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運用模糊資訊理論於客製化產品選購服務系統
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政院國家科學委員會補助專題研究計畫 ■ 成 果 報 告
□期中進度報告

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計畫參與人員：

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中　華　民 國　100 年　8 月　15　日

中文摘要

在顧客導向時代商品市場上，消費者可以視其不同需求狀況，購買不同型別或功能等級的產品，而製造商將各功能組件模組化後，即可以同一產品主體，延伸變化出不同類別等級的商品，增強產品的競爭力。

本文針對客製化模組產品設計，提供兩種不同理論模式，建立消費者需求、產品功能特徵及其兩者的關聯性評價，並運用不同理論，在經由專家意見建立模組產品資料庫中，評價出最合適的模組產品或功能元件；其後透過兩個不同的個案企業模組產品來建立消費者推薦服務系統，使企業可根據不同顧客需求，透過系統推薦顧客不同的模組產品，或是由顧客在系統上自行輸入基本需求，隨時可搜尋最合適顧客需求的商品。

本文客製化模組產品設計所建立的模式，產品設計模式一：以模糊資訊公理作為評價及決策法則；產品設計模式二：以層級分析法、模糊理論、倒傳遞類神經網路及灰關聯分析作為評價及決策法則；在今日網路與電子商務的技術已日趨成熟下，相信有許多的廠商，迫切需要一個能妥善引導顧客需求的推薦服務系統，廠商可從服務系統中、業務人員及廠商網站中取得顧客需求與選擇產品的相對資訊，這些資訊取得對企業產品的銷售及研發將有很大助益。

關鍵詞：客製化、模組產品、推薦服務、模糊資訊公理、層級分析法

Abstract: In this research, we use two different theoretical models for customized modular product design to establish the relationship of product evaluation between the status of consumer demands and the features of the product. Furthermore, by using different theories and the database of the product modules that built through the inputs of the experts we build the criteria for recommending the most suitable product by its modulated functions or components. Then, such mechanism is used to provide customer recommendation system for two different companies with their modulated products. The company can use the system to recommend suitable modulated product according to the needs of different customers. The customer can also use the system to search the desired products by inputting the requirement information.

The model build by the customized modular product design in this research, product design model I: we use fuzzy information axiom as the evaluation and decision principle of the product design model. Product design model I: the Analytical Hierarchy Process, Fuzzy Set Theory, Back-Propagation neural network, and Gray Relational Analysis are also used for the evaluation and decision principle of the product design model. With the maturity of current network technologies and e-commerce practices, a suitable recommendation service system to guide customer’s needs is needed for marketing. The manufacturers can use this system to extract the information of the needs for their customers as well as the choices of the products the made. Such information should provide valuable inputs for the sales and future improvement of the product to the company.

Keywords: Customization, Modular Product, Fuzzy Information Axiom, Analytical Hierarchy Process

1. Introduction

In commodity markets, customers or consumers can purchase products with different functional levels according to the conditions of their demands. How different consumer groups purchase products is a perspective enterprises use to plan the standardization of customized products. This approach ensures that enterprises not only attain higher sales amounts and profit space, but it will also be a key factor in industrial development of the electronic generation. This is especially true in the Internet age; this option can be at a customer’s "fingertips" to help them obtain good results. In particular, consumers face complex purchasing decisions. Defining how to help consumers buy products, based on specific recommendations for producers and consumers, is a major area under refinement.

Each customer’s degree of demand for a product is different. If every demand is viewed as equal in importance, objectivity and the desired outcome cannot be reached. Furthermore, there are various degrees of fuzzy relations between demand and product functional modules, so there needs to be an appropriate theory or rule that can solve the relation mode.

Therefore, in the product design process, we need to help consumers select the "right" goods. In past research, greater emphasis was on the design of products from the standpoint of product information decision-makers. The information could be easily accessed and handled. However, customers’ expectations are typically different from the designed products. For customer-centric information research, the classification of the customer groups and the operations of customer relationship management practices are usually emphasized. As for the complex relationships between customers and companies, policy decision-makers traditionally use a single algorithm to solve a single policy or evaluation. Rarely, they will focus on the complexity of the issues, finding an appropriate algorithm for different degrees of the demand and provide a better solution for every step.

Consumer habits often use adjectives to describe the demand for the product level, but the semantics of expression is full of a considerable degree of fuzzy logic and uncertainty. After Zadeh (1965) presented a fuzzy theory concerning how to open the order into a number of linguistic expressions of the first kind, research related to fuzzy theory could mushroom to promote the success of the domain. Moreover, if the true intent and product demand function zooms, a considerable degree of fuzzy association exists, which requires appropriate theoretical principles to solve the relational model. Today, product consumption by the customer is more than subjective self-awareness. In particular, consumption is strongly attached to a customer’s own vision and values. Characterized by the product's uniqueness and practicality of the purchase are two important indicators of reference. The products with these characteristics have a long product life cycle and they experience greater demand creation or customization. The resulting changes in product design are developed by considering the design intent.

The purpose of this study is as follows:

(1) Two different theoretical models are provided for a customized module design.
(2) Between the evaluations, consumer demand, product characteristics, and functional association are built up.
(3) Two different case modules are presented to create a consumer business referral services system.

Product designs recently researched for this article relate to scholars with a variety of theories to evaluate the product or purchase product decisions. Such scholars include Kulak

(2005), Kulak Durmusoglu & Tufekc (2005), Kulak & Kahraman (2005a, 2005b), Diyar & Kulak (2007), Durmusoglu & Kulak (2008). Scholars use the Fuzzy Information Axiom and Fuzzy Theory, as well as the Gray Theory ,Analytic Hierarchy Process(AHP) to explore the concept of multi-attribute products designed to support decision-making systems. Tsai & Hsiao (2004, 2005), Tsai, Hsiao & Hung (2006), and Tsai & Chou (2007) use a genetic algorithm, AHP, the Gray Theory, and the Fuzzy Theory with customers to explore the multi-functional product evaluation and selection. They also use computer-aided design.

Hsiao & Huang (2002) attempted the use of computer-aided design and neural networks to assist in product shape design consulting decisions. The scholars, Sun, Kalenchuk, Xue & Gu (2000), attempted to combine the Fuzzy Neural Network Theory(FNNT) as the case for the conceptual design for product-related evaluation and decisions.

Using fuzzy axiomatic design principles of information to design the best product is a simple and efficient method, and only the expression of consumer demand semantics can be used to quantify the fuzzy theory. It has been assembled for modular use. This product is easy to use in design principles to search for the best consumer products.

What if the characteristics of functional elements are not yet completed? If this is the case, the customized combination of modules can be obtained using the AHP to rank the importance of customer needs in order to get a back-propagation neural network to obtain the characteristic function of the importance and the gray relational analysis. This obtains the best combination of features for the modular product features.

Product designs feature many key factors to be considered for academic research and theory. Customized modules are designed to consider the following key items:

(1) Customer needs
(2) Functional characteristics (of the module)
(3) Database
(4) Evaluation and decision theory
(5) Optimum product search

Linking these five key factors will greatly influence the results of product design, as well as the product designers and product features. The customer needs identifyfor the module, so a lot of thought goes into the custom module products library database, and such style must also be sold to customers for the range of products. The final evaluation and decision theory are selected by the designer to achieve the end goal.

2. Research methods

The theoretical bases for the use of this research are briefly described as follows:

2.1 AHP

This research uses the theoretical analytic of analytic hierarchy process to set up the class weight of customer requirements. Each customer uses a scale of 1–9 (see Table 1) to compare the "importance degree" of the demands according to their "demand degree." If there are n items of basic demands, after the comparison from the customers, an n×n square matrix may be seen ($A_{n\times n}$).

$$\begin{array}{c} \quad N_1 \quad\; N_2 \quad \cdots \quad N_n \\ A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} \begin{matrix} N_1 \\ N_2 \\ \vdots \\ N_n \end{matrix} \end{array} \qquad \text{---------------------------------} \quad (1)$$

Table 1: Comparison rate of customers' basic needs

a_{ij}	comparison rate of i-demand and j-demand
1	i-demand and j-demand are equal important
3	i-demand is a bit important than j-demand
5	i-demand is more important than j-demand
7	i-demand is much more important than j-demand
9	i-demand is extremely more important than j-demand
2468	Intermediate values of the adjacent scale

In order to ensure consistency while conducting the paired comparison, a consistency test is performed. The Consistency Ratio (CR) is used to check whether the matrix was a consistent matrix. If $CR \leq 0.1$, the paired comparison matrix features a high level of consistency.

Therefore, one can obtain the eigenvector (**w**) of matrix A from the following formula:

$(A - \lambda I)\mathbf{w} = 0$-- (2)

I is an n×n unit matrix. λ is an eigenvalue of matrix A. Take the largest eigenvalue λ_{max} with the corresponding eigenvector, which will represent the "importance assessment" of customer demand.

2.2 Fuzzy Theory – Triangular Fuzzy Number (TFN)

A TFN is a special case of trapezoidal fuzzy numbers. Function $\tilde{t} = (t_1, t_2, t_3)$ is used to represent the distribution graph of the membership. As shown in Figure 1, real number t_1, t_2, and t_3 represent the reflection value of the x-axis in the three vertices of the triangle graph.

