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Patent Product Innovation Design and Analysis -for Emergent Escape Appliance as An Example

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ABSTRACT

By using the method of the comparison evaluation to select the innovated elements of the product innovation design, the better design structural organization is obtained. Furthermore, to carry out the suggestions from experts, the progressive and creative features embedded in products are enhanced. Therefore, this study offered 5WIH approach with capability of design assessment to assess and select the innovative design factors. During the cognition of experts' experience, then applied the combination of Analytical Hierarchy Process (AHP) and Grey Relational Analysis (GRA) to assess and investigate the design factors that could obtain the ranking of design factors. Afterward, the Grey Structural Modeling (GSM) was introduced to the innovative product design strategy in the way of structure diagram. From the result of this research, the design strategy was applied to the design creation of multi-functional escape appliance. It was not only obtained the effect of progress and innovation but also made the product in line with the patented application conditions that gave the evidence of practicability relevant to the research method.

Keywords: Product innovative design,* Analytical hierarchy process*, Grey relational analysis, Grey structural modeling, Patent product.

1. Introduction

The development of a new creative product design is to use the better design features than the current product and generate the new product [1-5]. Hence, to select the better design feature is one of the most important tasks for the design of innovative products [6~10]. This research expects to use data from different sources in order to get the better progressive design features. Therefore, the 5W1H method is widely used in the selection and evaluation of the design data. The more progressive design factors can be found and can be used as the key data for the new product design. In order to understand the importance of the relative design factors, this research uses the common evaluation from experts, do the inspection of the design factors, get the policy for creative product design, and used as the executive target of new product design. This method of using the opinions from experience experts is not only to get the correct design policy method, but also to avoid the chance of design mistakes which will affect the function and quality of products.

In this paper, the AHP method was introduced for assessment of the importance of design features and explored the strategies of innovative product design. During the calculation processing of Grey Relational Analysis (GRA), the procedural aspects of the implementation of the design strategy can be identified. Then, conveyed to the gray structure model that can clearly show the structural organization of the design strategy and became the strategic principles of a new product design applications.

The method proposed in this study is a new research combination that was a systematic combination of several mature single research techniques. According to the conditions of innovative design, consensus of design strategy can be provided by expertise and an excellent design strategy method can be obtained from the research method. The research method was from the initial selection of innovative design features to obtainment of design strategies, the whole study process in an objective and transparent assessment data and the research results was clearly defined. The systemic design methods revealed the organized design structure for innovative product design that can provide the strategic principles of the new products design and clarify the problem of the product design structure.

Analytical Hierarchy Process (AHP) analyze and establish the hierarchical structure that assessed the importance of innovative design features. Afterward, GRA was applied to analyze the design features that evaluated from expert assessment. It can calculate the degree of importance of innovative design features based on the analytical capability of uncertain

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problem Then, through the Grey Structural Modeling (GSM) conveyed the structural function from the results of the study and established a systematic research organization that was overall consideration of the research structure in sequence, continuity, articulation, and integration levels in order to calculate the research data to establish a vertical organization. This new research combination system can clearly identify innovative design methods. Therefore, it is suitable for the execution of this study.

The 5W1H method was chosen to explore the innovative design factors. It was used for selection and evaluation of the design data widely. Then, the more progressive design data can be found [11~13]. This method is compare new problem with old problem to get more progressive data and opinions under the specialized identification then to explore the research problem directly that provided more accurate research data. It became the method for getting features of innovative products design and more complete way for research data collecting.

2. Mathematics Method

This section reviews the literatures that are related to research. The following topics are covered in review: (1) The innovative design conception of products (2) Nagai method (3) AHP method (4) GRA theory and (5) GSM theory.

2.1 The Innovative Design Conception of Products

Product innovative design is an activity that converts new concepts (ideas) to realization of design. No matter it is to create new products or improve existing products by combining new science, new knowledge, new materials or new technology, it could be called product innovative design [14]. Innovative design is defined as: the design of new concept or new manufacturing process. According to the definition, innovative design could be categorized into three types: product innovation, process innovation, and technical innovation integration [15].

Product innovative design is the integration of product design factors by combining engineering technology and material application. If it is reflected in the design of quality and function of product, the profile and functional innovation of product could be promoted. The product innovative design has two phases. The first phase is to draw up the main design factors on the basis of design goal, such as functional analysis, structural analysis, application analysis, shape analysis, value and cost analysis, etc. The second phase is to combine the best factors and create new product type. The above methods were used to realize product innovation in this study.

The field of thinking in product innovative design includes: functional, quality, visual, social, art, economic and psychological, etc. [16]. According to above attributes, this study employed Nagai method and expert review to assess the innovative design of patent products to provide the direction of innovative design of new product.

2.2 Nagai Method

Nagai method is an analytical method of semantic structural composition. It was proposed by Masatake Nagai in 1989. This method uses mathematical calculation to find the maximum (the strongest) and the minimum (the weakest) values, subsequently to screen and compare these semantic structural compositions and develop the semantic properties of product innovative design [17,18]. In recent years, there are many success cases in this method.

The steps are as follow:

1. Strength and weakness analysis of design factors
   First, the design properties between new products and existing products are evaluated and compared. Secondly, the strength and weakness of design properties are analyzed after using 5W1H method to draft characters of products. Then the features of product design are determined in view of the values of strength and weakness.
2. The calculation of Interpretive Structure Modeling (ISM)
   Comparing and constructing a relationship matrix between the above extracted design properties, then using ISM analysis method to calculate the adjacency matrix and get the reachable matrix.
3. Explore the decision route chart of ISM
   Ranking the matrix and finding important features determine the route of design strategies.

2.3 The AHP Method

AHP was developed by Thomas L. Saaty in 1970 [19]. The basis of AHP is linear algebra and graph theory. Graph theory concepts are applied to analyze and establish the hierarchical structure of factors. The matrix concepts in linear algebra are used to measure the relative importance (priority) of a number of alternatives as references of making decisions.

In this study, AHP was employed to decide whether the evaluation data were correct or not. The purpose is to get the correct clean data.

2.4 Grey Relationship Analysis

2.4.1 GRA method

Dang proposed the grey system theory in 1989 [20], and GRA is one of the most effective analytical tools. Because gray system theory can be for uncertainty and incompleteness of message by relation analysis and model structuring, GRA can manage effectively uncertain, multi-dimensional, discrete, and incomplete data [21]. GRA has been applied to a variety of fields, such as product design survey, marketing research, social science, system modeling, computer science, etc [22~37]. By using GRA method in this study, the innovative design vocabularies and their ranking structure could be established and utilized in the creation of patent product design. The results could be provided to innovative design education in the creation of the patent products.

