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Combing Fuzzy Set Theory and Extent Analysis to Construct an Integrated Decision Making Approach in Medical Cosmetology Industry

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Abstract: Many researches on how price bundling affects bundle purchasing have been discussed but an analytic evaluation of customer value offered by medical cosmetology industry is still lacking. In this study, an integrated decision making approach that combined fuzzy set theory and extent analysis has developed and applied in evaluating medical cosmetology product bundles. Based on the results, manufacturers and marketers should utilize appropriate strategy in order to deliver functional, symbolic and safety performance to enhance customers' value image for medical cosmetology product bundles.

Key words: Fuzzy set theory, extent analysis, medical cosmetology, product bundle, product attributes, beneficial attributes, value image

INTRODUCTION

Product bundling is widely practiced in today's marketplace. For example, McDonalds offers "value meals" that includes a hamburger, a soft drink and French fries. Paun (1993) argued that bundling is a strategic marketing variable. To be able to increase customer's value, firms could utilize product bundles as an appropriate strategy to get better competitive position and then obtain more competitive advantages (Afuah, 2002). Thus, delivering value of bundling will enhance overall evaluation of a product bundle. From the previous studies, many researchers have mentioned and described the value concept in terms of a trade off. Sheth *et al*. (1991) proposed the dimensions of customer value-functional, social, emotional, epistemic and conditional value; however, the causal relationships are scanty. Woodruff (1997) pointed out that it is a good approach to adopt the hierarchy concept to better explain customer value but at that time the concrete variables are difficult to define. Thus, developing a systematic structure and a comprehensive methodology for product bundles is necessary for marketers, so as to understand the preferences of customers and to create a competitive advantage.

In the marketing field, it is not easy to explore customers' minds to understand their needs, wants and demands and therefore, it is difficult to understand customers' preferences. This is because when customers are during decision making process, they would consider multiple criteria for many alternatives. In this process, there is likely to be interaction among the different criteria. Thus, the evaluating process is complex (Oliver, 2000). In addition, the qualitative attributes for human assessment is always imprecise and subjective. Thus, the descriptions of customer requirements are usually linguistic and vague. For the question of facing the uncertainty due to customers' imprecision and vagueness, fuzzy set theory is suggested as a suitable tool to deal with such a situation (Lin *et al*., 2009). Furthermore, the fuzzy multiple criteria decision making approach can deal with qualitative information in addition to the quantitative data (Tsao, 2006). The benefit and premium capability of adopting fuzzy set theory to deal with qualitative and quantitative data is to represent unclear and indefinite data. As we know, perceptive organs of human brain provided and interpreted incomplete afferent data and vague information. To deal with such imprecise information and incomplete data, fuzzy set theory could not only perform numerical computation but also implement systematic calculus by using linguistic terms. Thus, this study combined fuzzy set theory and extent analysis in order to capture the subjective and imprecise perceptive data from customers and finally constructed an effective and integrated decision making approach.

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CONCEPTUAL FRAMEWORK

Product bundle: Product bundling is the process of securing two or more necessary goods or services from a single vendor. This strategy usually provides several advantages, including saving a great deal of money. Long a practice among businesses, the concept of product bundling has expanded to include residential customers over the last twenty years, especially in regard to various types of communication services. The basic nature of product bundling involves the willingness of a supplier or vendor to provide two or more services to a customer for basic rate. This rate normally provides significant savings over purchasing the products individually.

Product bundling also provides other benefits for the customer. One has to do with sheer convenience. Rather than having to deal with multiple vendors in order to have access to multiple products, the customer has one central vendor for all his or her needs (Yang, 2010; Montinaro and Sciascia, 2011). This concept of one-stop shopping means the client spends less time keeping up with payments to various vendors and has one central pipeline when there is a need for customer services. Product bundling is combining two or more products or services together, creating differentiation, greater value and therefore enhancing the offering to the customer (Asikhia, 2009; Jiang *et al*., 2011). Bundling is based on the idea that consumers value the grouped package more than the individual items (Sudhahar *et al*., 2006; Lee *et al*., 2009).