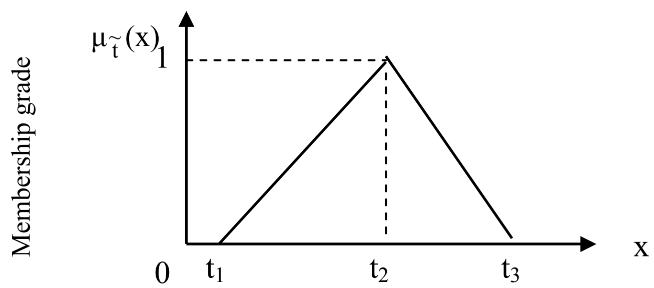

Figure 1: TFN $\tilde{t}$

Therefore, the TFN can be shown as:

$$\mu_{\tilde{t}}(x) = \begin{cases} 0, & x < t_1 \\ \dfrac{x - t_1}{t_2 - t_1}, & t_1 \leq x \leq t_2 \\ \dfrac{x - t_3}{t_2 - t_3}, & t_2 \leq x \leq t_3 \\ 0, & x > t_3 \end{cases} \quad \text{---------------------------------- (3)}$$

2.3 Back-Propagation Neural Network (BPNN)

Neural networks imitate human nervous conveyor systems, and the BPNN, like emulates a supervised learning neural network. As shown in Figure 2, the network structure can be divided into an input layer, a hidden layer, and an output layer. The theorem uses the non-linear reflecting relation of input and output; amending the error value step-by-step. This is used to calculate the appropriate network weights value and bias so that it can achieve the result of the output reflection in the range of tolerance error.

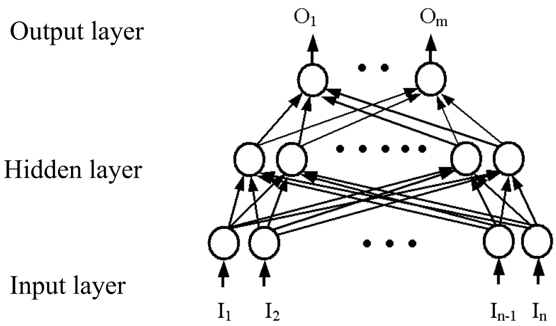

Figure 2: BPNN

2.4 The Gray Theory (GT)

In the gray system control theory, or GT, the grayscale of color is an index of the awareness level of the system. The color black indicates that nothing is known about a system's internal structural parameters and characteristics. The color white represents known information that is complete and has been fully understood for the system. The color gray, which lies in between black and white, represents that the system is composed of partially known information and partially unknown information. The GT is aimed at system uncertainty and incomplete information. Once the level of uncertainty and incomplete information is determined, then correlation analysis and model building are conducted, which relate to the system to assist in further prediction and decision-making.

This research uses the gray relational analysis in the GT to analyze the relation level between the main factors and other factors in the system. Through the calculation of the gray relation degree, the correlation between the two sequences is obtained.

If there is an object sequence $X_1 = (x_1(1), x_1(2), ..., x_1(n))$, and one wants to calculate the individual gray correlation γ between this and the other sequence $X_j = (x_j(1), x_j(2), ..., x_j(n))$, it can be calculated in the following formula:

$$\gamma(X_1, X_j) = \frac{1}{n-1}\sum_{k=1}^{n-1}\left(\frac{\min_j \min_k \Delta_{1j} + \rho \max_j \max_k \Delta_{1j}}{\left|x_1(k) - x_j(k)\right| + \rho \max_j \max_k \Delta_{1j}}\right) \quad \text{---------------------------------- (4)}$$

ρ is a resolution factor, usually the value is 0.5; $\Delta_{1j} = \left|x_1(k) - x_j(k)\right|$.

(5) Fuzzy Information Axiom (FIA)

Suh (1990, 1995, 1997, 2001) from the Massachusetts Institute of Technology (MIT), further developed QFD (Quality Function Deployment) and proposed the Axiomatic Design (AD). The main purpose of this axiom is to produce a simple design. Suh defined the information content as I, and it is calculated using the formula I (Information Content) = log (design range/common range). A small "I" implies a large common range, which means that as the common range becomes larger, it is easier for the product of this design parameter to be successful. This success signals the ability to meet its corresponding functional requirement. In this case, the system range refers to the manufacturing capability of manufacturers; the design range is the designer's requirements, while the common range is the overlapping part of the system range and the design range. Therefore, when the common range is larger, there is a higher possibility for manufacturers to produce a product according to the designer's concept, thus increasing the chance of success. This concept can be seen in Figure 3.

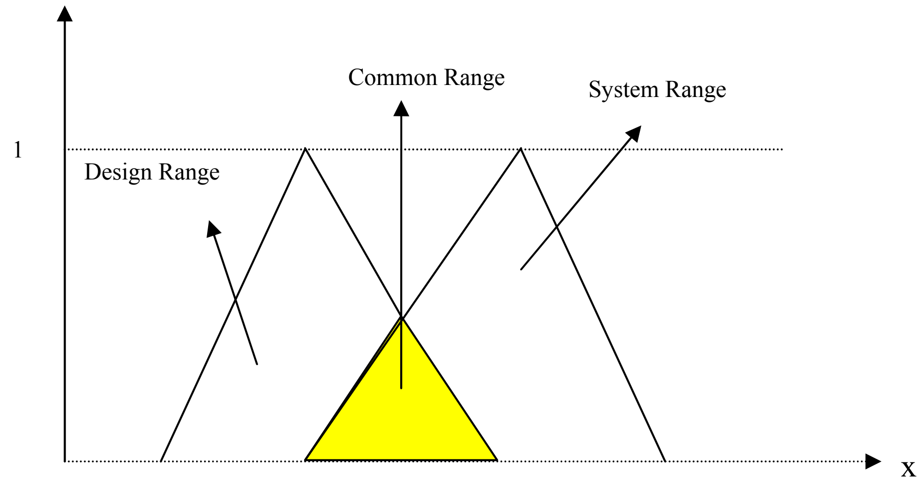

Figure 3. Triangular fuzzy relationship between the system range, design range, and common range

The second axiom of the AD is the information axiom, which states that among those designs that satisfy the independence axiom, the one with the smallest information content is the best design. The definition of information content (I_j), expressed in terms of the TFNs, is as follows:

$$I_j = \log_2(1/p_j) \quad \text{---} \ (5)$$

Where p_j is the ratio of the area of the common range to the area of the system range for the jth design requirement, which is also the probability of the system range meeting the design requirement.

$$p_j = \left[\frac{CommonRange}{SystemRange}\right] \quad \text{---} \ (6)$$

As shown in Figure 2, the overlap of the "design range" set by the designer and the “system range” of the system capacity is the acceptable common range; the larger the common range, the higher the success rate will be.

Assuming that a product has m number of design requirements, the summation of all the design requirements is such that:

Total Information Content (I_{total}) is defined below:

$$I_{total} = \sum_{j=1}^{m} I_j \quad \text{--} \ (7)$$

3. Customized Modular Product Design Model

For product research in the module design process, this article will be divided into two different theoretical models:

Model I: We use the FIA as the evaluation and decision principle of the product design model.

Model II: The AHP, Fuzzy Set Theory, BPNN, and Gray Relational Analysis are also used for the evaluation and decision principle of the product design.

3.1Construction of the FIA model

b_j

The model theory of the FIA is the evaluation criteria considered when evaluating the concept of the Taguchi method to conduct modular product design. Its research methods and design process are described as follows.

Using the concepts of the TFNs and the Taguchi method, the following were established:

(1) TFNs for the requirement levels

(2) The relationship between the evaluation of functional requirement options and product features, in order to establish rules to relate the evaluations of customers and designers.

For a designer, the functional requirements not only contain the main, obvious customer product parameters, but they also contain customers' potential needs. The functional requirements of customers are often hard to express explicitly, so fuzzy numbers are used to determine customer needs, as expressed using the seven levels listed in Table 2.

Table 2: TFNs showing seven requirement levels

Vocabulary	Denotation	TFNs
A Very low	VL	(0,0,1)
B Low	L	(0,1,3)
C Medium low	ML	(1,3,5)
D Medium	M	(3,5,7)
E Medium high	MH	(5,7,9)
F High	H	(7 ,9,10)
G Very high	VH	(9,10,10)

The computation formula for the selection of the best product is explained as follows:

(1) Assuming the customers' functional requirements to calculate the median of customers' functional requirements

If there are n basic customer needs, they are translated into seven levels of triangular fuzzy numbers and the median of customer needs is calculated and normalized to obtain the customer needs in the hierarchical order **w** ($w_1, w_2, \dots, w_n$), as shown in Formula (8).

$$\sum_{i=1}^{n} w_i = 1 \text{ --- } (8)$$

(2) Computation of the requirement level for a product feature

As shown in Table 4, the TFNs for the relationship matrix of customer needs and product features assessed by experts are $\tilde{A}$

$$\tilde{A} = \left[\tilde{a}_{ij}\right] \text{ --- } (9)$$

where i and j denote i-th customer need and j-th product feature.

The product of the relationships between the normalized customer requirement levels, weighted customer needs, and product features will give rise to a j-th TFN for product feature $\tilde{b}_j$.

$$\tilde{b}_j = \sum_{i=1}^{n} w_i \times \left[\tilde{a}_{ij}\right] \text{ --- } (10)$$

(3) Computation of information content I_j

Based on the results in step 2, using the design range and system range of the actual product shown in Figure 2, the information content I_j of the j-th product feature is determined:

$$I_j = \log_2(1/p_j) \text{ -- (11)}$$

(4) Establishment of rules for the selection of the best product

According to the fuzzy reasoning principles of feature requirements established in Table 4, the median of various product features is calculated, and the normalized weight of the j-th product feature is w_j^{nd}, whereby $\sum_{j=1}^{m} w^{nd}{}_j = 1$

(5) Finally, all the information content obtained is sequentially multiplied by the standardized level to obtain the grand total value for product information content E $_{min}$; its formula is as follows:

$$E_{\min} = \sum_{j=1}^{m} \left(I_j \times w_j^{nd.} \right) \text{-- (12)}$$

(6) Establishment of the ideal product purchasing interface for customers

The above algorithms are programmed to establish the ideal product purchasing programming interface. Consumers can use this interface to select their personal needs and the system will suggest the most suitable merchandise, or use this interface to preview the recommended products.

