FMCDM with Fuzzy DEMATEL Approach for Customers' Choice Behavior Model

Hsu Chen-Yi, Chen Ke-Ting, and Tzeng Gwo-Hshiung

Abstract

At present, there are many factors affecting customer's choice when they decide on what to buy in a fuzzy environment. In the current customer's market, everyone wants things that are affordable but of high quality. Taking this into consideration, it becomes very important for each business to make a competent marketing strategic decision. They must be aware of the customer's thoughts to expand their market share and outdo their competitors. Clearly, the market still has a lot of factors to consider. Therefore, the critical issue is to identify with the customer's thoughts and construct a Customer's Choice Behavior Model (CCBM) for solving this problem of Customer's Choice. In this paper, a framework that considers customer's choice behavior, applies the graph-theory-based fuzzy Decision Making Trial and Evaluation Laboratory (Fuzzy DEMATEL) approach combined with Fuzzy Multiple Criteria Decision Making (FMCDM) is proposed. First, fuzzy DEMATEL is used to find the key factors and attributes in building the structure relations of an ideal Customer's Choice Behavior. Then, FMCDM is demonstrated to evaluate whether the firm's performance and customer's satisfaction have differences or not. Empirical studies of Lexus and BMW are illustrated to show how well Lexus' sales is doing, whether or not they had satisfied Customers' needs, and determine the magnitude of the gap between them in order to correct this with the right strategy.

Keywords: Customer's market, Customers' Choice Behavior Model (CCBM), graph theory, Fuzzy DEMATEL, Fuzzy Multiple Criteria Decision Making (FMCDM).

1. Introduction

The environment becomes more complicated, so effective decision-making is more desired. In our life, we have to meet the complex and confusing situation everyday, thus making decisions are hard. We try to identify the causal or complex relationships of a problem, in order to make the appropriate solution when customers choosing or buying. The Decision Making Trial and Evaluation Laboratory (DEMATEL) method is presented in 1973 [11-14], [38], as a kind of structural modeling approach about a problem. It can clear see the cause-effect relationship of criteria when measuring a problem. Although this DEMATEL method is a good technique for evaluating problems and making decisions, we decide the relationships of systems are usually given by crisp values in establishing a structural model [9], [18], [20], [35]. However, in this real world, crisp values are inadequate to as clinical standard. Many evaluation criteria are surely imperfect [40-43]. They are probably uncertain factors, with the result that, these criteria cannot measure by crisp value [40-43]. Thus, we apply the concept of Fuzzy theory [40-43] to the DEMATEL method for solving multi-criteria decision-making problems. We propose the utilization of the fundamental principles encompassed in the fuzzy set theory to analyze and consider a multiplicity of complex criteria and determine the most suitable criteria in marketing strategic planning. The fundamental emphasis of the current Fuzzy Multiple Criteria Decision-Making (FMCDM) methodology [3], [6] is the determination, definition, testing and comparison of complex multi-level criteria used in the criteria selection process.

With this in mind, we provide a framework which considers both factors and applies the graph theory based on Fuzzy DEMATEL method combined with FMCDM approach; accurately aiming for a more useful way to solve customers purchasing-decision problems of automobile. Empirical studies of automobile modes (Lexus and BMW) in Taiwan are illustrated as our test case to demonstrate the proposed framework with regard to its usefulness and validity.

The rest of this paper is organized as follows. In Section 2, we will discuss the Customers' Choice Behavior Model (CCBM) of automobile. The methodology includes the Fuzzy DEMATEL with FMCDM approach of fuzzy environment is derived in Section 3. Empirical studies are presented to illustrate the procedure of the proposed method and to demonstrate its usefulness and validity in Section 4. Finally, based on

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the findings we make conclusions and suggestions are presented.