Marketers utilize joint pricing for the sale of two or more products and/or services in a single package (Guiltinan, 1987; Kaicker *et al*., 1995; Stremersch and Tellis, 2002). Most researchers have been interested in issues of how price bundling is a pricing and promotion tool to decrease price sensitivity and increase purchase likelihood for customers (Johnson *et al*., 1999; Soman and Gourville, 2001; Janiszewski and Cunha Jr., 2004). Simonin and Ruth (1995) utilized a quasi-experimental procedure to investigate the effects of bundling influence on consumers' evaluations and reservation price judgments. They found product bundling also could be a strategy for new product introduction through bundling with an existing product. Beside price information about bundling, Mulhern and Leone (1991) and Harlam *et al*. (1995) observed complementary effects in their study. Bundles composed of complements will have higher purchase intentions than the bundles of unrelated products. Sarin *et al*. (2003) applied product bundling as a strategy to reduce the perceived risk with new high-tech products. From the above literature, the value of a product bundle is not only in the momentary savings but it also involves other attributes for customers. Besides price factor, this study want to find the other influential factors and understand the preferences of customers which will help manufacturers to focus on the product attributes that concern customers.

Integrated decision making approach: The integrated decision making approach, the focus of this research, can be used in selection problems where decisions involve a finite number of alternatives and a set of performance attributes. The decision variables can be either quantitative or qualitative. The key difference in integrated decision making approach, as compared to multiple attributes decision making models and multiple objectives decision making ones, is that they include discreet variables with a number of pre-specified alternatives and more importantly, they do not require an explicit relation between input and output variables. Concerning multiple attributes decision making problems and multiple objectives decision making ones, the following methods could be utilized when the information of attribute preference is available from the decision maker: (1) The Simple Additive Weight (SAW) method; (2) The Weighted Product Method (EPM); (3) The Elimination et Choice Translating Reality method (ELECTRE); (4) The technique for order preference by similarity to ideal solution (TOPSIS) and (5) The Analytic Hierarchy Process (AHP).

Fuzzy set theory: Fuzzy set theory has been studied extensively over the past 30 years. Most of the early interest in fuzzy set theory pertained to representing uncertainty in human cognitive processes. Fuzzy set theory is now applied to problems in engineering, business, medical and related health sciences and the natural sciences (Lin *et al*., 2009). In an effort to gain a better understanding of the use of fuzzy set theory in product bundles research and to provide a basis for future research, a literature review of fuzzy set theory in product bundles has been conducted. While similar survey efforts have been undertaken for other topical areas, there is a need in product bundles for the same. Over the years there have been successful applications and implementations of fuzzy set theory in product bundles. Fuzzy set theory is being recognized as an important problem modeling and solution technique.

Kaufmann and Gupta (1988) report that over 7,000 research papers, reports, monographs and books on fuzzy set theory and applications have been published since 1965. Mahmoud (2003) reviews the literature on fuzzy industrial controllers and provide an index of applications of fuzzy set theory to 12 subject areas including decision making, economics, engineering and operations research.

As evidenced by the large number of citations found from the previous researches, fuzzy set theory is an established and growing research discipline. The use of fuzzy set theory as a methodology for modeling and analyzing decision systems is of particular interest to researchers in product bundles due to fuzzy set theory's ability to quantitatively and qualitatively model problems which involve vagueness and imprecision. Karwowski and Evans (1986) identify the potential applications of fuzzy set theory to the following areas of product bundles: new product development, facilities location and layout, production scheduling and control, inventory management, quality and cost benefit analysis. Karwowski and Evans identify three key reasons why fuzzy set theory is relevant to product bundles research. First, imprecision and vagueness are inherent to the decision maker's mental model of the problem under study. Thus, the decision maker's experience and judgment may be used to complement established theories to foster a better understanding of the problem. Second, in the product bundles environment, the information required to formulate a model's objective, decision variables, constraints and parameters may be vague or not precisely measurable. Third, imprecision and vagueness as a result of personal bias and subjective opinion may further dampen the quality and quantity of available information. Hence, fuzzy set theory can be used to bridge modeling gaps in descriptive and prescriptive decision models in product bundles research.

