first-level indicators. The analytic hierarchy process was used to build the hierarchical structure of the evaluation system. The judgment matrix of each level in the hierarchy was constructed by the pairwise comparison of importance. The sum-product method was utilized to calculate the weight vectors in order to form the ranking of levels in the hierarchy. The weight index of each level of the hierarchy in the evaluation system can also be obtained. The final step is to implement the examination and verification of this design evaluation system on the product styling designs for handheld transceivers.**

Keywords—*Handheld transceiver products, design evaluation, system, analytic hierarchy process*

I. Introduction

Quanzhou, Fujian has been one of the main production bases for worldwide handheld transceivers and has earned a good reputation of hometown to handheld transceivers. The handheld transceiver industry is one of the top three economic pillar industries in Quanzhou. There are a total of more than 300 handheld transceiver companies in this city and they have been contributing a lot to the local economy of the province and the city. As the competitions on the market are getting intensified, a company needs to revamp its products and get rid of the stale. It is necessary for enterprises to emphasize and extend the product research and development for handheld transceivers. Some data indicated that, almost one thousand new products are launched per year in Quanzhou, Fujian. This phenomenon indicates a large demand of product designs for handheld transceivers. Meanwhile, design houses usually provide these enterprises with a great number of design schemes for selection. It has become a big challenge for an enterprise to screen out a design scheme which meets its own enterprise standard from an enormous number of design schemes for handheld transceivers. If a bad design scheme is selected for production, an enterprise not only suffers huge losses from the economic aspect, but also makes its products lose market competitiveness. The situation might get worse so as to trigger enterprise crisis or lead to the suspension of work or bankruptcy. Therefore, it is critical for an enterprise to acquire the assistance in making objective, rational, and effective assessments and screening when facing numerous design schemes. It is expected to assist handheld transceiver enterprises or design houses in building a rational and objective product styling design evaluation system for handheld transceivers via this study. The perceptual design evaluation factors can be presented in a rational way. A quantitative standard serves as the evaluation basis so that the quality of design schemes can be presented to the enterprises in the most intuitive way. This approach can assist an enterprise in making the most correct decision.

II. Literature review

The evaluation of industrial product styling is mainly to observe and analyze the constituent elements of a product's styling and these include factors such as the product's form, color, texture, material, craft, and ergonomic consideration[8]. A user generates psychological feelings during the process of observing a product and forms his/her perception awareness via the human body's sensory system. This type of perception awareness belongs to the subjective type of affective responses. Due to the differences in individual's social attributes such as gender, age, occupation, and cultural level, large differences exist between the aesthetic conception, value, and social experience of different users. The perception and affection that are generated after using a product are also different (Cognitive Awareness, 2011). This type of perception easily forms subjective judgments due to a user's personal attributes and this

makes the user unable to form rational and objective product styling design evaluation results.

There are already some academic research achievements on the design evaluation systems for industrial product designs such as the study of industrial design evaluation system for brand styles and features[9], the study of multi-project evaluation system for product designs based on industrial designs[10], and the study of digital industrial design systems[11]. This type of review studies is oriented in the generalized and general direction but doesn't propose concrete design evaluation methods for the styling design of embodied products. Therefore, it is more suitable for general consumer products. Due to the special attributes of individual handheld transceiver products, this type of research provides some reference values but is not applicable due to the wide-ranging contents.

2.1 Styling design evaluation contents for handheld transceiver products

The conventional evaluation of product styling design schemes adopts industrial design programs and the contents of professional theories and methodology as the main framework. It emphasizes the main constituent elements of product styling designs and classifies these elements into several categories for further investigation so as to build product design evaluation systems and methods. A handheld transceiver product belongs to the category of security and protection products with wireless communication. Although it is still within the industrial product scope, its product styling design process is different from conventional ones due to the requirements of R&D and productions for the handheld transceiver industry. It is also required to make corresponding adjustments and changes for the contents and methods of the design evaluations. In order to guarantee the rationality of the evaluation process and contents, a multi-level questionnaire survey was implemented during the earlier stage of evaluating the contents of product designs for handheld transceivers. It was integrated with the evaluation experiences during the product design implementation process for handheld transceivers. The resulting data obtained from the quantization analysis was also used to verify the contents of product styling design evaluation for handheld transceivers. The fundamental framework of the contents of product styling design evaluation for handheld transceivers can be established.