2. Customers' Choice Behavior Model

For evaluating and selecting the automobile, both suppliers' and customers' factors must be considered such as: purpose, technology, style, capacity, stable brand and range of capability. Thus, it can be seen that automobile evaluation and selection is a kind of Fuzzy Mu1tiple Criteria Decision Making [3], [6] problem. The behavior becomes one of the most important themes for companies to build marketing strategies in order to have its products contained in the choice set of customers [29].

The origin of the concept of the choice set is very old and was initially proposed in the 1960's. However, it also can be a new concept because as the number of brands increases and competition among brands intensifies, the concept of choice set has been reconsidered and studied again with much interest. Howard and Sheth [17] defined the choice set as the set of brands which is known and thought to be purchased by the customer. In 1996, Moriguchi proposed a customer's choice behavior model with a choice set based on the nested logit model [23]. In this model, if the number of alternatives used in the model increases, the number of combination patterns of choice sets also increases exponentially. On the other hand, Sakamaki proposed an improve model against Moriguchi's model [27], [28]. His model has the feature such that we categorize the alternatives, and analyze the effect of choice set only on category level. We cannot know the effect on the alternative level. Since Howard and Sheth [17] the customer's choice model with the choice set was studied within only one brand strategy in 1969. Those studies could be the turning point for researchers to reconsider the basic concept of the choice set.

Shocker *et al.* [30] who reviewed a lot of preceding studies of the choice set and played an important role as a pioneer in the recent study of the choice set, the choice set is composed of the alternatives that are remarkable or attainable on the particular choice occasion. By the way, the number of brands contained in the choice set generally depends upon each consumer and product category [24]. In the current market, with so many brands, it will become of great interest to marketing managers how to get the products of their company to be included in the choice set of consumers. To satisfy such business needs, in the preceding studies, researchers focused on the marketing variables that worked significantly when consumers made choice behavior.

In this paper we aim to build the Customers' Choice Behavior Model (CCBM) and provide it for businesses to make efficiently marketing strategies by Fuzzy DEMATEL combined with FMCDM. The effect of our study in the CCBM would reduce the gap between firms and customers, to create a win-win situation.

3. Fuzzy DEMATEL and FMCDM

This Section will divide into two Subsections to explain the methodologies used by the research. According to these research problems, the research will interpret the Fuzzy DEMATEL, and then FMCDM is illustrated.

The FMCDM [3], [6] methods to analyze this issue but the criteria for automobile will not always be completely independent. Also, the traditional concept of strategy lacked multi-dimensional interaction. Since many traditional MCDM methods are based on the additive concept along with the independence assumption [44], the research decided to use the Fuzzy DEMATEL approach to solve this problem. Several previously proposed MCDM methods of evaluation are very useful but they have generally considered only independent during selection or evaluation criteria. This paper believes that automobile evaluation and selection are influenced by multiple factors from both supplier and customer aspects. The graph theory has a greater advantage with regards to various areas because it enables us to project and solve problems visually. The Fuzzy DEMATEL approach is based on graph theory. In this paper, the Fuzzy DEMATEL method is used to build the relative relationship of decision factors for customer purchasing behavior. The relationships support a multi-level viewpoint for marketing strategic planning.

3.1 Fuzzy DEMATEL

The matrices or digraph portrays a contextual relation between the elements of the system, in which a numeral represents the strength of influence. Hence, the Fuzzy DEMATEL method can convert the relationship between the causes and effects of criteria into an intelligible structural model of the system. The Fuzzy DEMATEL method has been successfully applied in many fields. For examples, Tamura *et al.* [31] used the Fuzzy DEMATEL method to extract various uneasy factors in the life, Yamazaki *et al.* [39] analyzed the obstructive factors of welfare service with the Fuzzy DEMATEL method, Hori and Shimizu [16] employed the Fuzzy DEMATEL method to design and evaluate the software of displaying-screen structure in analyzing a supervisory control system.