3.2 Construction of Fuzzy AHP, BPNN, and GT models

This research is based on the algorithms built by the AHP, the fuzzy set theory, and the BPNN to help customers or consumers calculate the membership grade of each functional module level according to their own preference of the demand condition.

(1). Establishment of an evaluation rule for the functional modules

This stage is intended to build up the relation and evaluation mode between “customer demand” and “functional module” in the following three steps.

Step 1. Ranking and development of customer demand

If there are n items of a basic customer demand, after conducting the paired comparison, one can use Formula (2) to calculate the eigenvector **w** (w_1, w_2, w_n) of the customer demand. Next, it is normalized, and the class sequences w^* (w_1^*, w_2^*, …, w_n^*) are obtained for customer demand and fuzzy the sequences into five-order TFNs individually. Table 3 represents the table and graph of the TFNs of five lexical grades.

Table 3: TFNs showing five requirement levels

Lexical Category	TFNs
A Fairly Unimportant/Lower	(0,0,3)
B Unimportant/Low	(1,3,5)
C General/Normal	(3,5,7)
D Important/High	(5,7,9)
E Fairly Important/Higher	(7,10,10)

Step 2. Establish the relevance of "customer demand" and "functional module"

In accordance with different customer demands, one identifies the functional module, with a greater satisfaction, as an important goal of this step.

Therefore, the relevance between “customer demand” and “functional module” must be established. Suppose there are n items of customer demand and m items of the functional components category. One can now set up a correlation level matrix $R_{n\times m}$.

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nn} \end{bmatrix}$$

Therefore, one can imitate the method in Step 1, where the fuzzy r_{ij} is in five grades of TFNs. The correlation level between “customer demand” and “functional module” is shown in Table 3.

Step 3. Evaluation of fuzzy lexical functional module

According to the importance degree of the lexical group (fairly important, important, normal, unimportant, fairly unimportant) and the correlation lexical group (high positive correlation, correlation), which is defined by the first two steps, one can follow the fuzzy logic structure “if…then” to evaluate the demand level (fairly high, high, normal, low, fairly lower) of the modular function. From the interaction into pairs of the 5 “importance level lexical," and 5 "correlation level lexical,” 25 fuzzy inference rules can be obtained.

For instance, if the ith demand level of a customer is “fairly important” and the functional module of jth that fulfills the demand correlation of ith is “highly relevant,” then that functional module will respond to the correlation demand in “fairly high” form. The statement above can be simplified with fuzzy logic as follows:

IF “Customer demand – fairly important” and “correlation – highly relevant”
THEN “Functional module demand – fairly high”

The 25 fuzzy logic inferences are shown in Table 4.

Table 4: Correlation for customer demands and functional modules

Customer Needs	Relationship Between Customer Needs and Product Features						
	VH	H	MH	M	ML	L	VL
VH	VH	VH	H	M	L	VL	VL
H	VH	H	H	M	L	L	VL
MH	H	H	MH	M	ML	L	L
M	H	MH	MH	M	ML	ML	L
ML	MH	MH	M	M	M	ML	ML
L	MH	M	M	M	M	M	ML
VL	M	M	M	M	M	M	M

(2). Establishment of the fuzzy algorithm of a neural network

As shown in Figure 2, a BPNN can be divided into: input layer, hidden layer, and output layer. In this research, we count 10 values of the 5 fuzzy levels of “customer demand” and “correlation” in the IF condition, and put them as the node values of the neural network input layer. Additionally, the five levels of “functional module demand” are put in the THEN condition as the output layer node. Therefore, the example of Step 3 can fuzzy the result of the input condition and output condition as:

INPUT: 1 0 0 0 0 1 0 0 0 0
OUTPUT: 1 0 0 0 0

The 25 fuzzy logic conditions, which are structured by the aforementioned, can be provided as neural network learning rules, and calculated by MATLAB software, to obtain the weighted value and bias of the neural network. The network that completes the training can help a customer get a basic demand that corresponds to the output sequence $P(p_{ij}(1), p_{ij}(2), p_{ij}(3), p_{ij}(4), p_{ij}(5))$ of each functional module according to a customer’s personal demand. This sequence can be shown as a line chart function f(x) and one can get the focus position p_{ij}^* in the line chart function of the ith demand and jth functional module.

$$p_{ij}^* = \frac{\int_0^1 f(x)x\,dx}{\int_0^1 f(x)\,dx} \text{ -- } (13)$$

Hence, one can take each functional module demand as the standard, weighted average demand level (eigenvector) for each functional module. Then, the sum of demand membership in each functional component can be obtained by Formula (14).

$$P_j^* = (\sum_{i=1}^{n} p_{ij}^* \cdot w_i^*) / \sum_i w_i^* \text{ --- } (14)$$

(3). Use of the GT decision model

The membership that is obtained by Formula (14) can be seen as an object sequence $P^G(p_1, p_2, \cdots, p_m)$. However, while the functional modules are in the free combination, some conflicts might occur between different functional style options. If the functional module can be reasonably assumed into pairs, or the manufacturers have set the matching methods at z combinations, one can see those combinations as z reference sequences $P_k^R(p_1, p_2, \cdots, p_m)$, and k = 1, 2,…,z. Different gray correlations of reference sequences and object sequences through Formula (4) can be attained. The maximum value γ_{max}, the sequence, which corresponds to γ_{max}, is the best product functional module style suggestion according to each customer’s personal demand.

4. Research Case

In this paper, our case enterprises include two companies in Chiayi: (1) a sales-based notebook computer company, and (2) a production and sales-based baby stroller manufacturing company.

These two companies will be used for the actual calculation of a modular product design model and model II, and the establishment of referral services system interface module products; these two companies can use this referral service system based on customer needs to have the most suitable module products for their customers. Each company can use the results, combined to promote these modules. Furthermore, the results can be placed on the company Web sites for consumers, in accordance with their needs, to assist their search for the most suitable modules.

4.1. Example 1

The basic customer needs are jointly developed by two experienced and professional computer sales staff, two laptop product planners, and one of Research and Development (R&D) staff member. Based on the basic customer requirements for the important features, the experts and consultants of this study selected seven Preferred Features (PF), namely: Central Processing Unit (CPU), Random Access Memory (RAM), Screen Size, Hard Disk Capacity, Display Card, Price, and Color (see Table 5).

Table 5: Designer's selection of customers' functional requirements and preferred product features

	Customer Needs	No.	Product Features
CN1	Word Processing	PF1	CPU
CN2	Professional Graphics	PF 2	RAM
CN3	Numerical Computation	PF 3	Screen Size
CN4	Portability	PF 4	Hard Disk Capacity
CN5	Price	PF 5	Display Card
CN6	Color	PF 6	Price
		PF 7	Color

Feigo would like to buy a laptop, but he knows nothing about computer hardware. In this study, the FIA algorithms are used to help him search for the ideal market laptop based on his actual needs, which are listed in Table 8.

Table 6: Feigo's requirements for computers and the requirement levels

Serial Number	Functional Requirements for Computer	Feigo's Requirement Level
CN1	Word Processing	H
CN2	Professional Graphics	VL
CN3	Numerical Computation	M
CN4	Portability	MH
CN5	Price	Below TWD 30,000 ML
CN6	Color	White

The notebook computer product purchasing interface is produced (see Figure 4).

Figure 4: Notebook computer product purchasing interface

A smaller information content indicates that the laptop is closer to the customer's requirements. Feigo's top three computers are NB21, NB41, and NB50. Looking at the laptop ranked first in the table, its price and color have satisfied Feigo's requirements, the screen size is comparable to his requirements, and it has a higher CPU and hard disk capacity. The customer has a greater need and priority for word processing and numerical computation; therefore, since the laptops that ranked second and third may have smaller screens, and their CPU and hard disk capacity are much smaller, they are placed below NB21.

4.2 Example 2

The setting of each baby stroller functional type classification is shown as Table 6. Each functional type has its own modular style. The modular style that has the same function can follow the low-to-high of the product positioning, equally divided between the value [0, 1]. In Table 7, the value in that column shows the relationship between customer demands and functional modules.

Table 7: Category of modular function for baby strollers

Item	Product Features	Alternatives	Membership Grade
F_1	Folding Operation	One-Hand Operation + Joint Pull	1
		Hook Pull + Joint Pull	0.5
		Joint Pull	0
F_2	Self-Standing after Folding	Included	1
		Not Included	0
F_3	Reversible Handle	Included	1
		Not Included	0
F_4	Accessories in Front of Seat	Tray + Toy Bar	1
		Tray	0.5
		Bumper	0

F_5	Seat Back Adjustability	Multi-Position	1
		Two Positions	0
F_6	Foot Rest	Adjustable	1
		Fixed	0
F_7	Wheel	Pivoted (6 Wheels or 8 Wheels)	1
		Fixed Direction (4 Wheels)	0
F_8	Suspension	Cantilever-Type	1
		Simple-Type	0.5
		Non	0

(1) The setting of customer demand

The set of six basic customer demands according to the product features is depicted in Table 8. These demands are: (1) sitting comfort for baby, (2) collapsibility, (3) portability, (4) operational usage, (5) additional components (toys, space), and (6) lower price.