2.4.2 Establishment of grey relational data

The GRA was conducted by establishing matrix containing reference vector and comparative vectors in Eq. (1) and Eq. (2) respectively.

$$x_0 = (x_0(1), x_0(2), \cdots, x_0(k), \cdots, x_0(m)); \quad k = 1,2,3,...,m \tag{1}$$

$$\begin{aligned} x_1 &= (x_1(1), x_1(2), \cdots, x_1(k), \cdots, x_1(m)) \\ x_2 &= (x_2(1), x_2(2), \cdots, x_2(k), \cdots, x_2(m)) \\ &\vdots \\ x_i &= (x_i(1), x_i(2), \cdots, x_i(k), \cdots, x_i(m)) \\ &\vdots \\ x_n &= (x_n(1), x_n(2), \cdots, x_n(k), \cdots, x_n(m)) \end{aligned} \quad i = 1,2,3,..,n \tag{2}$$

The data of comparative vectors could be clarified by the consistence index (*CI*) of AHP. In general, the consistence of the matrix can be accepted when $CI \leqq 0.1$.

$$[W]_i = \begin{array}{c} \\ A_{1,1} \\ A_{1,2} \\ A_{1,3} \\ \vdots \\ A_{1,m} \end{array} \begin{array}{c} \begin{array}{ccccc} A_{1,1} & A_{1,2} & A_{1,3} & \cdots & A_{1,m} \end{array} \\ \begin{bmatrix} 1 & w_{12} & w_{13} & \cdots & w_{1m} \\ w_{12}^{-1} & 1 & w_{23} & \cdots & w_{2m} \\ w_{13}^{-1} & w_{23}^{-1} & & \cdots & \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ w_{1m}^{-1} & w_{2m}^{-1} & w_{3m}^{-1} & \cdots & 1 \end{bmatrix}_i \end{array}, i = 1,2,3,\cdots,n \tag{3}$$

$$CI = \frac{\lambda_{\max} - n}{n-1}$$

2.4.3 Generation of grey relational analysis

The generation of grey relational analysis means extracting the available data by satisfying three rules: non-dimension, scaling and polarization. Subsequently the standardization of data could be obtained by three methods: larger-the-better, smaller-the-better, and nominal-the-better. The three methods are shown as follows.

1. Larger-the-better

$$x_i^*(k) = \frac{x_i(k) - \min_i x_i(k)}{\max_i x_i(k) - \min_i x_i(k)} \tag{4}$$

where $\max_i x_i(k)$ means the maximum number in j and $\min_i x_i(k)$ means the minimum number in items j.

2. Smaller-the-better: when we expect the target to be as small as possible.

$$x_i^*(k) = \frac{\max_i x_{ij}(k) - x_i(k)}{\max_i x_i(k) - \min_i x_i(k)} \tag{5}$$

3. Nominal-the-better: when we expect the target to be between the largest and the smallest data.

$$x_{ik}^* = \frac{\max_i \{e_{ik}\} - e_{ik}}{\max_i \{e_{ik}\} - \min_i \{e_{ik}\}}, \; e_{ik} = \frac{|OB - x_{ik}|}{|OB|} \tag{6}$$

The above Nagai's equation means that the object value will be between the maximum and minimum value, $\max_i x_{ij} \geq x_{OBj} \geq \min_i x_{ij}$, where $OB \neq 0$. If object value is zero, smaller-the-better will be used instead.

2.4.4 Calculation of grey relation grade

In Nagai's local grey relational equation, the reference vector is x_0 and the comparative vector is x_j. When x_0 and x_j have higher relation when Γ_{0i} approaching 1, and lower relation when Γ_{0i} approaching 0 [40~45]. The equation is shown as follows.

$$\Gamma_{0i} = \Gamma(x_o(k), x_i(k)) = \frac{\overline{\Delta}_{\max} - \overline{\Delta}_{0i}}{\overline{\Delta}_{\max} - \overline{\Delta}_{\min}} \tag{7}$$

in which $\overline{\Delta}_{0i} = \|x_{0i}\|_2 = (\sum_{k=1}^{n} [\Delta_{0i}(k)]^{\rho})^{\frac{1}{2}}$

Where $\overline{\Delta}_{\max}$ represents the maximum and $\overline{\Delta}_{\min}$ represents the minimum value.

The global grey relation equation is as follows.

$$\Gamma_{ij} = \Gamma(x_i, x_j) = 1 - \frac{\overline{\Delta}_{ij}}{\Delta_{\max}} \tag{8}$$

in which $\overline{\Delta}_{ij} = (\sum_{k=1}^{n} [\Delta_{ij}(k)]^2)^{\frac{1}{2}}$

2.4.5 Grey relational ordinal

According to the evaluation data of subjects, grey relational grade and grey relational ordinal are calculated and compared the value of Γ_{0i}. The larger grade means the more important item and becomes the ordinal criteria of structural system.

2.5 Grey Structure Method (GSM)

GSM is mainly applied to the analysis of uncertain factors and incomplete data and figures out the overall structure, and interprets the weight of discrete sequences by mathematical method. This research was based on Nagai's GSM structural analysis theory to establish the matrix [38~41]. Then the overall ranking structure was obtained by Matlab calculation. The grey relational matrix Γ is defined as the following.

$$\Gamma = \begin{bmatrix} \gamma_{11} & \gamma_{12} & \cdots & \gamma_{1m} \\ \gamma_{21} & \gamma_{22} & \cdots & \gamma_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \gamma_{m1} & \gamma_{m2} & \cdots & \gamma_{mm} \end{bmatrix} \quad (9)$$

where $i, j = 1,2,3,.....m;$

$$\gamma_{ij} = 1 - \frac{\left\| x_i - x_j \right\|_\zeta}{\max \forall_i \max \forall_j \left\| x_i - x_j \right\|_\zeta} \quad (10)$$

2.5.1 Establishing cluster structure

According to the result of local GRA, the structure graph of GSM will be attained. GSM graph is a vertical structural chart that correctly defines the structure and order of research data to be applied for cluster analysis to find the hierarchical relationship [42-46]. If $\ulcorner C \lrcorner$ represents a hierarchical structure the structure is consisted of a set of structural elements shown as follows.