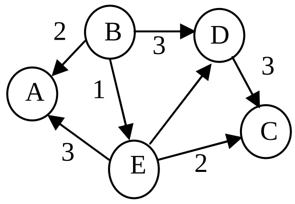

Figure 3.1: The digraph of the Fuzzy DEMATEL (example)

STEP 1: Defining the evaluation criteria and design the fuzzy linguistic scale

It is necessary to establish sets of criteria for evaluation. However, evaluation criteria have the nature of causal relationships and usually comprise many complicated aspects. To gain a structural model dividing involved criteria into cause and effect groups, the Fuzzy DEMATEL method is an appropriate technique. To deal with the ambiguities of human assessments, the research discard the comparison scale used in crisp DEMATEL method but adopt the fuzzy linguistic scale used in the group decision-making proposed by Li [19].

Table 3.1: The correspondence of linguistic terms and linguistic values (example)

Linguistic terms	*Linguistic values*
No influence (N): 1	(0, 0, 0.25)
Low influence (L): 2	(0, 0.25, 0.5)
High influence (H): 3	(0.25, 0.5, 0.75)
Strongly influence (S): 4	(0.5, 0.75, 1.0)

That is the different degrees of "influence" are expressed with five linguistic terms as "Strong", "High", "Low", "No" and their corresponding positive triangular fuzzy numbers are shown in Table 1.

STEP 2: Establishing the directed-relation matrix

To measure the relationship between criteria $C=\{C_i \mid i=1,2,...,n\}$, a decision group of p experts were asked to make sets of pair-wise comparisons in terms of linguistic terms. Hence, p fuzzy matrices $\tilde{Z}^1,\tilde{Z}^2,\cdots,\tilde{Z}^p$ each corresponding to an expert and with triangular fuzzy numbers as its elements, were obtained. Fuzzy matrix $\tilde{\boldsymbol{Z}}$ is called the initial direct-relation fuzzy matrix. For simplicity, denote $\tilde{\boldsymbol{Z}}$ as

$$\tilde{\boldsymbol{Z}}=\begin{array}{c} \\ C_1 \\ C_2 \\ \vdots \\ C_n \end{array}\begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} 0 & \tilde{z}_{12} & \cdots & \tilde{z}_{1n} \\ \tilde{z}_{21} & 0 & \cdots & \tilde{z}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{z}_{n1} & \tilde{z}_{n2} & \cdots & 0 \end{bmatrix} \end{array} \quad (1)$$

where $\tilde{z}_{ij}=\left(l_{ij,}m_{ij,}r_{ij}\right)$ are triangular fuzzy numbers, elements $\tilde{z}_{ii}$, $i=1,2,\ldots,n$, it will be regarded as a triangular fuzzy number (0, 0, 0), whenever it is necessary.

STEP 3: Establishing and analyzing the structural model

The linear scale transformation is used here as a normalization formula to transform the criteria scales into comparable scales. Let

$$\tilde{a}_{ij}=\sum_{j=1}^{n}\tilde{z}_{ij}=\left(\sum_{j=1}^{n}l_{ij},\sum_{j=1}^{n}m_{ij},\sum_{j=1}^{n}r_{ij}\right) \text{ and } r=\max_{1\le i\le n}\left(\sum_{j=1}^{n}r_{ij}\right) \quad (2)$$

Then, the normalized direct-relation fuzzy matrix, denoted by $\boldsymbol{X}$, equals

$\tilde{\boldsymbol{X}}=r^{-1}\otimes\tilde{\boldsymbol{Z}}$ then

$$\tilde{\boldsymbol{X}}=\begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix}, \text{where } \tilde{x}_{ij}=\frac{\tilde{z}_{ij}}{r}=\left(\frac{l_{ij}}{r},\frac{m_{ij}}{r},\frac{r_{ij}}{r}\right) \quad (3)$$

As that in crisp DEMATEL method, we assume at least one i such that $\sum_{j=1}^{n}r_{ij}<r$ and $\lim_{k\to\infty}\tilde{\boldsymbol{X}}^k=[0]_{n\times n}$. This assumption is well satisfied in practical cases.