Table 8: Setting demand for baby strollers

Item	Content of Demand
N_1	Sitting Comfort for Baby
N_2	Collapsibility
N_3	Portability
N_4	Operational Usage
N_5	Additional Components (Toys, Tray)
N_6	Lower Price

(2) Finally, the baby stroller product purchasing interface is provided (see Figure 5).

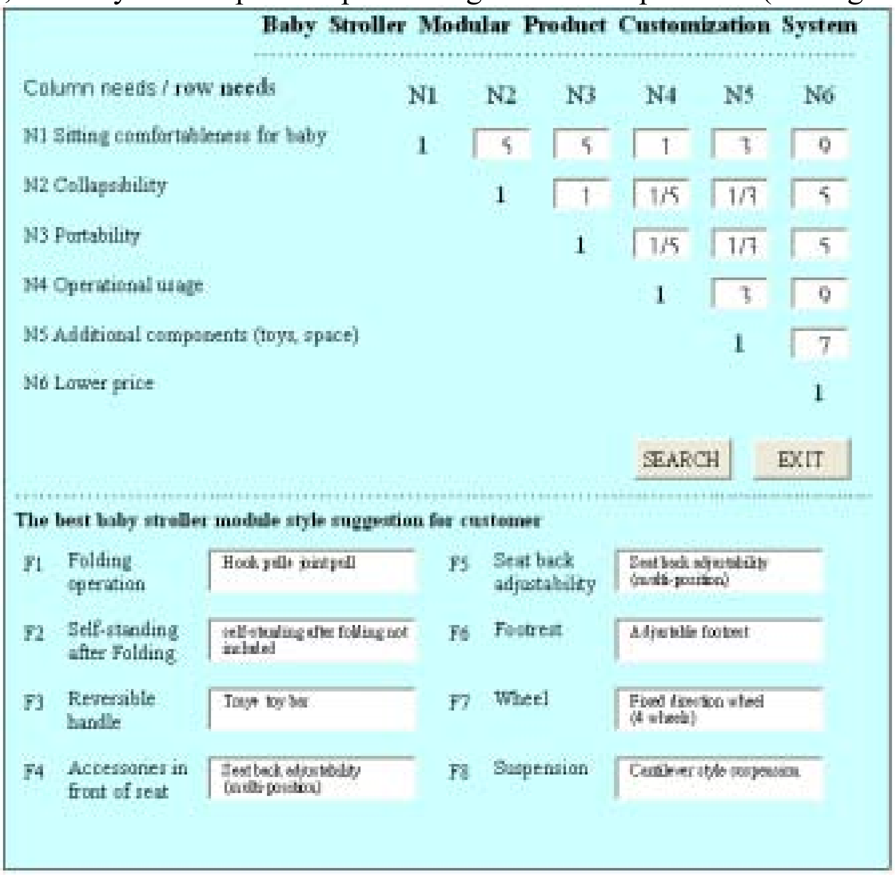

Figure 5: Baby stroller product purchasing interface

For this reason, the best baby stroller module style suggestion for customer A is: (1) hook pull + joint pull, (2) self-standing after folding not included, (3) reversible handle, (4) tray + toy bar, (5) seat back adjustability (multi-position), (6) adjustable foot rest, (7) fixed direction wheel (4 wheels), and (8) cantilever-style suspension.

5. Conclusions and Discussion

This paper discusses customized module design, model-building, and customer assistance in two case enterprises. These efforts are discussed to establish a service system and to make customers a variety of products where they can select a suitable product. The contribution of this paper is as follows:

(1) In the customized module design, two established design patterns, starting with the preferences of the customer's needs, attend to consumer purchase behavior, which may be waived by the designers for the lack of subjective guidance.
(2) In the product design process, some scholars design the FIA to evaluate the product, then consider this increase in customer expectations of the product quality characteristic factor in market practices, thereby enhancing consumer product satisfaction.
(3) In the product design process, after establishing an expert evaluation of the database modules, consumers can buy more products based on similar module choices.
(4) Once this module product design model is established, then versatile enterprises can use this model to establish the company's consumer referral service system to provide consumer buying preferences of the different modules of their products.
(5) A company can apply what is in this paper to provide the service system recommendation to consumers who fall within the interface of the obtained results, with the actual consumer purchasing decisions in the market comparison. The different results may help a company's marketing and product development strategies. They may need to be strengthened in part (e.g., determine if advertising spending is adequate; identify if the introduction of the modules is appropriate to customer needs, etc.).
(6) The case study companies (a computer company and manufacturer of baby strollers) are actual operations. Experienced sales staff and product R&D planning personnel may conduct staff evaluations of functional characteristics and may find the results of this study to be very helpful. This industry cooperation model will serve as a model for forward work.

In a customer-oriented era, being able to quickly assess and respond to changing consumer demands and service requirements are the only ways to be successful in business. In the pursuit of an exemplary modern society, the quality of a product or a system's design strengths and weaknesses directly affect market competitiveness.

Consumer demands for products and different levels of semantics are not yet clear, and in the face of relatively unfamiliar (or functionally more complex) requirements, there are often bewildering choices. One does not know how to choose the appropriate function module; therefore, reliance upon product experts' designs is imperative.

This custom-built modular product design has two patterns. Design pattern I is the axiomatic evaluation of fuzzy information and decision-making rules. Design mode II involves the level of analysis, fuzzy theory, neural network and gray relational analysis employed as evaluation and decision-making rules.

The customized module design framework is an established calculus, starting from the setting of customer needs, identifying the important functional characteristics of modular products and components, to the evaluation of the relationship between the two. The establishment of the database modules, evaluation, and use of theoretical models make the decision to choose the best products, and the establishment of the universal module products and enterprises can then be selected based on the desired mode. Additionally, there is a basis for a calculation process to build a product recommendation service system.

Blurring the customer needs for a reasonable and rigorous theory is a mapping of the transition to the product characteristics. The logic of the research framework is reasonable, objective, and accurate, and it can operate on the practical application of business practices in the design process, enterprise research, and development. Sales personnel can provide assistance, engaging in various discussions in which both sides should be inspired by this process to have a resulting industry-university cooperation.

With today's Internet, e-commerce technology has matured, so some believe that for many manufacturers, the urgent need is to properly guide customer needs to a recommendation service system. Companies can then service systems, business, and manufacturers to obtain customer needs and the site can select the relative information. This information can be obtained from company sales and R&D, which may ultimately be of great help to consumers.

6. Acknowledgments

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附件四

國科會補助專題研究計畫項下出席國際學術會議心得報告

日期：100 年 08 月 15 日

計畫編號	NSC99－2410－H－343－016－		
計畫名稱	運用模糊資訊理論於客製化產品選購服務系統		
出國人員姓名	洪飛恭	服務機構及職稱	吳鳳科技大學副教授
會議時間	100 年 07 月 27 日 至 100 年 07 月 29 日	會議地點	馬來西亞吉隆坡的 Universiti Kebangsaan Malaysia（UKM）
會議名稱	(中文)2011 國際組織創新研討會議 (英文)2011 ICOI he International Conference on OrganizationalInnovation		
發表論文題目	(中文)建立客製化模組產品購買系統之研究 (英文) Research to Establish a Customized Modular Product Purchase System		

一、參加會議經過

國際組織創新協會(IAOI)是一個專門的國際組織，在美國，台灣和中國，通過會議和期刊之間來互動。該協會成立於 2005 年，IAOI 的目標是將國際組織創新會議(ICOI)成為世界一流的會議。而 ICOI 會議已經進入第五年。

第五屆國際組織創新會議（2011ICOI）在馬來西亞吉隆坡的 Universiti Kebangsaan Malaysia（UKM）舉行，時間是 2011 年 7 月 27　29 日。會議中有各種各樣主題的理論發展和應用，為了達到本會的目標，經驗交流和共享，將有許多的討論。

ICOI 大會主席 Dr. Frederick L. Dembowski 首先歡迎來自世界各地的學者參加此次

會議，接下來有包含台灣學者 Dr. Shieh, Chich-Jen 上台發表談話，開幕會議在大家互相握手互道 hello 中結束。

接下來由三位學者分別發表演講，演講者及主題如下(1)Dr. Anton de Waal, Christchurch Polytechnic Institute of Technology, New Zealand 講題 ：Innovation in a Small Island Nation.(2)Dr. Fernando Cardoso de Sousa, President Of The Portuguese Association for Creativity And Innovation, Loule, Portugal 講題：Collaborative Practices on Organizational Innovation in High Technology Industries

(3)Dr. John Nirenberg, a Mentor to Doctoral Students ,Walden University, USA 講題：Innovation in Organizations: Why We Don't Practice What We Know

午餐過後，分組報告開始，我的文章編號 11R-045，題目：Research to Establish a Customized Modular Product Purchase System，討論分組為 Iformation Management，報告時很多先進提出意見收穫甚多。

二、與會心得

參加此次會議，看到很多台灣學者在國際舞台發光，尤其很多教授帶領碩博士研究生參加會議，提早了解國際會議的各項過程，相信對他們未來將有很多影響。

我則對此次研討會很多主題感到興趣，將來可以啟發許多研究方向。

三、考察參觀活動(無是項活動者略)

無

四、建議

無

五、攜回資料名稱及內容

2011 ICOI he International Conference on OrganizationalInnovation 接受函

Dear Fei-Kung Hung

Congratulation!!! According to our record your manuscript Rec. No. 11R-045 entitled is “Research to Establish a Customized Modular Product Purchase System”, and coauthors are Miao-Sheng Chen and Yi-Chun Lu , it has been accepted for publication in 2011 The International Conference on Organizational Innovation proceeding.