1. Let C indicate a set of elements.

$$C_i = \{X_j \left| e_{ij} \le \theta \right.\} \quad (11)$$

where $i, j = 1,2,3,...,m;$ θ is a hierarchical coefficient, $0 \le \theta \le 1$; and

$$E = \begin{bmatrix} e_{11} & e_{12} & \cdots & e_{m1} \\ e_{21} & e_{22} & \cdots & e_{m2} \\ \vdots & \vdots & \ddots & \vdots \\ e_{m1} & e_{m2} & \cdots & e_{mm} \end{bmatrix} \quad (12)$$

Is the error matrix denoted as $e_{ij} = \left| \gamma_{0i} - \gamma_{0j} \right|$,

$0 \le e_{ij} \le 1$ and $e_{ii} = 0$.

2. The hierarchical structure elements should be homogeneous by satisfying the following conditions.
   a. $\{C_i\} = \min_{\forall i}$.
   b. $C_i \not\subset C_j$ for all j, $i \ne j$.

2.5.2 Setting graphic path

According to the hierarchical structure theory, the GSM graph is divided to layers, and several relevant elements will be clustered as followed.

$$P = \{(x_i, x_j) \left| \gamma_{ij} \ge \psi, \gamma_{oi} \prec \gamma_{oj} \right.\} \quad (13)$$

where ψ is a path coefficient as $0 \le \psi \le 1$.

Next, establish a direct path for all pairs (x_i, x_j) of P from x_i to x_j.

3. Patent Products Design Survey

The theory of Nagai method, AHP and GRA are the three major methods in this paper while the Nagai method will be used to select the vocabularies about the innovative design factors, the AHP and GRA are employed to assessment the innovative design factors and importance ordinal. Research is carried out as follows.

3.1 The Coding of Subjects

Eight designers with patent products design experience were chose as investigation subjects, and their cognizance of innovative effect on new product innovation design were assessed as our data source. To build the original decision-making matrix, the subjects and design factors were coded according to the design word. The eight subjects were coded as *S*(1) to *S*(8) respectively, shown as Table 1. For protecting subjects, the names and occupations of subjects were not listed

3.2 The Selection of Innovative Design Vocabularies

Nagai's method was used to draft the innovative design vocabularies and relevant factors or features of design were found by pair comparison. Based on this method, design logic could be conducted through systematic thinking in all of field and avoid the loss of important factors or features of design. The process of the method is shown as follow.

First, 5W1H was used to draft the vocabularies of patent products innovative design and general design correspondingly. Secondly, vocabulary of innovative design and general design was compared correspondingly to assess the strength. Finally, the stronger (better) vocabulary was selected as featured vocabulary shown in Table 2.

3.3 The Formation of Innovative Design Factors

According to the innovative design theory of Jiang Bing, the thinking field of product innovative design in this study contains eight categories: visual, social, art, quality, economical, psychological, functional, and technological, etc [13]. The selected vocabulary from 5W1H method was integrated and defined by qualitative in-depth experts' interview to be reorganized into the eight categories coded as $K(1)$~$K(8)$, respectively. The result was presented in Table 3

3.4 The Establishment of The Raw Decision-Making Matrix

First, the data of decision-making matrix were normalized and followed the three principles: (1) non-dimension; (2) scaling and (3) polarization. Then, the matrix was processed pair-wise comparison and scaled as 9, 7, 5, 3, 1, 1/3, 1/5, 1/7, 1/9 by subjects according the strength of relationship, respectively. The matrix is called the subjects matrix.

3.5 The Formation of GRA on Subjects

The decision-making matrix was established by combining AHP and GRA methods as shown in Table 4 and Table 5. The matrix was taken into Nagai's equation for calculating Localization Grey Relational Analysis (LGRA) based on the larger-the-better method. Because all of consistency indexes were less than 0.1 ($CI < 0.1$), the data were confirmed as clean data

3.6 The Formation and Calculation of LGRA-S

The eight subjects (S) were coded into the ordinate of LGRA-S, and the eight main factors of product innovative design (K) were assigned to the abscissa of LGRA-S as show in Table 6. Then the larger-the-better row was set into the matrix to provide the computation of the subject's evaluation by using Nagai's equations and Matlab [41~43]. The result and the GRA ordinal are presented in Table 7.

In Table 7, the first order is S (6) where the Gamma value is "1" to expressed the S (6) subject evaluation results, All subjects were closest to the consensus evaluation. The last one is S (4), where the Gamma value is "0" and expressed deviate from the consensus of all, between the each subject's gap assessments, is determined by Gamma value.

Table 7 LGRA-S ordinal

Subjects	Gamma		Subjects	Gamma	Ordinal
$S(1)$	0.88		$S(6)$	1	**1**
$S(2)$	0.80		$S(1)$	0.88	**2**
$S(3)$	0.29		$S(7)$	0.82	**3**
$S(4)$	0		$S(2)$	0.80	**4**
$S(5)$	0.49		$S(5)$	0.49	**5**
$S(6)$	1		$S(8)$	0.48	**6**
$S(7)$	0.82		$S(3)$	0.29	**7**
$S(8)$	0.48		$S(4)$	0	**8**
Raw data			Ordinal data		

4. Formation and Analysis of GSM

The results of the assessment and analysis of the grey structure model, and applied to product innovation design.

4.1 The Formation and Calculation of LGRA-K

LGRA-K was formed by transporting the ordinate and abscissa are shown from Table 6 to Table 8. Then the matrix in Table 8 was taken into Nagai's equation for calculation (LGRA) and the larger-the-better again [41~43]. The result and the GRA ordinal were presented in Table 9. Finally, the evaluation result was

$$K(7) \succ K(8) \succ K(4) \succ K(6) \succ K(2) \succ K(5) \succ K(1) \succ K(3)$$

4.2 The Results of Evaluation and Analysis

According to the aforementioned results, the research got the important order of main factors of product innovative design as shown in Table 10.

The first three factors in product innovative design in the result of evaluation were functional (K (7)), technological (K(8)), and quality (K(4)), while the last one is art (K(3)).

In Table 10, the contents of functional (K(7)) were creative, innovative, functional, pragmatic, safe, stable, variable, and identifiable. Among the vocabulary, "creative, innovative, variable" possessed the innovative meaning, "functional and pragmatic" possess the effect of actually application, and "safe, stable, identifiable possess" the psychological affirmation of human being. Therefore, it is said K(7) is an integration of the meaning and condition of innovative design. Combining those important design factors, it will promote the creation of product.

The innovative design of the patent product fulfills the development of progressive design by using the features, form, and structure quality, etc. of product design. It can reach the creation design of innovation combining the "functional", "technological" and "quality" in the product design

theory.