STEP 4: The total-relation matrix

Once the normalized directed-relation matrix into degree matrix $\tilde{\boldsymbol{X}}$ is obtained, the total-relation matrix $\tilde{\boldsymbol{T}}$ can be acquired by using the following equation.

$$\begin{aligned} \tilde{\boldsymbol{T}} &= \tilde{\boldsymbol{X}}+\tilde{\boldsymbol{X}}^2+\cdots+\tilde{\boldsymbol{X}}^k \\ &= \tilde{\boldsymbol{X}}(\boldsymbol{I}+\tilde{\boldsymbol{X}}+\tilde{\boldsymbol{X}}^2+\cdots+\tilde{\boldsymbol{X}}^{k-1}) \\ &= \tilde{\boldsymbol{X}}(\boldsymbol{I}+\tilde{\boldsymbol{X}}+\tilde{\boldsymbol{X}}^2+\cdots+\tilde{\boldsymbol{X}}^{k-1})(\boldsymbol{I}-\tilde{\boldsymbol{X}})(\boldsymbol{I}-\tilde{\boldsymbol{X}})^{-1} \\ &= \tilde{\boldsymbol{X}}(\boldsymbol{I}-\tilde{\boldsymbol{X}})^{-1}, \ when \ \lim_{k\to\infty}\tilde{\boldsymbol{X}}^k=[0]_{n\times n} \end{aligned}$$

$$\tilde{\boldsymbol{T}}=\begin{bmatrix} \tilde{t}_{11} & \tilde{t}_{12} & \cdots & \tilde{t}_{1n} \\ \tilde{t}_{21} & \tilde{t}_{22} & \cdots & \tilde{t}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{t}_{m1} & \tilde{t}_{m2} & \cdots & \tilde{t}_{mn} \end{bmatrix}; \ where \ \tilde{t}_{ij}=\left(l_{ij}^{"},m_{ij}^{"},r_{ij}^{"}\right) \quad (4)$$

$$\left[l_{ij}^{"}\right]=\boldsymbol{X}_l\times(\boldsymbol{I}-\boldsymbol{X}_l)^{-1}$$

$$\left[m_{ij}^{"}\right]=\boldsymbol{X}_m\times(\boldsymbol{I}-\boldsymbol{X}_m)^{-1}$$

$$\left[r_{ij}^{"}\right]=\boldsymbol{X}_r\times(\boldsymbol{I}-\boldsymbol{X}_r)^{-1}$$

STEP 5: The sum of rows and columns

The sum of rows and the sum of columns are separately denoted as d and r within the total-relation matrix $\boldsymbol{T}$ through the following equations.

$\tilde{\boldsymbol{T}}=\left[\tilde{t}_{ij}\right],\ i,\ j\in\{1,2,\ldots,n\}$

$$\tilde{\boldsymbol{d}}=(\tilde{d}_i)_{n\times1}=[\sum_{j=1}^{n}\tilde{t}_{ij}]_{n\times1},\quad \tilde{\boldsymbol{r}}=(\tilde{r}_j)'_{1\times n}=[\sum_{i=1}^{n}\tilde{t}_{ij}]'_{1\times n} \quad (5)$$

STEP 6: Analyzing the results

Suppose $\tilde{d}_i$ denotes the row sum of $i-th$ row of matrix $\tilde{\boldsymbol{T}}$; then, $\tilde{d}_i$ shows the sum of influence dispatching from factor i to the other factors both directly and indirectly. Suppose $\tilde{d}_i$ denotes the column sum of $j-th$ column of matrix $\tilde{\boldsymbol{T}}$. Then, $\tilde{r}_i$ shows the sum of influence that factor i is receiving from the other factors.