The fundamental framework of the contents of product styling design evaluation includes three levels as follows. The first level is the evaluation target which is the also the first-level indicator. The second level is the evaluation standard level, which includes three second-level indicators. The third level is the fractionized evaluation standard level, which includes several third-level indicators. The exact contents of these levels are as follows. The *evaluation target* indicates the product styling design evaluation of handheld transceivers. The *second-level indicator* includes three contents which are the subjective factor, neutral factor, and objective factor. The verification of this indicator is apparently different from the conventional styling design indicators. This is mainly due to the special product attributes of a handheld transceiver itself. The

user group of this product is relatively fixed and the overall cultural level of its users is relatively lower. It was known from the questionnaire survey that the users expected to avoid using professional industrial design terminology during the evaluation process. They preferred using popularized language to describe or define categories as much as possible. After sufficient reviews and analysis by the questionnaire survey, we decided to use three indicators including the subjective factor, neutral factor, and objective factor to replace and simplify the complicated second-level classification in the conventional evaluation system such as form, color, crate, human-machine interactions. The *subjective factor* includes the contents that can only be sensed by explanation. It can be expanded into overall form stability, proportional form reconciliation, degree of form saturation, form novelty, form fashion, form color variation, and form characteristics. The *neutral factor* includes the delimitation of the difference between the sensed and the visible contents. It can be expanded into form texture comfort, form layout rationality, product delicacy, product operability, and product sturdiness. The *objective factor* include visible and sensible contents which can be expanded into the innovation of product structure, product structure rationality, variation in product materials, advances in product technology, innovation of product functions, product waterproof characteristics, product surface texture, product volume, and product cost.

This evaluation framework covers every main contents of the product styling design for handheld transceivers and has a higher level of feasibility. During the follow-up process of the analysis of this evaluation method, it is required to make adequate adjustments depending on the embodied influential factors such as user, operating conditions, product type, and local characteristics. This is to verify the integrality, authenticity, and effectiveness of the evaluation contents.

The evaluation of industrial product designs is a comprehensive evaluation and decision-making process with multiple targets. A design evaluation includes a large number of evaluation contents which cannot be analyzed by conventional quantitative methods such as the aesthetics of the appearance, the degree of proportional reconciliation, and color balance. At the moment, the frequently used industrial design evaluation approaches include fuzzy set theory evaluation method, mathematical statistics evaluation method, weighted coefficient evaluation method, and question evaluation method [12][13]. During the design evaluation system research process in this study, several commonly used evaluation methods were compared by integrating the product design process for handheld transceivers and their own special product attributes. The approach of analytic hierarchy process was selected as the research methodology for the evaluation system.

2.2 Theory of analytic hierarchy process

The approach of analytic hierarchy process (AHP) can realize the quantitative description and analysis of non-quantitative factors during the subjective judgment of design evaluation contents. For a complicated systematic question which has multiple evaluation targets, multiple evaluation criteria, and is difficult to be quantized, the AHP approach allows a description by mathematical method. It

belongs to a multi-target design decision-making and analysis approach which is both quantitative and qualitative. The fundamental theory of this method is to clarify the questions of the design target strategy and make it structured with multiple levels. Questions are classified into evaluation factors or evaluation criteria of different levels. This approach forms a hierarchical structure and is helpful for constructing the structural model of the design evaluation system. The constituent factors of the model can be analyzed by constructing the pairwise comparison judgment matrix and calculating the importance of all of the factors in a level as compared to a certain constituent factor in the upper level for a quantitative study. The weights of each factor can be determined by calculating the maximum eigenvalues of the judgment matrix and the corresponding eigenvectors.