The registration fee of the 2011-ICOI conference is US$300 for each paper registered before May 23, 2011 or US$350 after May 23, 2011. Notably, the student registration fee is US$280 .Each paper should be registered at least by

one author; otherwise it will be regarded as withdrawn automatically.

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Thank you very much for submitting your paper to 2011ICOI The International Conference on Organizational Innovation.

Looking forward to see you in Bangi, Malaysia

Best regards

Conference Chair

2011 ICOI the International Conference

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May, 15 2011

研討會攜回：

1. 光碟

2. 研討會議程

3. 所有發表者文章摘要

4. 研討會發表論文(100/7/28 上午 9:00)

Research to Establish a Customized Modular Product Purchase System

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Abstract:*In this research, we use two different theoretical models for customized modular product design to establish the relationship of product evaluation between the status of consumer demands and the features of the product. Furthermore, by using different theories and the database of the product modules that built through the inputs of the experts we build the criteria for recommending the most suitable product by its modulated functions or components. Then, such mechanism is used to provide customer recommendation system for two different companies with their modulated products. The company can use the system to* *recommend suitable modulated product according to the needs of different customers. The customer can also use the system to search the desired products by inputting the requirement information.*

The model build by the customized modular product design in this research, product design model I: we use fuzzy information axiom as the evaluation and decision principle of the product design model. Product design model I: the Analytical Hierarchy Process, Fuzzy Set Theory, Back-Propagation neural network, and Gray Relational Analysis are also used for the evaluation and decision principle of the product design model. With the maturity of current network technologies and e-commerce practices, a suitable recommendation service system to guide customer's needs is needed for marketing. The manufacturers can use this system to extract the information of the needs for their customers as well as the choices of the products the made. Such information should provide valuable inputs for the sales and future improvement of the product to the company.

Keywords: Customization, Modular Product, Fuzzy Information Axiom, Analytical Hierarchy Process

1. Introduction

In commodity markets, customers or consumers can purchase products with different functional levels according to the conditions of their demands. How different consumer groups purchase products is a perspective enterprises use to plan the standardization of customized products. This approach ensures that enterprises not only attain higher sales amounts and profit space, but it will also be a key factor in industrial development of the electronic generation. This is especially true in the Internet age; this option can be at a customer's "fingertips" to help them obtain good results. In particular, consumers face complex purchasing decisions. Defining how to help consumers buy products, based on specific recommendations for producers and consumers, is a major area under refinement.

Each customer's degree of demand for a product is different. If every demand is viewed as equal in importance, objectivity and the desired outcome cannot be reached. Furthermore, there are various degrees of fuzzy relations between demand and product functional modules, so there needs to be an appropriate theory or rule that can solve the relation mode.

Therefore, in the product design process, we need to help consumers select the "right" goods. In past research, greater emphasis was on the design of products from the standpoint of product information decision-makers. The information could be easily accessed and handled. However, customers' expectations are typically different from the designed products. For customer-centric information research, the classification of the customer groups and the operations of customer relationship management practices are usually emphasized. As for the complex relationships between customers and companies, policy decision-makers traditionally use a single algorithm to solve a single policy or evaluation. Rarely, they will focus on the complexity of the issues, finding an appropriate algorithm for different degrees of the demand and provide a better solution for every step.

Consumer habits often use adjectives to describe the demand for the product level, but the semantics of expression is full of a considerable degree of fuzzy logic and uncertainty. After Zadeh (1965) presented a fuzzy theory concerning how to open the order into a number of linguistic expressions of the first kind, research related to fuzzy theory could mushroom to promote the success of the domain. Moreover, if the true intent and product demand function zooms, a considerable degree of fuzzy association exists, which requires appropriate theoretical principles to solve the relational model. Today, product consumption by the customer is more than subjective self-awareness. In particular, consumption is strongly attached to a customer's own vision and values. Characterized by the product's uniqueness and practicality of the purchase are two important indicators of reference. The products with these characteristics have a long product life cycle and they experience greater demand creation or customization. The resulting changes in product design are developed by considering the design intent.

The purpose of this study is as follows:

(1) Two different theoretical models are provided for a customized module design.
(2) Between the evaluations, consumer demand, product characteristics, and functional association are built up.
(3) Two different case modules are presented to create a consumer business referral services system.

Product designs recently researched for this article relate to scholars with a variety of theories to evaluate the product or purchase product decisions. Such scholars include Kulak (2005), Kulak Durmusoglu & Tufekc (2005), Kulak & Kahraman (2005a, 2005b), Diyar & Kulak (2007), Durmusoglu & Kulak (2008). Scholars use the Fuzzy Information Axiom and Fuzzy Theory, as well as the Gray Theory ,Analytic Hierarchy Process(AHP) to explore the concept of multi-attribute products designed to support decision-making systems. Tsai & Hsiao (2004, 2005), Tsai, Hsiao & Hung (2006), and Tsai & Chou (2007) use a genetic algorithm, AHP, the Gray Theory, and the Fuzzy Theory with customers to explore the multi-functional product evaluation and selection. They also use computer-aided design.

Hsiao & Huang (2002) attempted the use of computer-aided design and neural networks to assist in product shape design consulting decisions. The scholars, Sun, Kalenchuk, Xue & Gu (2000), attempted to combine the Fuzzy Neural Network Theory(FNNT) as the case for the conceptual design for product-related evaluation and decisions.

Using fuzzy axiomatic design principles of information to design the best product is a simple and efficient method, and only the expression of consumer demand semantics can be used to quantify the fuzzy theory. It has been assembled for modular use. This product is easy to use in design principles to search for the best consumer products.

What if the characteristics of functional elements are not yet completed? If this is the case, the customized combination of modules can be obtained using the AHP to rank the importance of customer needs in order to get a back-propagation neural network to obtain the characteristic function of the importance and the gray relational analysis. This obtains the best combination of features for the modular product features.

Product designs feature many key factors to be considered for academic research and theory. Customized modules are designed to consider the following key items:

(1) Customer needs
(2) Functional characteristics (of the module)
(3) Database
(4) Evaluation and decision theory
(5) Optimum product search

Linking these five key factors will greatly influence the results of product design, as well as the product designers and product features. The customer needs identifyfor the module, so a lot of thought goes into the custom module products library database, and such style must also be sold to customers for the range of products. The final evaluation and decision theory are selected by the designer to achieve the end goal.

2. Research methods

The theoretical bases for the use of this research are briefly described as follows:

2.1 AHP

This research uses the theoretical analytic of analytic hierarchy process to set up the class weight of customer requirements. Each customer uses a scale of 1–9 (see Table 1) to compare the "importance degree" of the demands according to their "demand degree." If there are n items of basic demands, after the comparison from the customers, an n×n square matrix may be seen ($A_{n\times n}$).

$$A = \begin{array}{c} \begin{matrix} N_1 & N_2 & \cdots & N_n \end{matrix} \\ \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} \begin{matrix} N_1 \\ N_2 \\ \vdots \\ N_n \end{matrix} \end{array} \text{----------------------------------} (1)$$

Table 1: Comparison rate of customers' basic needs

a_{ij}	comparison rate of i-demand and j-demand
1	i-demand and j-demand are equal important
3	i-demand is a bit important than j-demand
5	i-demand is more important than j-demand
7	i-demand is much more important than j-demand
9	i-demand is extremely more important than j-demand
2468	Intermediate values of the adjacent scale

In order to ensure consistency while conducting the paired comparison, a consistency test is performed. The Consistency Ratio (CR) is used to check whether the matrix was a consistent matrix. If CR$\leq$0.1, the paired comparison matrix features a high level of consistency.

Therefore, one can obtain the eigenvector (**w**) of matrix A from the following formula:

$(A - \lambda I)\mathbf{w} = 0$-- (2)

I is an n×n unit matrix. λ is an eigenvalue of matrix A. Take the largest eigenvalue λ_{max} with the corresponding eigenvector, which will represent the "importance assessment" of customer demand.

2.2 Fuzzy Theory – Triangular Fuzzy Number (TFN)

A TFN is a special case of trapezoidal fuzzy numbers. Function $\tilde{t} = (t_1,t_2,t_3)$ is used to represent the distribution graph of the membership. As shown in Figure 1, real number t_1, t_2, and t_3 represent the reflection value of the x-axis in the three vertices of the triangle graph.

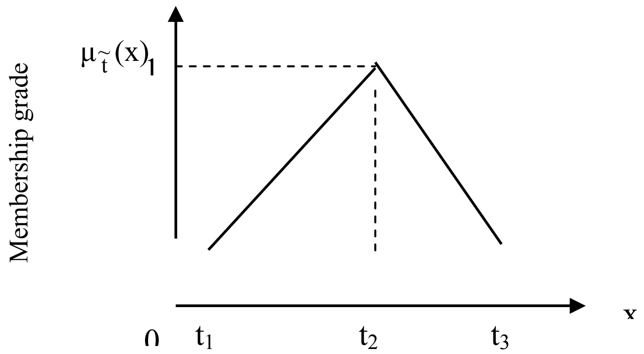

Figure 1: TFN $\tilde{t}$

Therefore, the TFN can be shown as:

$$\mu_{\tilde{t}}(x)=\begin{cases}0, & x<t_1\\ \dfrac{x-t_1}{t_2-t_1}, & t_1\le x\le t_2\\ \dfrac{x-t_3}{t_2-t_3}, & t_2\le x\le t_3\\ 0, & x>t_3\end{cases}$$ ---------------------------------- (3)

2.3 Back-Propagation Neural Network (BPNN)

Neural networks imitate human nervous conveyor systems, and the BPNN, like emulates a supervised learning neural network. As shown in Figure 2, the network structure can be divided into an input layer, a hidden layer, and an output layer. The theorem uses the non-linear reflecting relation of input and output; amending the error value step-by-step. This is used to calculate the appropriate network weights value and bias so that it can achieve the result of the output reflection in the range of tolerance error.