CONSTRUCTION OF FUZZY JUDGMENT MATRIX

After a hierarchical model is constructed, experts are asked to compare a series of pair-wise comparisons and establish the relative importance of customer requirements in achieving the upper level criterion. The linguistic variables that people used to express their feelings or judgment are vague. For example, the question asked to experts is: "what is the relative impact on the value by performance A when compared to performance B in using various medical cosmetology products?" In such comparisons, linguistic terms are used to assess any two elements, namely equally, moderately, strongly, very strongly, or extremely preferred. In this study, the widely adopted triangular fuzzy number technique (Chan *et al*., 1999) is used to represent a pair-wise comparison of customer requirements. Experts express their preferences between options based on the definition of linguistic variables in Table 1. For example, someone may consider

Table 1: Linguistic variables and triangular fuzzy number

Linguistic variables	Fuzzy number	Triangular fuzzy number	Triangular fuzzy reciprocal number
Equally important (EI)	1	(1, 1, 3)	(1/3, 1, 1)
Weakly important (WI)	3	(1, 3, 5)	(1/5, 1/3, 1)
Strongly important (SI)	5	(3, 5, 7)	(1/7, 1/5, 1/3)
Very important (VI)	7	(5, 7, 9)	(1/9, 1/7, 1/5)
Absolutely important (AI)	9	(7, 9, 9)	(1/9, 1/9, 1/7)

that element i is strongly important as compared with the element j under certain criteria; he/she may set $e_{ij} = (3, 5, 7)$. If element j is thought to be less important than element i, the pair-wise comparison between j and i can be presented by using the fuzzy number, $e_{ij} = (1/7, 1/5, 1/3)$.

APPLICATION OF EXTENT ANALYSIS METHOD

In previous research, many scholars have engaged in the fuzzy extension of Saaty's priority theory; for example, Van Laarhoven and Pedrycz (1983) in the Netherlands, proposed a method, where the fuzzy comparison judgment is represented by triangular fuzzy numbers. They used fuzzy numbers with triangular membership function and simple operation laws. According to the method of Logarithmic least squares (LLSM), the priority vectors were obtained. However, there is one defect in the calculation process. Researchers used fuzzy numbers to describe the "linguistic vagueness" and the crisp values could then be obtained by using a "clear" defuzzification formula for calculating the priority vector. However, this does not seem to match the original concept of ambiguity. In a better alternative, the extent analysis method and the principles for comparing fuzzy numbers are employed to obtain weight vectors of individual levels for customer requirements (Chang, 1996). The extent analysis method is used to consider the extent to which an object can satisfy the goal, that is, satisfaction extent. In this method, the "extent" is quantified by using a fuzzy number. On the basis of the fuzzy values for the extent analysis of each object, a fuzzy synthetic degree value can be obtained, which is defined as follows:

Let $X = \{x_1, x_2,..., x_n\}$ be an object set and $G = \{g_1, g_2, ..., g_m\}$ be a goal set. According to the method of Chang (1996) extent analysis, each object is taken and the extent analysis for each goal, g_i, is performed, respectively. Therefore, m extent analysis values for each object can be obtained, with the following signs:

$$\tilde{M}^1_{gi},\ \tilde{M}^2_{gi},...,\ \tilde{M}^m_{gi}, \qquad i = 1,\ 2,...,\ n \tag{1}$$

where, all the $\tilde{M}^j_{gi}$ $(j = 1,\ 2,...,\ m)$ are triangular fuzzy numbers.