Furthermore, when $i = j$, it means the sum of row sum and column sum $\left(\tilde{d}_i + \tilde{r}_j = \tilde{d}_i + \tilde{r}_i\right)$ shows the index of representing the strength of influence both dispatching and receiving, that is, $\left(\tilde{d}_i - \tilde{r}_j = \tilde{d}_i - \tilde{r}_i\right)$ shows the degree of central role that the factor i plays in the problem. If $\left(\tilde{d}_i - \tilde{r}_j = \tilde{d}_i - \tilde{r}_i\right)$ is positive, then the factor i is rather dispatching the influence to the other factors, and if $\left(\tilde{d}_i - \tilde{r}_j = \tilde{d}_i - \tilde{r}_i\right)$ is negative, then the factor i is rather receiving the influence from the other factors [9], [18], [20], [31], [35].

3.2 FMCDM

To evaluate building the customers' choice behavior model (CCBM) is a complex and wide-ranging problem, so this problem requires the most inclusive and flexible method. Since the AHP [25] developed by Saaty is a very useful decision analysis tool in dealing with multiple criteria decision problem, and has successfully been applied to many construction industry decision areas [7], [8], [10], [15], [21], [22]. However, in operation process of applying AHP method, it is more easy and humanistic for evaluators. Hence, Buckley [4] extended AHP to the case where the evaluators are allowed to employ fuzzy ratios in place of exact ratios to handle the difficulty for people to assign exact ratios when comparing two criteria and derive the fuzzy weights of criteria by geometric mean method [37].

Fuzzy FMCDM analysis has been widely used to deal with decision-making problems involving multiple criteria evaluation of alternatives. The practical applications reported in the literature [1], [2], [5], [22], [32-34], [36] have shown advantages in handling unquantifiable or qualitative criteria and obtained quite reliable results. Thus, this paper applied fuzzy set theory to managerial decision-making problem of alternative selection [40-43], with the intention of drawing a relationships diagram of incorporating Fuzzy DEMATEL and FMCDM (including FAHP and FANP), in order to find key success factors, to build a customers' choice behavior model (CCBM), and then to help a manager make efficient marketing strategic planning for the automobile market.

The tools and formulas employed are:

(1) Triangular fuzzy numbers and linguistic values characterized by triangular fuzzy numbers which are used to evaluate the preference rating system;

(2) The method of graded mean integration, and the FAHP, FANP weighting methods which are jointly used to adjust integration weights of all sub-criteria above those of the alternatives;

(3) The concepts of ideal and anti-ideal solutions which are employed to calculate the relative closeness of the various alternatives versus ideal solutions to rank their priorities, and finally, to determine the best alternative.

We use this method to determine the evaluation criteria weights and to evaluate the automobile mode (Lexus) performance and rank the priority for them accordingly. After drawing a relationships diagram by Fuzzy DEMATEL, we use the FAHP [4], [25], [44] or FANP [26] to determine the criteria weights. Furthermore, the FMCDM was used to evaluate the synthetic performance of the automobile mode (Lexus), and then compare the performance with their real sales volume, in order to justify the key success factors found are credible, further to sketch the marketing strategic planning. To handle qualitative criteria those are difficult to describe in crisp values. Thus strengthen the comprehensiveness and reasonableness of the customers' decision-making process.

4. Empirical Studies of Customers' Choice Behavior Model

Based on the problems and purposes of this study, this section includes that the analysis of customers' choice behaviors and the measurement of the relationships among customer decision criteria. We use this framework to find the key criteria for illustrating the modes of purchasing automobile based on customers' choice behaviors. And we take the high-class automobile modes (Lexus and BMW) made in Taiwan as a test example or case to demonstrate the proposed framework with regard to its usefulness and validity.

Through the literature reviews, experts' discussion, brain storming, and interview with salesmen, we find the considered dimensions and criteria when customers purchase Lexus. It includes six dimensions and eighteen criteria. The dimensions are equipment factors, technological factors, brand factors, price factors, sense perceptions, and service factors. The criteria include safety devices, interior equipment, exterior equipment, theft-proof devices, intelligent communication system, global positioning system, extra equipment, public praise, popularity, image, price, terms of payment, car space, style appearance, comfortableness, fashion style, maintenance points, and maintenance cost. They are illustrated in Table 4.1 and Table 4.2.