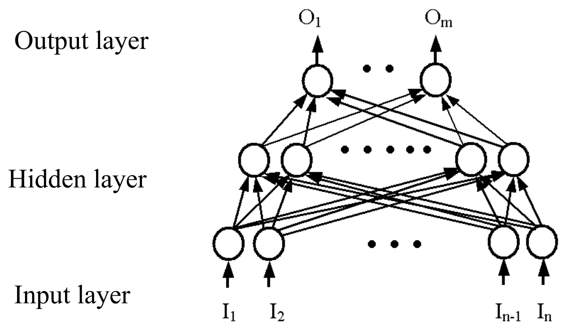

Figure 2: BPNN

2.4 The Gray Theory (GT)

In the gray system control theory, or GT, the grayscale of color is an index of the awareness level of the system. The color black indicates that nothing is known about a system's internal structural parameters and characteristics. The color white represents known information that is complete and has been fully understood for the system. The color gray, which lies in between black and white, represents that the system is composed of partially known information and partially unknown information. The GT is aimed at system uncertainty and incomplete information. Once the level of uncertainty and incomplete information is determined, then correlation analysis and model building are conducted, which relate to the system to assist in further prediction and decision-making.

This research uses the gray relational analysis in the GT to analyze the relation level between the main factors and other factors in the system. Through the calculation of the gray relation degree, the correlation between the two sequences is obtained.

If there is an object sequence $X_1=(x_1(1),x_1(2),...,x_1(n))$, and one wants to calculate the individual gray correlation γ between this and the other sequence $X_j=(x_j(1),x_j(2),...,x_j(n))$, it can be calculated in the following formula:

$$\gamma(X_1,X_j)=\frac{1}{n-1}\sum_{k=1}^{n-1}\left(\frac{\min_j\min_k\Delta_{1j}+\rho\max_j\max_k\Delta_{1j}}{\left|x_1(k)-x_j(k)\right|+\rho\max_j\max_k\Delta_{1j}}\right)$$ ---------------------------------- (4)

ρ is a resolution factor, usually the value is 0.5; $\Delta_{1j}=\left|x_1(k)-x_j(k)\right|$.

(5) Fuzzy Information Axiom (FIA)

Suh (1990, 1995, 1997, 2001) from the Massachusetts Institute of Technology (MIT), further developed QFD (Quality Function Deployment) and proposed the Axiomatic Design (AD). The main purpose of this axiom is to produce a simple design. Suh defined the information content as I, and it is calculated using the formula I (Information Content) = log (design range/common range). A small “I” implies a large common range, which means that as the common range becomes larger, it is easier for the product of this design parameter to be successful. This success signals the ability to meet its corresponding functional requirement. In this case, the system range refers to the manufacturing capability of manufacturers; the design range is the designer's requirements, while the common range is the overlapping part of the system range and the design range. Therefore, when the common range is larger, there is a higher possibility for manufacturers to produce a product according to the designer's concept, thus increasing the chance of success. This concept can be seen in Figure 3.

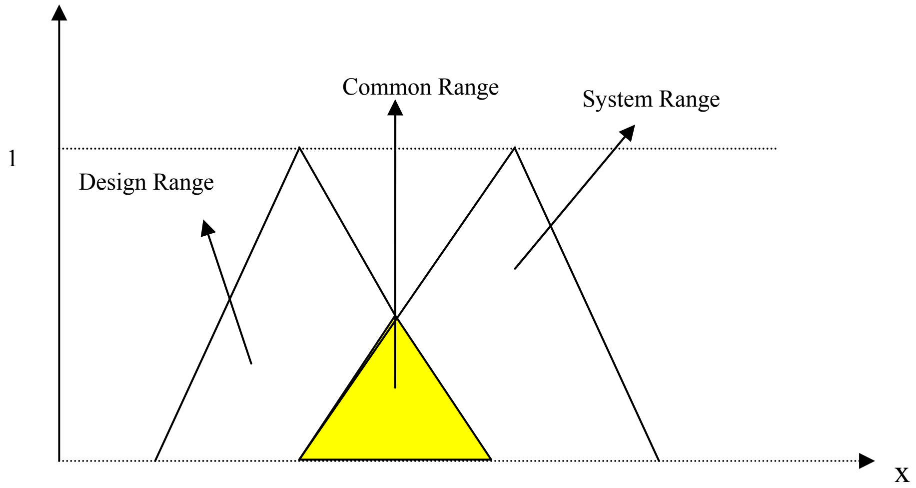

Figure 3. Triangular fuzzy relationship between the system range, design range, and common range

The second axiom of the AD is the information axiom, which states that among those designs that satisfy the independence axiom, the one with the smallest information content is the best design. The definition of information content (I_j), expressed in terms of the TFNs, is as follows:

$$I_j = \log_2(1/p_j) \quad \text{--} \ (5)$$

Where p_j is the ratio of the area of the common range to the area of the system range for the jth design requirement, which is also the probability of the system range meeting the design requirement.

$$p_j = \left[\frac{CommonRange}{SystemRange}\right] \quad \text{---} \ (6)$$

As shown in Figure 2, the overlap of the "design range" set by the designer and the “system range” of the system capacity is the acceptable common range; the larger the common range, the higher the success rate will be.

Assuming that a product has m number of design requirements, the summation of all the design requirements is such that:

Total Information Content (I_{total}) is defined below:

$$I_{total} = \sum_{j=1}^{m} I_j \quad \text{--} \ (7)$$

3. Customized Modular Product Design Model

For product research in the module design process, this article will be divided into two different theoretical models:

Model I: We use the FIA as the evaluation and decision principle of the product design model.

Model II: The AHP, Fuzzy Set Theory, BPNN, and Gray Relational Analysis are also used for the evaluation and decision principle of the product design.

3.1Construction of the FIA model

The model theory of the FIA is the evaluation criteria considered when evaluating the concept of the Taguchi method to conduct modular product design. Its research methods and design process are described as follows.

Using the concepts of the TFNs and the Taguchi method, the following were established:

(1) TFNs for the requirement levels
(2) The relationship between the evaluation of functional requirement options and product features, in order to establish rules to relate the evaluations of customers and designers.

For a designer, the functional requirements not only contain the main, obvious customer product parameters, but they also contain customers' potential needs. The functional requirements of customers are often hard to express explicitly, so fuzzy numbers are used to determine customer needs, as expressed using the seven levels listed in Table 2.

Table 2: TFNs showing seven requirement levels

Vocabulary	Denotation	TFNs
A Very low	VL	(0,0,1)
B Low	L	(0,1,3)
C Medium low	ML	(1,3,5)

D	Medium	M	(3,5,7)
E	Medium high	MH	(5,7,9)
F	High	H	(7 ,9,10)
G	Very high	VH	(9,10,10)

The computation formula for the selection of the best product is explained as follows:

(1) Assuming the customers' functional requirements to calculate the median of customers' functional requirements

If there are n basic customer needs, they are translated into seven levels of triangular fuzzy numbers and the median of customer needs is calculated and normalized to obtain the customer needs in the hierarchical order **w** ($w_1, w_2, \ldots, w_n$), as shown in Formula (8).

$$\sum_{i=1}^{n} w_i = 1 \text{--} (8)$$

(2) Computation of the requirement level for a product feature

As shown in Table 4, the TFNs for the relationship matrix of customer needs and product features assessed by experts are $\widetilde{A}$

$$\widetilde{A} = \left[\widetilde{a}_{ij}\right] \text{--} (9)$$

where i and j denote i-th customer need and j-th product feature.

The product of the relationships between the normalized customer requirement levels, weighted customer needs, and product features will give rise to a j-th TFN for product feature $\widetilde{b}_j$.

$$\widetilde{b}_j = \sum_{i=1}^{n} w_i \times [\widetilde{a}_{ij}] \text{---} (10)$$

(3) Computation of information content I_j

Based on the results in step 2, using the design range and system range of the actual product shown in Figure 2, the information content I_j of the j-th product feature is determined:

$$I_j = \log_2(1/p_j) \text{ ---} (11)$$

(4) Establishment of rules for the selection of the best product

According to the fuzzy reasoning principles of feature requirements established in Table 4, the median of various product features is calculated, and the normalized weight of the j-th product feature is w_j^{nd} , whereby $\sum_{j=1}^{m} w^{nd}{}_j = 1$

(5) Finally, all the information content obtained is sequentially multiplied by the standardized level to obtain the grand total value for product information content E $_{min}$; its formula is as follows:

$$E_{\min} = \sum_{j=1}^{m} \left(I_j \times w_j^{nd.}\right) \text{--} (12)$$

(6) Establishment of the ideal product purchasing interface for customers

The above algorithms are programmed to establish the ideal product purchasing programming interface. Consumers can use this interface to select their personal needs and the system will suggest the most suitable merchandise, or use this interface to preview the recommended products.