The steps of extent analysis can be given as follow:

Step 1: The value of fuzzy synthetic extent with respect to the ith object is defined as:

$$\tilde{S}_i = \sum_{j=1}^{m} \tilde{M}_{g_i}^{j} \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} \tilde{M}_{g_i}^{j}\right]^{-1} \tag{2}$$

where, $\tilde{s}$ is defined as the fuzzy synthetic extent value and $\otimes$ is defined as the fuzzy operation multiplication.

To obtain $\sum_{j=1}^{m} \tilde{M}_{g_i}^{j}$ perform the fuzzy addition operation of m extent analysis values for a particular matrix such that:

$$\sum_{j=1}^{m} \tilde{M}_{g_i}^{j} = \left(\sum_{j=1}^{m} l_j,\ \sum_{j=1}^{m} m_j,\ \sum_{j=1}^{m} u_j\right) \tag{3}$$

and to obtain $[\sum_{i=1}^{n}\sum_{j=1}^{m} \tilde{M}_{g_i}^{j}]^{-1}$, perform the fuzzy addition operation of $\tilde{M}_{g_i}^{j}\ (j = 1, 2, ..., m)$ values such that:

$$\sum_{i=1}^{n}\sum_{j=1}^{m} \tilde{M}_{g_i}^{j} = \left(\sum_{i=1}^{n} l_i,\ \sum_{i=1}^{n} m_i,\ \sum_{i=1}^{n} u_i\right) \tag{4}$$

and then compute the inverse of the vector in Eq. 8 such that:

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} \tilde{M}_{g_i}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i},\ \frac{1}{\sum_{i=1}^{n} m_i},\ \frac{1}{\sum_{i=1}^{n} l_i}\right) \tag{5}$$

Step 2: The degree of possibility of

$$\tilde{M}_2 = (l_2,\ m_2,\ u_2) \geq \tilde{M}_1 = (l_1,\ m_1,\ u_1)$$

is defined as:

$$V(\tilde{M}_2 \geq \tilde{M}_1) = \sup_{y \geq x} [\min(u_{\tilde{M}_1}(x),\ u_{\tilde{M}_2}(y))]$$

and can be equivalently expressed as follows:

$$\begin{aligned} & V(\tilde{M}_2 \geq \tilde{M}_1) \\ & = hgt(\tilde{M}_1 \cap \tilde{M}_2) = u_{\tilde{M}_2}(d) \\ & = \begin{cases} 1, & \text{if} \quad m_2 \geq m_1, \\ 0, & \text{if} \quad l_1 \geq u_2, \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & \text{otherwise.} \end{cases} \end{aligned} \tag{6}$$

where, d is the ordinate of the highest intersection point D between μ_{M1} and μ_{M2} (Fig. 1).

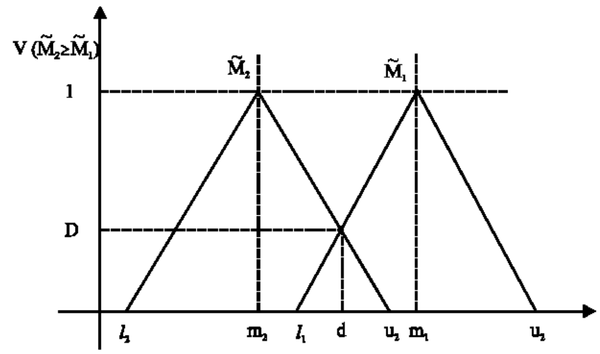

Fig. 1: The intersection between M_1 and M_2

To compare M_1 and M_2, the values of V ($M_1 \geq M_2$) and V ($M_2 \geq M_1$) are needed.