The fundamental procedure of the AHP approach is to make the design evaluation targets structured with multiple levels so as to build a hierarchical structure at first. After that, it is required to carry out pairwise comparison of the importance by referring to the importance indicators and assign a value in the range of 1~9 to each of the design evaluation factors in order to build the judgment matrix. Depending on the degree of importance, the resulting conclusion of the indicator is described as follows. 9-extremely important, 7-very important, 5-apparently important, 3-important, 1-equally important, 1/3-very unimportant, 1/5-unimportant, 1/7-apparently unimportant, and 1/9-very unimportant. At the final step, the summation method, eigenvalue method, and root method are used to calculate weight vectors so as to form a hierarchical unilateral ranking.

In this study, the summation method was used for calculating the weight vectors. During the hierarchical ranking process, it is required to carry out the consistency check on the judgment matrix. The procedure of the consistency check is as follows.

（1）The first step is to determine the eigenvectors of Matrix A, which is also the comparison judgment matrix of the relative weights of each factor.

$$A = \begin{bmatrix} a_{11} & a_{12} & ... & a_{1n} \\ a_{21} & a_{22} & ... & a_{2n} \\ ... & ... & ... & ... \\ a_{n1} & a_{n2} & ... & a_{nn} \end{bmatrix}.$$

（2）Using the sum-product method to calculate the judgment matrix and obtain values.

The implementation procedure is as follows.

A、Normalizing each of the rows of Matrix A by the below equation.

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \qquad (i, = 1, 2, , , , n \quad)$$

B、Summing up each row by columns of the judgment matrix after normalization.

$$\overline{W}_i = \sum_{j=1}^{n} b_{ij} \qquad (i, = 1, 2, , , n \quad)$$

C、Normalizing Vector $\overline{W} = \begin{bmatrix} \overline{W}_1 & \overline{W}_2 & ... & \overline{W}_n \end{bmatrix}^T$ by the following equation.

$$W_i = \frac{\overline{W}_i}{\sum_{i=1}^{n} \overline{W}_i} \qquad (i = 1, 2, , , , n \quad)$$

wherein $W = \begin{bmatrix} W_1 & W_2 & ... & W_n \end{bmatrix}^T$, which is the eigenvector to be obtained.

D、Calculating the maximum eigenvalue of the judgment matrix: $\lambda_{max} = \sum_{i=1}^{n} \frac{(AW)_i}{nW_i}$, in which (AW) i is the ith component of Matrix [AW].

（3）Consistency check

As mentioned above, since the judgment matrix is estimated but not very accurate, it is not capable of making each of the elements in the judgment matrix satisfy

$a_{ij} = \dfrac{a_{ik}}{a_{jk}}$ Therefore, it is required to carry out the consistency

check, which is to calculate the consistency index as follows.

$$C.I. = \frac{\lambda_{max} - n}{n - 1}$$

When λmax =n, *C.I.*=0, this indicates complete consistency. When the *C.I.* value is larger, the complete consistency is worse. Typically speaking, the consistency of a judgment matrix is acceptable as long as *C.I.≤0.1*. Otherwise, it is required to carry out pairwise comparison again. When the number of dimensions of a judgment matrix is larger, its judgment consistency is worse. Therefore, it is required to relax the consistency requirements of a matrix with a large number of dimensions. As a result, a correction value *R.I.* should be introduced by referencing average random consistency values. Moreover, a more reasonable *C.R.* should be taken as the indicator for evaluating the consistency of a judgment matrix.

$$C.R. = \frac{C.I.}{R.I.}$$

In other words, the consistency of a judgment matrix is viewed as acceptable as long as *C.R.≤0.1*. Otherwise, it is required to carry out pairwise comparison to determine.

The above analysis can only determine the relative single level hierarchical weight. Therefore, during the AHP operation, it is also required to calculate the weight of all of the elements in the same level to the highest level (overall criterion) for the ranking operation. The typical approach is to obtain the composite weight index of elements in each level in relation to the overall hierarchy in a top-down approach. The scores can be calculated according to the evaluation criteria and the composite weight index so as to carry out evaluation and selection.