Because of the above-mentioned fact, the three factors become the top three design factors.

The function of innovative design gives people a particular favorite and psychological identification, so it can directly communicate the effect of product and reasonably become the top one factor. As the progress of the times and the change in people's thinking, single function of design can not satisfy the needs of consumers. Therefore, the multifunctional are the best way to satisfy the mass psychology.

As for the psychological, society, economic and visual design factors, they are ranked as the 5^{th} to 7^{th} factors in this paper. Besides, the contents of the design factor, $K(3)$ are specific, ideal, elegant, distinctive, decorative, curve, and fashionable. Those factors are not easy to express the meaning by the structure of product design. By comparing with other design factors, it has the lowest contribution of design, so, it is sort of the last one.

Based on the Gamma value and order of the subjects and innovative design factors in Table 6 and Table 8, the curve chart was drawn as shown in Fig. 1

Two curves of the subjects (S) and innovative design factors (K) were almost parallel and the gap between them was very close

4.3 The Formation of GSM Structure Chart

According to the data from Table 6 to Table 8, LGRA and the larger-the-better method by Matlab were used to draw the GSM chart as in Fig. 2 and Fig. 3, and followed the GSM structure to be divided into four classes. The vocabularies in each class were clustered into a group so as to be easily understood their relationship for designer to grasp the application and creation direction in product innovative design

For identifying GSM structure easily, the equally important factors were grouped together as a cluster. The Fig. 2 and Fig. 3 presented the vertical structure and the sequential structure for convenient to recognize the importance and relevance of design factors [44~46].

4.4 Confirmatory Analysis of GSM

From Fig.1, Fig. 2, and Fig.3, this research found if the Gamma value is different between two vocabularies, the GSM presented vertical arrangement. It means the two vocabularies have significant difference, but they still have relevance with each other. If the gamma value is similar, they will be arranged parallel in the GSM figure. It shows the importance of vocabulary is very similar, even they still have a little difference and gather within the same class. The result proved that Fig.1 absolutely corresponds to GSM chart.

From the above analysis, GSM figure not only presents the ranking structure, but also can clearly identify the importance between each other. Therefore, GSM is better than curve diagram in conveying the results. This helps us to convey the design behavior by design vocabularies and we can observe the relevance in the classes of system immediately. That is the most important contribution of this study in graph theory

4.5 The Presentation of Design Creation of the Results

This study used the ranking of innovative design factors in Table 10 and Fig. 3 to design "multi-functional escape appliance." The design proposal created an unprecedented new product that was granted a patent afterward. The creative content is shown as follow:

1. This innovative design work is a multi-function escape appliance.
2. This work contains the oxygen system, lighting function, laser light and sound effect.
3. The work has charging function and decorative function for placing on the desk or hanging on the wall.
4. It is used as lamp or night light in daily life, but becomes an escape appliance in an emergence.
5. During breaking out a fire, this work can provide multi-functional usage by directly putting it into the neck.
6. The oxygen supply system can avoid smoke damage. The high bright LED light is an illuminator. The lasers light and sound function can help easily find victims for relief workers.
7. The consideration of the multi-functional design, the creation of practical design, and the diversity of the product.

The equipment is a combination of lamp and emergent escape; that is, the lamp can transfer to be an emergent escape appliance. Furthermore, the appliance with the disassembled type and the charging functional structure can be used alternatively as emergent light, distress light, and oxygen mask in a fire, an earthquake, or power cut. Because the charging cradle can be separated from the charging body, the body can be put it into neck and both hands are flexible to use for quickly going away in the danger area in emergent situation. The LED light and laser light could be used as escape light source and warning light. The equipment also has the sound function designed for giving the alarm. Therefore, the

appliance not only can be used in daily life but also in emergent escape. The new product based on practical and art design is made from plastic, the size and volume are hence smaller and easy to use. So, the innovative design product not merely matches with the psychological identity of the people but fulfills the main factors of innovative design.

The vocabulary in Table 10 is used in the design of the appliance in Table 11.

The high bright LED light used in this appliance has the effects of power saving and environmental protection. The creation of the new product is equipped with the innovative characters such as variable, progressive, reformative, structural, innovative principles, etc. The major design factors include functional, technological, and quality as above-mentioned characters

This work uses the texture and color with the sense of technology to correspond to the visual principles has the combination of "delicate, complete, novelty, vogue, elegance and decorative function." It is in line with innovative design factors including psychological, visual and artistic. Besides, this work being made of plastic enables mass production and low production costs. Because this work have many features of product design creation, the principles of pragmatic, popular, convenience, simple and reasonable, etc. could be achieved in line with innovative design factors: economic.

Besides, this work is made of recyclable plastic; it corresponds with the definition of green design. To combine the "normal" lighting design with various functions, the easy-to-operate design also corresponds with universal design principle. Equipped with oxygen supply system, this work complies with feasibility design and enhances the quality of product, in line with innovative design factors. This new product is equipped with the contents of innovative design factors and is expressed in Table 12.

According to the research results, the multi-functional escape appliance including quality, function, innovation and visual sense was applied for the invention patent in 2011. The work also participated in "2011 young designers' exhibition" (30thYODEX) in Taipei, and won the praise, appreciation and recognition. Especially, the method is relatively complete and the usage of technology is applied, that help the match between quality and function of product to become an innovative design product. We create a distinctive design style based on considering the psychology of consumers, and create an art for daily life based on economical and art in this work. This work for human being is psychologically identified with the escape appliance [47~49], so it can bring the value of delicate usage and safe life for consumers. The structural content and design illustration of this work are shown in Fig. 4 to Fig. 6.

In Fig. 6, the user brings up the body of the appliance, and sets it into his neck and positions it with magnet. The flexible design can help user to quickly escape from the dangerous area. At the same time, it provides a high-pressure oxygen bottle to avoid the damage of smoke, LED lamp for light up the way, laser light and sound function help for rapid rescuing work. The release of the appliance is shown in Fig. 7.

Fig. 6 The use of state works

Fig. 7 The open the subject conditions

This work based on the outer aesthetic of the innovative design is made of light-weight PE and ABS plastics that let the outer surface look delicate. In the daily life, user can change the color and brightness of the light and let it coincide with the space for decorative effect.

4.6 Results and Discussion of the Design Creation

The results of the paper offered the innovative design features and strategy for products design. The study only applied in the case of emergency escape

products design execution. Furthermore, the kinds of design conditions were also suitable for others products design operation. In order to verify the power of the results obtained from the research. The paper offered relevant products comparison with quality and function.