Step 3: The degree of possibility for a convex fuzzy number to be greater than k convex fuzzy numbers $\tilde{M}_i\ (i = 1, 2, ..., k)$ can be defined by:

$$\begin{aligned} & V(\tilde{M} \geq \tilde{M}_1,\ \tilde{M}_2, ...,\ \tilde{M}_k) \\ & = V[(\tilde{M} \geq \tilde{M}_1) \cap (\tilde{M} \geq \tilde{M}_2) \cap ... \cap (\tilde{M} \geq \tilde{M}_k)] \\ & = \min\ V(\tilde{M} \geq \tilde{M}_i), \qquad i = 1, 2, ..., k. \end{aligned} \tag{7}$$

Assume that:

$$d'(A_i) = \min\ V(\tilde{S}_i \geq \tilde{S}_k), \qquad k = 1, 2, ..., n; \quad k \neq i \tag{8}$$

Then the weight vector is given by:

$$W' = [d'(A_1),\ d'(A_2), ...,\ d'(A_n)]^T \tag{9}$$

where, A_i (i = 1, 2,..., n) = are n elements.

Step 4: Via normalization, the normalized weight vectors are:

$$W = [d(A_1),\ d(A_2), ...,\ d(A_n)]^T \tag{10}$$

where, W is a nonfuzzy number.

Empirical example of pair-wise comparison for hierarchy dependency: Assume i =1~4 and j =1~4, to be able to evaluate the value of medical cosmetology product bundles, with the use of Step 1, the fuzzy synthetic degree values of all elements for the performance level can be calculated as shown below:

$$[\sum_{i=1}^{4}\sum_{j=1}^{4}\tilde{M}_{V_i}^{j}] = (1.00, 1.00, 3.00) + (0.43, 1.13, 1.89) + \times\times\times + (1.00, 1.00, 3.00)$$
$$= (17.10, 26.87, 46.84)$$

$$[\sum_{i=1}^{4}\sum_{j=1}^{4}\tilde{M}_{V_i}^{j}]^{-1} = (0.02, 0.04, 0.06)$$

$$\sum_{j=1}^{4}\tilde{M}_{g_i}^{j} = (1.00, 1.00, 3.00) + (0.43, 1.13, 1.89) + (0.73, 1.44, 3.00)$$
$$+ (2.33, 4.33, 6.33) = (4.50, 7.91, 14.22)$$

Hence, the fuzzy synthetic degree values of the element V1, D_{V1} can be calculated as follows:

$$D_{V1} = \sum_{j=1}^{4}\tilde{M}_{g_i}^{j} \otimes [\sum_{i=1}^{4}\sum_{j=1}^{4}\tilde{M}_{g_1}^{j}]^{-1} = (0.10, 0.29, 0.83)$$

Following a similar calculation, the fuzzy synthetic degree values of all elements for the category level of the hierarchy can be obtained as shown below:

- G: D_{V1}= (0.10, 0.29, 0.83)
- D_{V2}= (0.15, 0.41, 1.00)
- D_{V3}= (0.08, 0.24, 0.67)
- D_{V4}= (0.03, 0.06, 0.24)

Next, the following comparison results are derived based on step 2 in order lo calculate the weight vectors of the category level of the hierarchy:

$$V(D_{V1} \geq D_{V2}) = \frac{(0.15-0.83)}{(0.29-0.83)-(0.41-0.15)} = 0.86$$
$$V(D_{V1} \geq D_{V3}) = 1$$
$$V(D_{V1} \geq D_{V4}) = 1$$

$$V(D_{V2} \geq D_{V1}) = 1$$
$$V(D_{V2} \geq D_{V3}) = 1$$
$$V(D_{V2} \geq D_{V4}) = 1$$

$$V(D_{V3} \geq D_{V1}) = \frac{(0.10-0.67)}{(0.24-0.67)-(0.29-0.10)} = 0.91$$
$$V(D_{V3} \geq D_{V2}) = \frac{(0.15-0.67)}{(0.24-0.67)-(0.41-0.15)} = 0.75$$
$$V(D_{V3} \geq D_{V4}) = 1$$

$$V(D_{V4} \geq D_{V1}) = \frac{(0.10-0.24)}{(0.06-0.24)-(0.29-0.10)} = 0.38$$
$$V(D_{V4} \geq D_{V2}) = \frac{(0.15-0.24)}{(0.06-0.24)-(0.41-0.15)} = 0.20$$
$$V(D_{V4} \geq D_{V3}) = \frac{(0.08-0.24)}{(0.06-0.24)-(0.24-0.08)} = 0.47$$