III. METHODS

3.1Construcing the fundamental principles of the product styling design evaluation system for handheld transceivers

It is required to make sure that the product design

evaluation system that is built has a higher degree of effectiveness and authenticity. It is also required to ensure an enterprise make the correct selection when carrying out the analysis and evaluation of product styling design schemes for handheld transceivers. An evaluation system needs to follow the following principles including comprehensiveness, systematicness, integration of quantitative and qualitative approaches, feasibility, operability, and flexibility.

3.2 Constructing the product styling design evaluation system for handheld transceivers

The contents of an evaluation system for industrial design include form factors such as product styling, color, material, and craft. It is also required to consider correlation factors such as human-machine engineering, social environment, economy, and culture. The evaluation process is relatively more complicated and therefore it is difficult to carry out quantitative evaluations by mathematical models. It can be integrated with the modern industrial design evaluation system based on the attributes owned by a handheld transceiver itself [14][15][16][17]. The contents of the product styling design evaluation for handheld transceivers can be structured with multiple levels in order to build the hierarchical structure of the product styling design evaluation for handheld transceivers as shown in Figure 3-1. With an attempt to make sure that the product styling design evaluation system for handheld transceivers is comprehensive, scientific, objective, and feasible, the handheld transceiver product evaluation model that was built served as the questionnaire contents for the investigation by market questionnaire.

The main purpose of this investigation is to acquire sample data for statistical analyses. It is also expected to refine and improve the model of the evaluation system based on the questions during the investigation process. Secondly, for the second-level indicators and third-level indicators of the product styling design evaluation system, the relative importance between indicators within a hierarchy can be determine by pairwise comparison for data collection.

Figure 3-1 Hierarchical structure of product styling design evaluation for handheld products

Target layer A	Criterion layer (B)	Criterion layer (C)	Scheme layer (D)
		Overall form stability	
	Subjective factor (B1)	Form proportional reconciliation	
		Degree of form saturation	Scheme D1
		Form novelty	
		Form fashion	
		Form color variation	
		Form characteristics	
		Form texture comfort	
	Natural factor (B2)	Form layout rationality	
		Product delicacy	Scheme D2
		Product operability	
Fundamental framework of evaluation contents of product styling designs for handheld transceivers (A)		Product sturdiness	
		Innovation of product structure	
		Product structure rationality	
	Objective factor (B3)	Variation in product materials	
		Advances in product technology	
		Innovation of product functions	Scheme D2
		Product waterproof characteristics	
		Product surface texture	
		Product volume and weight	
		Product cost	

3.3 Research subjects

In this study, 100 people were selected for the questionnaire survey and in-depth interviews. The data of the investigation subjects is described as follows. On the gender of the research subjects, 65 of them are male and thus the percentage is 65%. On the occupation of the research subjects, they are classified into security personnel with a total of 18 people (18%), 21 hotel waiters and waitresses (21%), 11 construction site inspectors (11%), 20 handheld transceiver salespeople (20%), 15 enterprise management personnel (15%), 15 product designers (15%). On their cultural level, 39 of them have their level of education at college or higher (39%), 58 of them are above junior high school and below senior high (58%). On their age brackets, 27 of them are in the range of 20-35 years old (27%), 38 of them are in the range of 36-45 years old (38%), and 35 of them are 46 years old or older (35%).

IV. CONCLUSION

4.1 Summary

This study verified three main directions including subjective, neutral, and objective factors for evaluating handheld transceivers. A questionnaire survey in a broader range of market was carried out in order to acquire the investigation data. The raw data was collected, calculated, and analyzed based on the AHP principles and method. The evaluation contents were refined and improved so as to determine the constituent design elements for each level with the influence on the design scheme evaluation. A product styling design evaluation system for handheld transceivers was

built and the weights of the influence of evaluation factors at each level of the evaluation system were verified. Finally, the implementation and examination of the product styling design projects for handheld transceivers verified the product styling design evaluation system that was proposed in this study is valid. This system can effectively assist enterprises or design project clients in quickly determining the quality of a design scheme and making the correct choice. The implementation verified that this evaluation system can change the conventional evaluation approach by subjective assumptions. This approach is provided with consistent rationality and effectiveness.

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