In the first place, the samples of 18 products has been collected via extensive data collecting that was based on the design characters of product samples which obtained from related product catalogues, internet, newspaper, magazine, and multimedia information. Then, the 9 similar samples with function, form, and structure were eliminated and the 9 samples were abstracted for comparing with the creation. From the views of quality and function of the design creation, the effect of progress, innovation, and convenience were revealed. The related product samples were coded into (A)～(J) as shown in Fig. 7

From Fig. 8, it shows that the portable function, lighting function, power-storage function, and hanging function are the same features for all of the existent products in marketplace. Among those features, the multi-functional escape appliance is the only product associated with ringtone function, laser light, and oxygen system that manifested the quality of the product with progress, innovation, and convenience. In the case of emergency rescue, the supply of ringtone function, laser light, and oxygen systems are crucial to the situation. It not only can extend time for escape but also can get more chances for survival. Those design factors become the main design features for emergency escape. It follows from what has been said that the design effect of multi-functional escape appliance is better than the others marketplace products. According to the product function features as shown in Fig. 8, this paper offered the function structure comparison table in order to reveal the creation characters of the multi-functional appliances that shown in Table 13.

From the results of this paper, the design of function, quality, and structure for multi-functional escape appliance is accomplished. The contribution and usefulness is shown as follow

1. The results of the research created the effect of the new features and quality in accordance with design theme application execution. It not only complied with the patent application conditions but also became an innovative product for home life.
2. This research uses the common cognitive opinions from experts to get the strategy that has more mature design thinking for creative product design, hence the design method is not only suitable to execute product design but also convey the integration of expert opinions.
3. The design strategy in this paper is based on the design cognition that obtained from experts' estimate. It not only can reduce the mistakes during design process but also increase design identification. The research result became a reliable innovative design method.

5. Conclusions

In this study, AHP was used as the evaluation criteria, and it is made for verifying the clean data. GRA was used to analyze the importance and order of the innovative design factors. Then using the GSM theory to explain the results, it provides design direction and method. The GSM is a new research method to build the vertical organization for making the result more practical and clear by considering the sequence, continuity, articulation and integration.

The results in this study apply to the creation of escape equipment, and get the value of function and the quality of innovative design. Those effects that have both quality and function are applied to design the work, let the work achieve the "novelty, progressive, and producible" and correspond to the patent requirement. This works can to apply for patent, in the evaluation and identity of this study method and apply of teaching can be used in product design education. Therefore, the successful strategy of innovative design can apply to other fields in the future.

This research uses AHP and GRA for data analysis and processing. This combined method integrates the decision-making matrix and grey relational matrix into a new matrix. This innovative method can transfer the complex data to transparent and clean data. Besides, the figure of GSM presents better than other general diagram theory. The contribution is shown as follow:

1. GSM diagram is produced by the correct calculation of GRA. Gamma value range is between 0 and 1, so all of the data can be correctly positioned without repeat. GSM coordinated the operation and analysis of multi-quantity data to show the data regularly and orderly. General diagram analysis can not present the same results, so the combination is a new research method.
2. GSM is a vertical arrangement chart can offer right information between top class and bottom class, or understand the structural relationship of data. That processing is made for impelling more systematical and integrated design of product.
3. GSM chart can divide the data into classes directly. According of these classes, the design factors are compared to each other and process the cluster analysis. Understanding the

relationship and contents of factors completely, it is helpful to create the design considerations.

4. The effect of visual sense in GSM vertical chart is better than curve diagram. At the same time the clear organizational structure can provide the information.

The results in this study correspond to the patent requirement. That patent verified that the evaluation and assessment method in this study was correct and could apply to the product design education. Therefore, the successful strategy of innovative design can apply to product design or design education.

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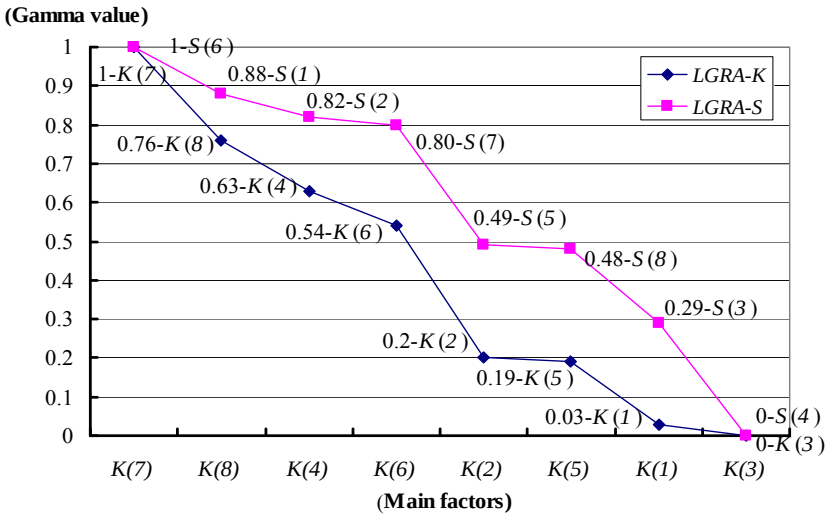


Fig. 1 Curve chart of the subject and Innovative design main factors

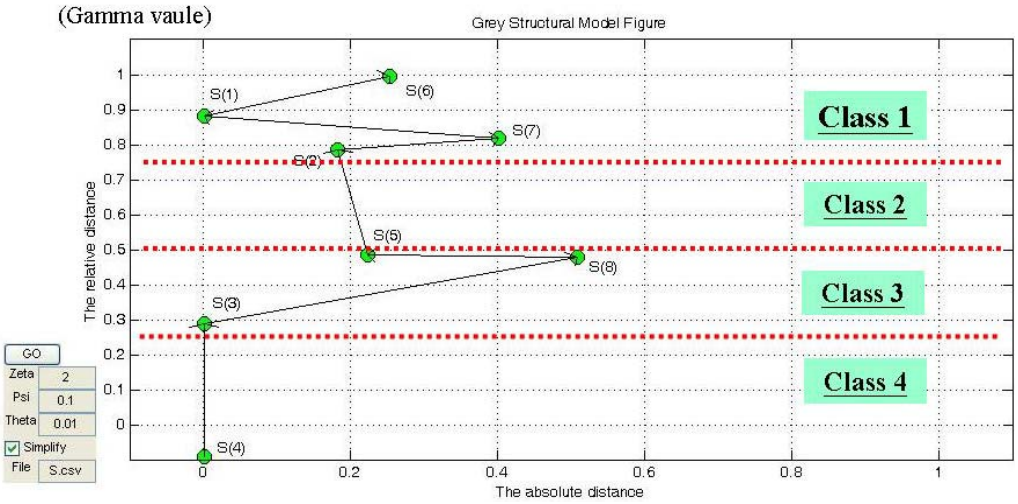


Fig. 2 GSM chart of the subject (*S*)