3.2 Construction of Fuzzy AHP, BPNN, and GT models

This research is based on the algorithms built by the AHP, the fuzzy set theory, and the BPNN to help customers or consumers calculate the membership grade of each functional module level according to their own preference of the demand condition.

(1). Establishment of an evaluation rule for the functional modules

This stage is intended to build up the relation and evaluation mode between "customer demand" and "functional module" in the following three steps.

Step 1. Ranking and development of customer demand

If there are n items of a basic customer demand, after conducting the paired comparison, one can use Formula (2) to calculate the eigenvector **w** (w_1, w_2, w_n) of the customer demand. Next, it is normalized, and the class sequences w^* ($w_1^*, w_2^*, \ldots, w_n^*$) are obtained for customer demand and fuzzy the sequences into five-order TFNs individually. Table 3 represents the table and graph of the TFNs of five lexical grades.

Table 3: TFNs showing five requirement levels

Lexical Category	TFNs
A Fairly Unimportant/Lower	(0,0,3)
B Unimportant/Low	(1,3,5)
C General/Normal	(3,5,7)
D Important/High	(5,7,9)
E Fairly Important/Higher	(7,10,10)

Step 2. Establish the relevance of "customer demand" and "functional module"

In accordance with different customer demands, one identifies the functional module, with a greater satisfaction, as an important goal of this step.

Therefore, the relevance between "customer demand" and "functional module" must be established. Suppose there are n items of customer demand and m items of the functional components category. One can now set up a correlation level matrix $R_{n\times m}$.

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nn} \end{bmatrix}$$

Therefore, one can imitate the method in Step 1, where the fuzzy r_{ij} is in five grades of TFNs. The correlation level between "customer demand" and "functional module" is shown in Table 3.

Step 3. Evaluation of fuzzy lexical functional module

According to the importance degree of the lexical group (fairly important, important, normal, unimportant, fairly unimportant) and the correlation lexical group (high positive correlation, correlation), which is defined by the first two steps, one can follow the fuzzy logic structure "if…then" to evaluate the demand level (fairly high, high, normal, low, fairly lower) of the modular function. From the interaction into pairs of the 5 "importance level lexical," and 5 "correlation level lexical," 25 fuzzy inference rules can be obtained.

For instance, if the ith demand level of a customer is "fairly important" and the functional module of jth that fulfills the demand correlation of ith is "highly relevant," then that functional module will respond to the correlation demand in "fairly high" form. The statement above can be simplified with fuzzy logic as follows:

IF "Customer demand – fairly important" and "correlation – highly relevant"
THEN "Functional module demand – fairly high"

The 25 fuzzy logic inferences are shown in Table 4.

Table 4: Correlation for customer demands and functional modules

Customer Needs	Relationship Between Customer Needs and Product Features						
	VH	H	MH	M	ML	L	VL
VH	VH	VH	H	M	L	VL	VL
H	VH	H	H	M	L	L	VL
MH	H	H	MH	M	ML	L	L
M	H	MH	MH	M	ML	ML	L
ML	MH	MH	M	M	M	ML	ML
L	MH	M	M	M	M	M	ML
VL	M	M	M	M	M	M	M

(2). Establishment of the fuzzy algorithm of a neural network

As shown in Figure 2, a BPNN can be divided into: input layer, hidden layer, and output layer. In this research, we count 10 values of the 5 fuzzy levels of “customer demand” and “correlation” in the IF condition, and put them as the node values of the neural network input layer. Additionally, the five levels of “functional module demand” are put in the THEN condition as the output layer node. Therefore, the example of Step 3 can fuzzy the result of the input condition and output condition as:

INPUT: 1 0 0 0 0 1 0 0 0 0

OUTPUT: 1 0 0 0 0

The 25 fuzzy logic conditions, which are structured by the aforementioned, can be provided as neural network learning rules, and calculated by MATLAB software, to obtain the weighted value and bias of the neural network. The network that completes the training can help a customer get a basic demand that corresponds to the output sequence $P(p_{ij}(1), p_{ij}(2), p_{ij}(3), p_{ij}(4), p_{ij}(5))$ of each functional module according to a customer’s personal demand. This sequence can be shown as a line chart function f(x) and one can get the focus position p^*_{ij} in the line chart function of the ith demand and jth functional module.

$$p^*_{ij} = \frac{\int_0^1 f(x)x\,dx}{\int_0^1 f(x)\,dx} \text{ --- } (13)$$

Hence, one can take each functional module demand as the standard, weighted average demand level (eigenvector) for each functional module. Then, the sum of demand membership in each functional component can be obtained by Formula (14).

$$P^*_j = (\sum_{i=1}^{n} p^*_{ij} \cdot w^*_i) / \sum_i w^*_i \text{ --- } (14)$$

(3). Use of the GT decision model

The membership that is obtained by Formula (14) can be seen as an object sequence $P^G(p_1, p_2, \cdots, p_m)$. However, while the functional modules are in the free combination, some conflicts might occur between different functional style options. If the functional module can be reasonably assumed into pairs, or the manufacturers have set the matching methods at z combinations, one can see those combinations as z reference sequences $P^R_k(p_1, p_2, \cdots, p_m)$, and k = 1, 2,…,z. Different gray correlations of reference sequences and object sequences through Formula (4) can be attained. The maximum value γ_{max}, the sequence, which corresponds to γ_{max}, is the best product functional module style suggestion according to each customer's personal demand.

4. Research Case

In this paper, our case enterprises include two companies in Chiayi: (1) a sales-based notebook computer company, and (2) a production and sales-based baby stroller manufacturing company.

These two companies will be used for the actual calculation of a modular product design model and model II, and the establishment of referral services system interface module products; these two companies can use this referral service system based on customer needs to have the most suitable module products for their customers. Each company can use the results, combined to promote these modules. Furthermore, the results can be placed on the company Web sites for consumers, in accordance with their needs, to assist their search for the most suitable modules.

4.1. Example 1

The basic customer needs are jointly developed by two experienced and professional computer sales staff, two laptop product planners, and one of Research and Development (R&D) staff member. Based on the basic customer requirements for the important features, the experts and consultants of this study selected seven Preferred Features (PF), namely: Central Processing Unit (CPU), Random Access Memory (RAM), Screen Size, Hard Disk Capacity, Display Card, Price, and Color (see Table 5).

Table 5: Designer's selection of customers' functional requirements and preferred product features

	Customer Needs	No.	Product Features
CN1	Word Processing	PF1	CPU
CN2	Professional Graphics	PF 2	RAM
CN3	Numerical Computation	PF 3	Screen Size
CN4	Portability	PF 4	Hard Disk Capacity
CN5	Price	PF 5	Display Card
CN6	Color	PF 6	Price
		PF 7	Color

Feigo would like to buy a laptop, but he knows nothing about computer hardware. In this study, the FIA algorithms are used to help him search for the ideal market laptop based on his actual needs, which are listed in Table 8.

Table 6: Feigo's requirements for computers and the requirement levels

Serial Number	Functional Requirements for Computer	Feigo's Requirement Level
CN1	Word Processing	H

CN2	Professional Graphics	VL
CN3	Numerical Computation	M
CN4	Portability	MH
CN5	Price	Below TWD 30,000 ML
CN6	Color	White

The notebook computer product purchasing interface is produced **(**see Figure 4).

Figure 4: Notebook computer product purchasing interface

A smaller information content indicates that the laptop is closer to the customer's requirements. Feigo's top three computers are NB21, NB41, and NB50. Looking at the laptop ranked first in the table, its price and color have satisfied Feigo's requirements, the screen size is comparable to his requirements, and it has a higher CPU and hard disk capacity. The customer has a greater need and priority for word processing and numerical computation; therefore, since the laptops that ranked second and third may have smaller screens, and their CPU and hard disk capacity are much smaller, they are placed below NB21.

4.2 Example 2

The setting of each baby stroller functional type classification is shown as Table 6. Each functional type has its own modular style. The modular style that has the same function can follow the low-to-high of the product positioning, equally divided between the value [0, 1]. In Table 7, the value in that column shows the relationship between customer demands and functional modules.

Table 7: Category of modular function for baby strollers

Item	Product Features	Alternatives	Membership Grade
F_1	Folding Operation	One-Hand Operation + Joint Pull	1
		Hook Pull + Joint Pull	0.5
		Joint Pull	0
F_2	Self-Standing after Folding	Included	1
		Not Included	0
F_3	Reversible Handle	Included	1
		Not Included	0
F_4	Accessories in Front of Seat	Tray + Toy Bar	1
		Tray	0.5
		Bumper	0
F_5	Seat Back Adjustability	Multi-Position	1
		Two Positions	0
F_6	Foot Rest	Adjustable	1
		Fixed	0
F_7	Wheel	Pivoted (6 Wheels or 8 Wheels)	1
		Fixed Direction (4 Wheels)	0
F_8	Suspension	Cantilever-Type	1
		Simple-Type	0.5
		Non	0

(1) The setting of customer demand

The set of six basic customer demands according to the product features is depicted in Table 8. These demands are: (1) sitting comfort for baby, (2) collapsibility, (3) portability, (4) operational usage, (5) additional components (toys, space), and (6) lower price.

Table 8: Setting demand for baby strollers

Item	Content of Demand
N_1	Sitting Comfort for Baby

N_2	Collapsibility
N_3	Portability
N_4	Operational Usage
N_5	Additional Components (Toys, Tray)
N_6	Lower Price

(2) Finally, the baby stroller product purchasing interface is provided (see Figure 5).