Table 4.1: Considered dimensions of purchasing high-class automobiles

No.	***Dimensions***
D_1	Equipment Factors
D_2	Technological Factors
D_3	Brand Factors
D_4	Price Factors
D_5	Sense Perceptions
D_6	Service Factors

Table 4.2: Considered decision criteria of purchasing high-class automobiles

No.	***Customer Decision Criteria***
C_1	Safety devices
C_2	Interior equipment
C_3	Exterior equipment
C_4	Theft-proof devices
C_5	Intelligent communication system
C_6	Global Positioning System
C_7	Extra equipment
C_8	Public praise
C_9	Popularity
C_{10}	Image
C_{11}	Price
C_{12}	Terms of payment
C_{13}	Car space
C_{14}	Style appearance
C_{15}	Comfortableness
C_{16}	Fashion style
C_{17}	Maintenance points
C_{18}	Maintenance cost

4.1 Analysis of results

The traditional concepts of setting strategies lacked consideration in interactions of multi- dimensions. Aside from this, they should also consider the interactive relationships among these criteria. In the real world, the independence of the dimensions and criteria does not exist. It is important to find not only the key success factors but also to evaluate the relationships among these criteria. Strategy is an interactive decision-making process and is influenced by many factors. We understand the thinking of customers by Fuzzy DEMATEL approach to discuss the customer customers' choice behaviors in automobile market and how the firms use this information to make management strategy, to earn more benefit to them and to the customers. Thus key success factors are important to marketing managers and customers at the same time. According to the formula of Fuzzy DEMATEL, we find the influence value of dimensions and criteria; they show as Table 4.3 and Table 4.4.

Table 4.3: The total direct-relation matrix $\tilde{T}$ of six dimensions

	D_1	D_2	D_3	D_4	D_5	D_6
D_1	1.115	1.160	1.162	1.316	1.012	1.018
D_2	1.201	0.905	1.053	1.198	0.943	0.926
D_3	1.101	0.952	0.830	1.084	0.837	0.840
D_4	1.234	1.073	1.072	1.040	0.945	0.970
D_5	0.964	0.856	0.860	0.953	0.669	0.805
D_6	0.972	0.864	0.872	0.998	0.778	0.687

Note: threshold value of average: 0.980

Based on the Step 4 and Step 5 of Fuzzy DEMATEL approach, a causal diagram is created. The features of decision criteria are visualized as oriented graphs. This study uses the threshold value (p) to obtain the total relationship follow different matrix. It is the most appropriate value to acquire a suitable relationship. Using the threshold values of dimensions (0.980) and criteria (0.371), we illustrate the diagram of the total relation of dimensions and criteria as shown in Figure 4.1 and Figure 4.2.