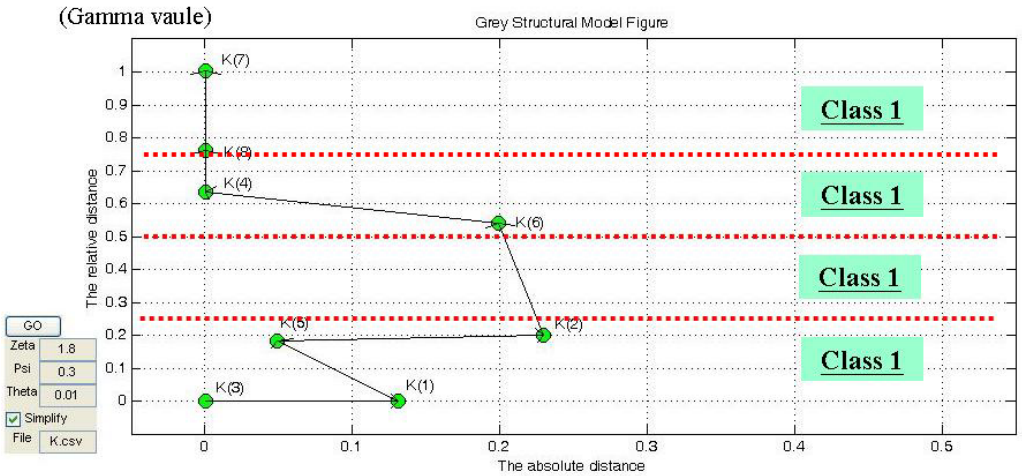


Fig. 3 GSM chart of the main factors (*K*)

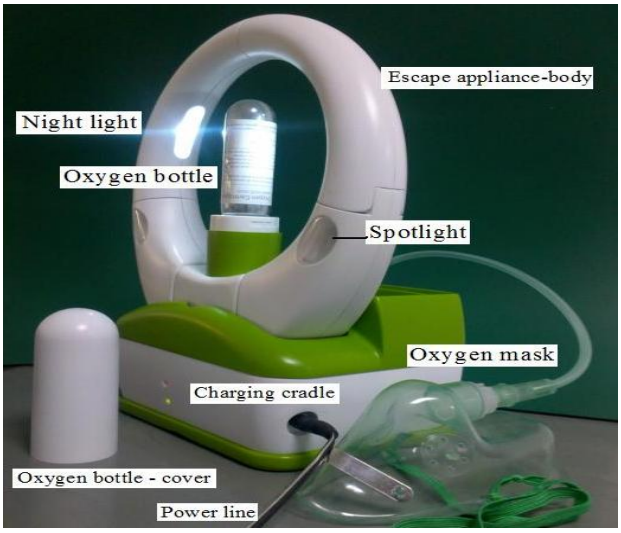
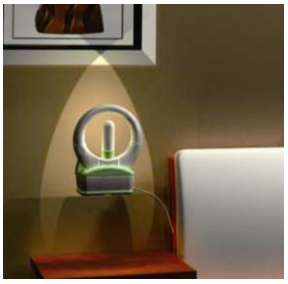
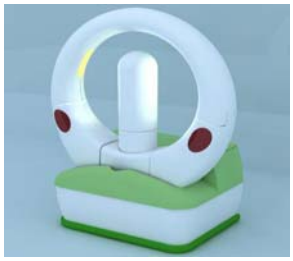


Fig. 4 The structure of the works described

Table lamps-usage



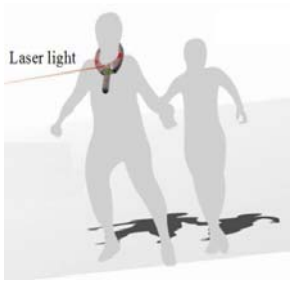
Wall lamp-usage



Normally-decorative effect

Separately-main body and charging cradle

Oxygen system-rotating and positioning



Laser light-transmission conditions

Fig. 5 Introduction to the use of works

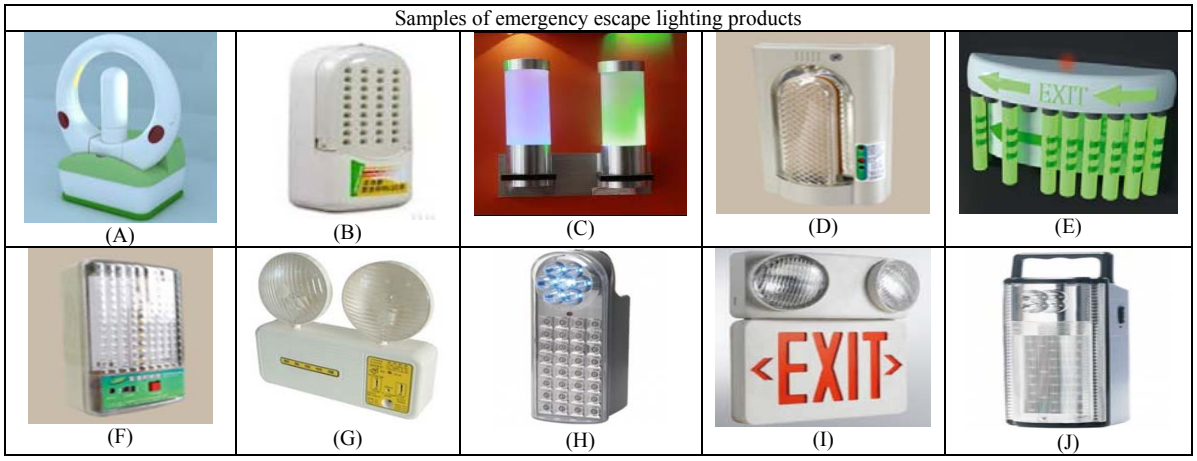


Fig. 8 The coded product samples

Table 1 Data of subjects

Subject	Experts experience	Innovative design experience
S(*1*)	5 years	Tool product, rehabilitation product, bike, sport product, machinery product, kitchen utensils, etc.
S(*2*)	7 years	Light product, furniture, kitchenware, bathroom product, daily supplies, etc.
S(*3*)	8 years	Electric equipment, 3C product, emergency light, car appliance, electronic product, motorcycle product, etc.
S(*4*)	8 years	Sport product, rehabilitation product, bike, etc.
S(*5*)	10 years	Office product, machinery product, computer desk, daily supplies, office desk, office chair, etc.
S(*6*)	11 years	Car appliance, machinery product, 3C product, electronic product, electric vehicle, etc.
S(*7*)	12 years	Sporting goods, machinery product, daily supplies, household product, tool product, etc.
S(*8*)	15 years	Electronic product, bathroom product, machinery product, tool product, car appliance, furniture, etc.