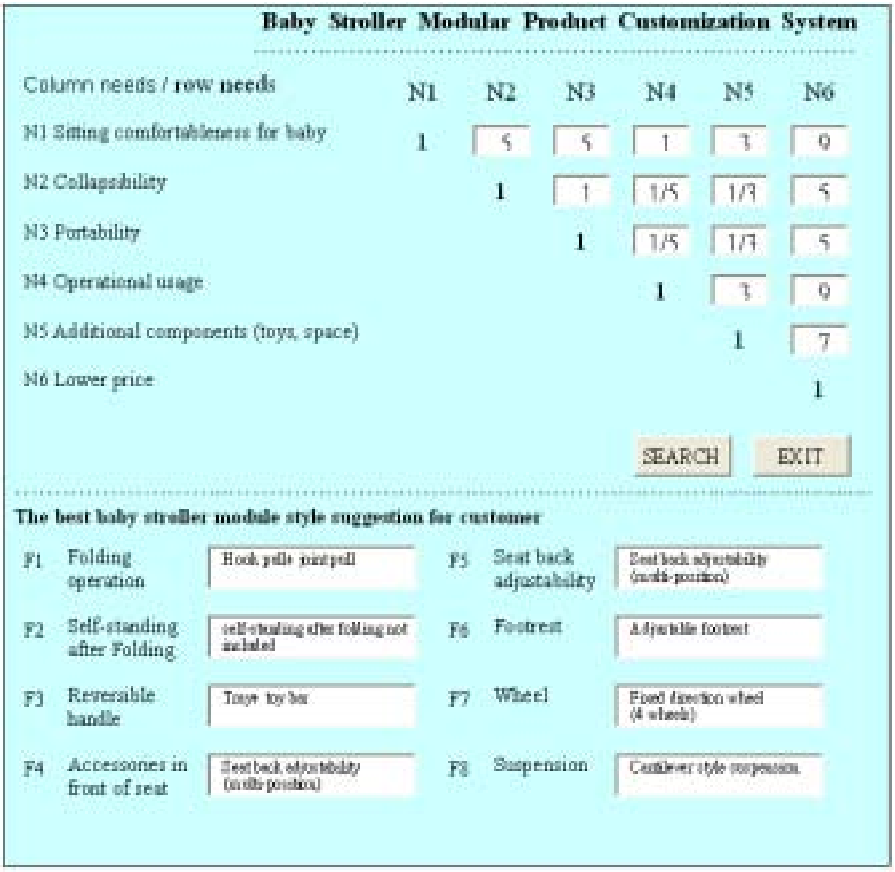

Figure 5: Baby stroller product purchasing interface

For this reason, the best baby stroller module style suggestion for customer A is: (1) hook pull + joint pull, (2) self-standing after folding not included, (3) reversible handle, (4) tray + toy bar, (5) seat back adjustability (multi-position), (6) adjustable foot rest, (7) fixed direction wheel (4 wheels), and (8) cantilever-style suspension.

5. Conclusions and Discussion

This paper discusses customized module design, model-building, and customer assistance in two case enterprises. These efforts are discussed to establish a service system and to make customers a variety of products where they can select a suitable product. The contribution of this paper is as follows:

(1) In the customized module design, two established design patterns, starting with the preferences of the customer's needs, attend to consumer purchase behavior, which may be waived by the designers for the lack of subjective guidance.
(2) In the product design process, some scholars design the FIA to evaluate the product, then consider this increase in customer expectations of the product quality characteristic factor in market practices, thereby enhancing consumer product satisfaction.
(3) In the product design process, after establishing an expert evaluation of the database modules, consumers can buy more products based on similar module choices.
(4) Once this module product design model is established, then versatile enterprises can use this model to establish the company's consumer referral service system to provide consumer buying preferences of the different modules of their products.
(5) A company can apply what is in this paper to provide the service system recommendation to consumers who fall within the interface of the obtained results, with the actual consumer purchasing decisions in the market comparison. The different results may help a company's marketing and product development strategies. They may need to be strengthened in part (e.g., determine if advertising spending is adequate; identify if the introduction of the modules is appropriate to customer needs, etc.).
(6) The case study companies (a computer company and manufacturer of baby strollers) are actual operations. Experienced sales staff and product R&D planning personnel may conduct staff evaluations of functional characteristics and may find the results of this study to be very helpful. This industry cooperation model will serve as a model for forward work.

In a customer-oriented era, being able to quickly assess and respond to changing consumer demands and service requirements are the only ways to be successful in business. In the pursuit of an exemplary modern society, the quality of a product or a system's design strengths and weaknesses directly affect market competitiveness.

Consumer demands for products and different levels of semantics are not yet clear, and in the face of relatively unfamiliar (or functionally more complex) requirements, there are often bewildering choices. One does not know how to choose the appropriate function module; therefore, reliance upon product experts' designs is imperative.

This custom-built modular product design has two patterns. Design pattern I is the axiomatic evaluation of fuzzy information and decision-making rules. Design mode II involves the level of analysis, fuzzy theory, neural network and gray relational analysis employed as evaluation and decision-making rules.

The customized module design framework is an established calculus, starting from the setting of customer needs, identifying the important functional characteristics of modular products and components, to the evaluation of the relationship between the two. The establishment of the database modules, evaluation, and use of theoretical models make the decision to choose the best products, and the establishment of the universal module products and enterprises can then be selected based on the desired mode. Additionally, there is a basis for a calculation process to build a product recommendation service system.

Blurring the customer needs for a reasonable and rigorous theory is a mapping of the transition to the product characteristics. The logic of the research framework is reasonable, objective, and accurate, and it can operate on the practical application of business practices in the design process, enterprise research, and development. Sales personnel can provide assistance, engaging in various discussions in which both sides should be inspired by this process to have a resulting industry-university cooperation.

With today's Internet, e-commerce technology has matured, so some believe that for many manufacturers, the urgent need is to properly guide customer needs to a recommendation service system. Companies can then service systems, business, and manufacturers to obtain customer needs and the site can select the relative information. This information can be obtained from company sales and R&D, which may ultimately be of great help to consumers.

6. Acknowledgments

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六、其他

無

國科會補助計畫衍生研發成果推廣資料表

日期:2011/08/15

國科會補助計畫	計畫名稱: 運用模糊資訊理論於客製化產品選購服務系統
	計畫主持人: 陳淼勝
	計畫編號: 99-2410-H-343-016- 學門領域: 作業研究／數量方法

無研發成果推廣資料

99 年度專題研究計畫研究成果彙整表

計畫主持人：陳淼勝	計畫編號：99-2410-H-343-016-

計畫名稱：運用模糊資訊理論於客製化產品選購服務系統

成果項目			量化			單位	備註（質化說明：如數個計畫共同成果、成果列為該期刊之封面故事...等）
			實際已達成數（被接受或已發表）	預期總達成數(含實際已達成數)	本計畫實際貢獻百分比		
國內	論文著作	期刊論文	0	0	100%	篇	
		研究報告/技術報告	0	0	100%		
		研討會論文	0	0	100%		
		專書	0	0	100%		
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（本國籍）	碩士生	0	0	100%	人次	
		博士生	0	0	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		
國外	論文著作	期刊論文	0	1	100%	篇	
		研究報告/技術報告	0	0	100%		
		研討會論文	1	1	100%		
		專書	0	0	100%	章/本	
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（外國籍）	碩士生	0	0	100%	人次	
		博士生	0	0	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		

其他成果 (無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。)	無

	成果項目	量化	名稱或內容性質簡述
科教處計畫加填項目	測驗工具(含質性與量性)	0	
	課程/模組	0	
	電腦及網路系統或工具	0	
	教材	0	
	舉辦之活動/競賽	0	
	研討會/工作坊	0	
	電子報、網站	0	
	計畫成果推廣之參與（閱聽）人數	0	

國科會補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

■達成目標

□未達成目標（請說明，以 100 字為限）

□實驗失敗

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說明：

2. 研究成果在學術期刊發表或申請專利等情形：

論文：□已發表 ■未發表之文稿 □撰寫中 □無

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技轉：□已技轉 □洽談中 ■無

其他：（以 100 字為限）

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）（以500 字為限）

一、研究成果

1. 在客製化模組產品設計，所建立之兩種設計模式，皆起始於顧客需求的喜好，可免去受設計者主觀引導的缺失。

2. 在產品設計過程中，增加考量顧客對產品品質特性的期望因子，在市場銷售實務上，可增強消費者在選購產品後的滿意度。

3. 在產品設計過程中，建立專家評價後之模組產品資料庫，能使消費者在選購模組產品時有更多樣的選擇。

4. 本文所建立模組產品設計模式，具有通用性，企業可利用此模式建立該企業的消費者推薦服務系統。

5. 公司可應用本論文提供之推薦服務系統介面所得到之消費者選購結果，與實際消費者在市場上選購決策比較。

6. 本論文的個案公司，有電腦公司及嬰兒推車之製造廠商人員協助進行實際作業及討論，這種產學合作模式，將是未來可推廣模式。

二、進一步發展可行性

1. 增加評估模式：本文採用兩種產品設計評估模式，後續的發展可以嘗試使用其他更為複雜和精確的方法來設計產品評估模式。

2. 考量品牌忠誠度：本文中未考量顧客在選購時對品牌忠誠度，未來研究可考慮消費者對品牌的喜好度。

3. 價格因子調整：價格因子設定是重要課題。

4. 虛擬實境的使用：目前網路上虛擬實境的使用，已經慢慢被消費者所接受，即時呈現產品設計之成果，將是與顧客互動最好方式。