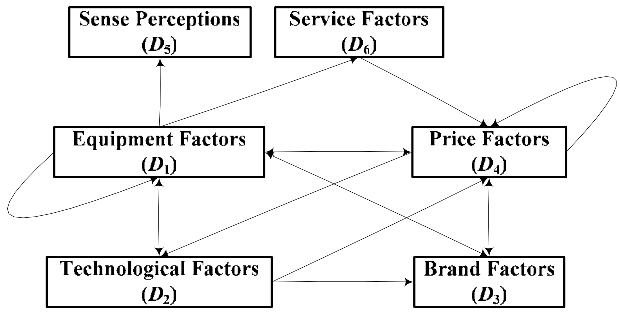

Figure 4.1: The impact-digraph-map of dimensions

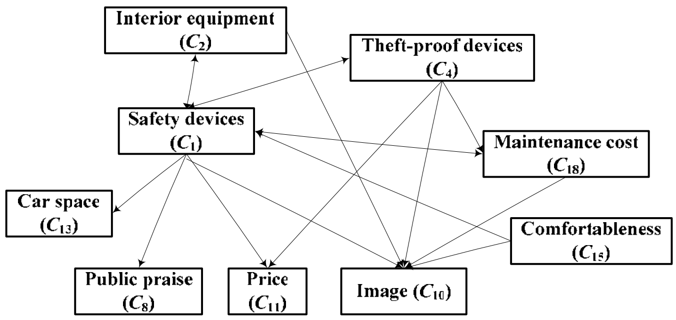

Figure 4.2: The impact-digraph-map of criteria

Table 4.4: The total direct-relation matrix $\tilde{\boldsymbol{T}}$ of eighteen criteria

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}
C_1	0.348	0.386	0.355	0.410	0.339	0.349	0.319	0.378	0.364	0.377	0.387	0.362	0.381	0.335	0.348	0.309	0.370	0.388
C_2	0.380	0.295	0.318	0.370	0.313	0.316	0.284	0.337	0.319	0.383	0.322	0.323	0.345	0.308	0.320	0.291	0.341	0.361
C_3	0.361	0.323	0.255	0.347	0.287	0.297	0.267	0.320	0.304	0.366	0.330	0.284	0.328	0.294	0.309	0.271	0.323	0.339
C_4	0.402	0.361	0.331	0.322	0.321	0.337	0.304	0.349	0.336	0.402	0.372	0.343	0.327	0.320	0.342	0.301	0.357	0.377
C_5	0.304	0.279	0.258	0.291	0.221	0.273	0.239	0.272	0.258	0.306	0.288	0.255	0.280	0.245	0.265	0.241	0.279	0.289
C_6	0.303	0.279	0.260	0.305	0.256	0.232	0.236	0.269	0.257	0.307	0.281	0.258	0.286	0.265	0.256	0.246	0.280	0.297
C_7	0.301	0.278	0.248	0.287	0.256	0.268	0.199	0.262	0.254	0.299	0.275	0.255	0.275	0.250	0.251	0.225	0.261	0.280
C_8	0.364	0.335	0.308	0.352	0.297	0.309	0.271	0.273	0.297	0.369	0.334	0.309	0.328	0.293	0.300	0.267	0.296	0.334
C_9	0.342	0.316	0.293	0.335	0.283	0.296	0.258	0.308	0.251	0.354	0.316	0.293	0.314	0.277	0.285	0.256	0.296	0.302
C_{10}	0.347	0.352	0.314	0.366	0.323	0.341	0.295	0.343	0.332	0.324	0.361	0.314	0.332	0.318	0.351	0.286	0.330	0.365
C_{11}	0.384	0.324	0.320	0.358	0.318	0.327	0.288	0.329	0.330	0.382	0.300	0.335	0.344	0.319	0.347	0.291	0.337	0.375
C_{12}	0.311	0.307	0.259	0.307	0.270	0.282	0.246	0.290	0.281	0.326	0.310	0.238	0.288	0.271	0.289	0.257	0.289	0.317
C_{13}	0.333	0.314	0.278	0.304	0.278	0.308	0.261	0.301	0.291	0.340	0.313	0.290	0.263	0.290	0.311	0.267	0.301	0.329
C_{14}	0.344	0.318	0.284	0.334	0.273	0.311	0.274	0.315	0.306	0.349	0.322	0.289	0.303	0.248	0.303	0.271	0.306	0.335
C_{15}	0.379	0.347	0.301	0.363	0.303	0.300	0.279	0.328	0.319	0.376	0.341	0.313	0.343	0.315	0.275	0.280	0.322	0.354
C_{16}	0.317	0.294	0.267	0.306	0.274	0.281	0.235	0.285	0.280	0.310	0.292	0.269	0.280	0.273	0.273	0.211	0.274	0.300
C_{17}	0.331	0.311	0.280	0.317	0.279	0.290	0.252	0.282	0.289	0.340	0.306	0.287	0.302	0.290	0.298	0.262	0.254	0.331
C_{18}	0.373	0.351	0.316	0.358	0.318	0.325	0.282	0.346	0.299	0.374	0.350	0.319	0.331	0.316	0.329	0.290	0.331	0.304