Table 2 Selection of product innovative design

5W1H	Innovative design factors	Compare	General design factors		Selected features
What	Random	<<	Functional		Functional
	Technological	>>	General		Technological
	Creative	>	Law		Creative
	Safety conscious	>>	Safety considerations		Safe
	Well structured	>	Simple structure		Structural
	Easy assembly	>	Quick assembly		Assembly
	Recyclable	>>	Saving material		Environmental
	Universal	>>	General		Universal
When	Identity	>	Convenience		Identifiable
	Multi-function	>	Random function		Variable
	Casual	<	Fashion		Fashionable
	Improve	>	Ordinary		Improvable
	Visual	>>	Sensory		Visual
	Specific	<	Convenience		Convenient
	Easy operation	>>	Simple operation		Operational
Where	Pragmatic	>	Generality		Pragmatic
	Elegance	<<	Beautiful		Beautiful
	Enough	>	Feasibility		Feasibility
	Stability	>>	Feasibility		Stable
	Applicability	<	Feasibility		Feasible
Who	Easy making	>>	Rapid making		Productive
	Simple	<	Easy		Simple
	Trendy	>	Pretty		Pure
	Unprecedented	>	New Idea		Novel
	Leadership	<	Vogue		Voguish
	Delicate	>>	Beautiful		Delicate
	Balance	<<	Reasonable		Reasonable
	Emotional	>	Rational		Pleasure
Why	Actual	>	Random		Actual
	Appreciation	<	Comfortable		Comfortable
	Concept	<<	Pragmatic		Pragmatic
	New idea	>>	Traditional		Ideal
	Spiritual	<	Communication		Communicable
	Emotional	>	Rational		Emotional
	Complete	>>	Reliability		Complete
	Easy to match	>	Easy to combine		Environmental
How to	Distinctive	>>	Decoration		Distinctive
	Reformative	>	Improvement		Reformative
	Quality	>>	Universality		Quality
	Lively	<	Style		Stylish
	Decoration	>	Random		Decorative
	Human factor	<<	Public behavior		Customary
How many	New effects	>>	New approach		Innovative
	Progressive	>>	Normal		Progressive
	Personality	<<	Popular		Popular
	Curve	>	Geometry		Curve
	Elegance	>	Ordinary		Elegant
	Loosely	<	Identity		Coherent
How much	Change	<	Modern		Modern
	Few	<	Most		Most
	Emotional	>	Friendly		Emotional
	Noble	>>	Value		Noble
	Human	>	Habits		Friendly
How long	Stable	>	Quality		Sturdy
	Reliability	<<	Durability		Durable
	Normal	>	Nature		Normal
	Trustful	>>	Pragmatic		Trustful

Table 3 The Innovative design evaluation data

Innovative design (main factors)	**Content items of main factors**
K(*1*) Visual	Novel, Pleasure, Friendly, Voguish, Variable, Pure and Spiritual.
K(*2*) Social	Quality, Environmental, Modern, Customary, Popular, Feasible, Operational, Universal and Normal.
K(*3*) Art	Specific, Ideal, Elegant, Distinctive, Decorative, Curve and Fashionable.
K(*4*) Quality	Stable, Durable, Comfortable, Visual, Noble, Delicate and Structural.
K(*5*) Economical	Pragmatic, Popular, Convenient, Simple, Reasonable, Sturdy, and Structural.
K(*6*) Psychological	Delicate, Stylish, Comfortable, Coherent, Complete, Emotional, Most and Perceptual.
K(*7*) Functional	Creative, Innovative, Functional, Pragmatic, Safe, Stable, Variable and Identifiable.
K(*8*) Technological	Progressive, Technological, Productive, Environmental, Creative, Innovative, Assembly and Reformative.

Table 4 The matrix of GRA about subjects *S*(*1*)～*S*(*8*)(only show the *S*(*1*))

S(*1*)	*K*(*1*)	*K*(*2*)	*K*(*3*)	*K*(*4*)	*K*(*5*)	*K*(*6*)	*K*(*7*)	*K*(*8*)	LGRA
Larger-the-better	5	1	7	3	7	1	1	1	
S(*1*)	1	1	3	1/3	1	1/3	1/5	1/5	0.175
S(*2*)	1	1	3	1/3	3	1	1	1	0.338
S(*3*)	1/3	1/3	1	1/5	1	1/5	1/7	1/5	0
S(*4*)	3	3	5	1	1	1	1	1/3	0.361
S(*5*)	1	1/3	1	1	1	1/5	1/5	1/7	0.059
S(*6*)	3	1	5	1	5	1	1	1	0.756
S(*7*)	5	1	7	1	5	1	1	1	0.899
S(*8*)	5	1	5	3	7	1	1	1	1
CI＝0.097＜0.1									

Table 5 The LGRG of main factors(*K*)

Subjects	**Main factors (*K*) LGRA value**								***CI* (value)**
	K(1)	*K*(2)	*K*(3)	*K*(4)	*K*(5)	*K*(6)	*K*(7)	*K*(8)	
S(*1*)	0.175	0.338	0	0.361	0.059	0.756	0.899	1	***CI*＝0.097＜0.1**
S(*2*)	0.040	0.167	0	0.460	0.2	0.462	1	0.643	***CI*＝0.044＜0.1**
S(*3*)	0.019	0.121	0	0.258	0.036	1	0.446	0.608	***CI*＝0.083＜0.1**
S(*4*)	0	0.118	0	0.576	0.019	0.09	1	0.400	***CI*＝0.066＜0.1**
S(*5*)	0	0.047	0.025	1	0.156	0.307	0.626	0.471	***CI*＝0.064＜0.1**
S(*6*)	0	0.502	0.002	1	0.043	0.442	1	0.897	***CI*＝0.085＜0.1**
S(*7*)	0.030	0.047	0	0.199	1	0.406	0.842	0.534	***CI*＝0.016＜0.1**
S(*8*)	0	0.034	0.022	0.671	0.140	0.319	1	0.454	***CI*＝0.065＜0.1**