Based on Step 3, the weight vector P of the performance level of the hierarchy can be calculated by using the following formula:

$$d(V1) = \min V(D_{V1} \geq D_{V2}, D_{V3}, D_{V4}) = \min\{0.86, 1, 1\} = 0.86,$$

$$d(V2) = \min V(D_{V2} \geq D_{V1}, D_{V3}, D_{V4}) = \min\{1, 1, 1\} = 1,$$

$$d(V3) = \min V(D_{V3} \geq D_{V1}, D_{V1}, D_{V4}) = \min\{0.91, 0.75, 1\} = 0.75,$$

$$d(V4) = \min V(D_{V4} \geq D_{V1}, D_{V2}, D_{V3}) = \min\{0.38, 0.20, 0.47\} = 0.20,$$

$$Wt = (d(V1), d(V2), d(V3), d(V4))^T = (0.86, 1.00, 0.75, 0.20).$$

After the normalization of Step 4, the normalized weight vectors of the performance level are as shown below:

$$G: (W_{V1}, W_{V2}, W_{V3}, W_{V4}) = (0.30, 0.36, 0.27, 0.07).$$

DISCUSSION

In the previous studies, most researchers has proposed decision making as the process of making an appropriate choice in order to realize one or more aims (Zanjani *et al*., 2009). Thus, multiple criteria decision making is used to balance the conflicts or tradeoff among different aims. There have been many studies on decision making algorithms and methods in recent years (Chen and Lee, 2003; Bharati and Chaudhury, 2004; Tasa and Whyte, 2005; Forgionnea and Newman, 2007; Hewahi, 2009; Dong *et al*., 2010; Hosseinpourtehrani and Ghahraman, 2011). The above mentioned researches have some general approaches that not only can support this study but also can be used to solve a multiple criteria decision making problem. The general approaches that used in these researches are multiple objectives decision making methods and multiple attributes decision making. The objectives are sometimes in conflict with one another, meaning an optimal solution of one objective does not meet the optimal solution of another. The planner should then make a compromise between the objectives to come up with the best solution. This gives rise to an infinite number of compromised solutions, usually called Pareto-optimum solutions (Opricovic and Tzeng, 2004). These types of models employ decision variables that are determined in a continuous domain with either an infinite or a large number of choices. The best decision is then made so as to satisfy the planner's preference information as well as the problem constraints and objectives (Lee *et al*., 2008).

In this study, by combing fuzzy set theory and extent analysis, an integrated decision making approach has developed and applied in evaluating medical cosmetology product bundles. In addition, it is an aid for manufactures and marketers to understand customers in making prudent decisions when the complexities make their decision task quite complicated. Besides, this decision making approach is capable of taking into consideration both qualitative and quantitative information. Furthermore, this decision making approach could also be used for evaluating the most valuable medical cosmetology product bundles to serve as a competitive forecast for marketers.

CONCLUSION

Concerning medical cosmetology product development, the efforts of manufacturers in bringing product attributes in line with customers' expectations is worthwhile. Marketers, moreover, should focus on customer preferences to plan the multiple consequences of the product bundle. Both manufacturers and marketers should not only utilize "price" as a main marketing strategy for medical cosmetology product bundles but also to deliver functional, symbolic and safety performance to consumers and enhance the value image in their minds.

In practice, medical cosmetology companies utilize direct mail, email and media as advertising tools to attract customers' attention. Through this communication process, manufacturers and marketers could understand customers' preferences and concerns and then help them purchase the medical cosmetology products they need to be able to satisfy their needs, wants and demands. Thus, manufacturers and marketers could focus on the product attributes that match customers' preferences and through advertisements appeal to customers.

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