Table 6 LGRA-*S* chart

	K(1)	*K*(2)	*K*(3)	*K*(4)	*K*(5)	*K*(6)	*K*(7)	*K*(8)
Larger the better	0.175	0.502	0.025	1	1	1	1	1
S(*1*)	0.175	0.338	0	0.361	0.059	0.756	0.899	1
S(*2*)	0.040	0.167	0	0.460	0.200	0.462	1	0.643
S(*3*)	0.019	0.121	0	0.258	0.036	1	0.446	0.608
S(*4*)	0	0.118	0	0.576	0.019	0.090	1	0.400
S(*5*)	0	0.047	0.025	1	0.156	0.307	0.626	0.471
S(*6*)	0	0.502	0.002	1	0.043	0.442	1	0.897
S(*7*)	0.030	0.047	0	0.199	1	0.406	0.842	0.534
S(*8*)	0	0.034	0.022	0.671	0.140	0.319	1	0.454

Table 8 LGRA-*K* chart

	S(*1*)	*S*(*2*)	*S*(*3*)	*S*(*4*)	*S*(*5*)	*S*(*6*)	*S*(*7*)	*S*(*8*)
Larger the better	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
K(*1*)	0.175	0.040	0.019	0	0	0	0.030	0
K(*2*)	0.338	0.167	0.121	0.118	0.047	0.502	0.047	0.034
K(*3*)	0	0	0	0	0.025	0.002	0	0.022
K(*4*)	0.361	0.460	0.258	0.576	1	1	0.199	0.671
K(*5*)	0.059	0.200	0.036	0.019	0.156	0.043	1	0.140
K(*6*)	0.756	0.462	1	0.090	0.307	0.442	0.406	0.319
K(*7*)	0.899	1	0.446	1	0.626	1	0.842	1
K(*8*)	1	0.643	0.608	0.400	0.471	0.897	0.534	0.454

Table 9 LGRA-*K* ordinal

Main Factors	**Gamma**		**Main Factors**	**Gamma**	**Ordinal**
K(*1*)	0.03		*K*(*7*)	1	**1**
K(*2*)	0.20		*K*(*8*)	0.76	**2**
K(*3*)	0		*K*(*4*)	0.63	**3**
K(*4*)	0.63		*K*(*6*)	0.54	**4**
K(*5*)	0.19		*K*(*2*)	0.20	**5**
K(*6*)	0.54		*K*(*5*)	0.19	**6**
K(*7*)	1		*K*(*1*)	0.03	**7**
K(*8*)	0.76		*K*(*3*)	0	**8**
(Raw data)			(Ordinal data)		

Table 10 Innovation of product design about ranking the main factors and content items

Sort	**Content item description**
K(*7*)Functional	Creative, Innovative, Functional, Pragmatic, Safety, Stable, Variability, and Identity.
K(*8*)Technical	Progressive, Technology, Productive, Environmental, Creative, Innovative, Assembly and Reformative.
K(*4*)Quality	Stability, Durability, Comfortable, Visual, Noble, Delicate and Structural.
K(*6*)Psychological	Delicate, Style, Comfortable, Identity, Complete, Emotional, Most and Perceptual.
K(*2*)Society	Quality, Environmental, Modern, Customary, Popular, Feasibility, Operational, Universal and Normal.
K(*5*)Economic	Pragmatic, Popular, Convenience, Simple, Rational, Stable, and Structural.
K(*1*)Visual	Novelty, Pleasure, Friendly, Vogue, Variability, Pure and Spiritual.
K(*3*)Artistic	Specificity, New idea, Elegance, Distinctive, Decoration, Curve and Fashion.

Table 11 Innovation design contents

Ranking	**Content items of main factors**
K(*7*) Functional	With the oxygen system, lighting function, laser light and sound effects.
K(*8*) Technological	Usually, it is a lamp or night light but it can transfer into an escape appliance in emergent situation.
K(*4*) Quality	With the oxygen system, lighting function, laser light and sound effects.
K(*6*) Psychological	This is innovative design works and also a multi-functional appliance for escape.
K(*2*) Social	This is suitable for everyone to use the design creation of the multi-functional product.
K(*5*) Economical	The combined functional design, with many of the useful values can reduce costs.
K(*1*) Visual	With streamlined design and artistic lighting effect of shape.
K(*3*) Art	High-quality design features also can beautify the living environment which is an unprecedented works of art.

Table 12 Innovative design features

Ranking	Description of contents
K(7) Functional	Integrating the merits of various products create an unprecedented design style, and becomes the representatives works of the novelty product of escape.
K(*8*) Technological	The function with LED light, works out the ability of escape with the shape structure of design portfolio, so the work becomes the necessary science products for life.
K(*4*) Quality	The small and multi-functional work occupies no space and uses in the emergent situation. So it has beautified the environment and becomes a kind of distinctive product.
K(*6*) Psychological	The innovative design achieves security for daily life, and the complete thinking of design is made for escape in emergent situation.
K(*2*) Social	Establishing the design point of view from the human, economic, convenience and low cost, it fulfills the needs of human being.
K(*5*) Economical	It is simple, light and convenient as to operate easily, protect environment, save energy and have mass produce effect. So it is a competitive product.
K(*1*) Visual	The personalized product gets the attention of public by combining aesthetics, style, and color aesthetics to focus on product design.
K(*3*) Art	The design of natural light, beautiful colors and streamline pattern not only thinks over the usage of human behavior and decorative effect, but also is an artistic work.

Table 13 The comparison table for multi-functional escape appliance and others marketplace products

Features of the Products & Codes of Emergency escape lighting products	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8:	R_9	R_{10}:	R_{11}
(A)	★	★	★	★	★	★	★	★	★	★	★
(B)	★		★	★					★		
(C)	★	★	★	★		★			★	★	★
(D)	★		★	★					★		
(E)	★	★	★	★					★		★
(F)	★		★	★					★		
(G)	★		★	★					★		
(H)	★		★	★					★		
(I)	★		★	★					★		
(J)	★		★	★					★		

*(The symbol「★」indicates the features of the product)

R_1: Portable function; R_2: Nightlight function; R_3: Lighting function; R_4: Power-storage function; R_5: Ringtone function; R_6: Color lighting effects; R_7: Oxygen systems; R_8: Laser light; R_9: Hanging function; R_{10}: Decorative function; R_{11}: Decomposition design

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