Note: threshold value of quartile: 0.371

In Figure 4.1, it can be seen that evaluation dimensions have interaction and feedback relationships; they are not independent and have difference with the assumptions of independent structure. Thus we obtain the weights of evaluation dimensions by concept of FANP. We use the total direct-relation matrix $\tilde{\boldsymbol{T}}$ of evaluation dimensions to get weights. Because the total direct-relation matrix $\tilde{\boldsymbol{T}}$ is a geometric series, once it reaches the limit, the influence degree will be stable, which then generates a stable result. This idea is used because of its similarity to FANP method; the steady-state priority of fuzzy weighted super-matrix is surely convergent and rational thus attaining a stable result. The weights of evaluation dimensions for FANP methods are shown in Table 4.5.

Table 4.5: The weights of dimensions of FANP methods

Dimensions	Weights
Equipment Factors	0.1870 (0.1804, 0.1871, 0.2096)
Technological Factors	0.1650 (0.1660, 0.1661, 0.1602)
Brand Factors	0.1657 (0.1576, 0.1648, 0.1685)
Price Factors	0.1867 (0.1757, 0.1912, 0.2159)
Sense Perceptions	0.1469 (0.1292, 0.1432, 0.1538)
Service Factors	0.1488 (0.1274, 0.1477, 0.1556)

The weights of evaluation dimensions are different from the weights of independent structure. These values obtained are lower but more accurate because these include three weighted conditions: independent, dependent, and interaction. Then we rank each alternative by SAW method which is illustrated in Table 4.6.

Table 4.6: The performance value of each alternative

Dimensions	*Weights*	*Lexus*	*BMW*
Equipment Factors	0.1870	68.8294	40.6604
Technological Factors	0.1650	76.8837	78.9087
Brand Factors	0.1657	79.5657	76.1004
Price Factors	0.1867	85.5464	84.3593
Sense Perceptions	0.1469	70.7006	68.0067
Service Factors	0.1488	67.0631	67.4452
Sales Quantity		*6,541*	*5,520*
Performance Value		0.3640 (1)	0.3218 (2)

On the other hand, it can be seen that evaluation criteria have interaction relationships in Figure 4.2: they are not fully independent. Thus we first obtain the weights of evaluation criteria by FAHP (as Table 4.7).

Table 4.7: The weights of evaluation items for FAHP methods

Dimensions/Criteria	**Weights**		**Total Weights**	
Equipment Factors	0.2431 (1)	(0.2268, 0.2343, 0.2391)		
Safety devices	0.2657	(0.2560, 0.2595, 0.2707)	0.0646 (1)	(0.0581, 0.0608, 0.0647)
Interior equipment	0.2453	(0.2491, 0.2467, 0.2403)	0.0596 (6)	(0.0565, 0.0578, 0.0575)
Exterior equipment	0.2276	(0.2401, 0.2364, 0.2317)	0.0553 (12)	(0.0545, 0.0554, 0.0554)
Theft-proof devices	0.2614	(0.2548, 0.2575, 0.2573)	0.0635 (2)	(0.0578, 0.0603, 0.0615)
Technological Factors	0.1335 (4)	(0.1443, 0.1517, 0.1591)		
Intelligent communication system	0.3439	(0.3390, 0.3378, 0.3355)	0.0459 (17)	(0.0489, 0.0512, 0.0534)
Global Positioning System	0.3462	(0.3414, 0.3367, 0.3355)	0.0462 (16)	(0.0493, 0.0511, 0.0534)
Extra equipment	0.3099	(0.3196, 0.3255, 0.3291)	0.0414 (18)	(0.0461, 0.0494, 0.0523)
Brand Factors	0.1750 (3)	(0.1679, 0.1697, 0.1728)		
Public praise	0.3280	(0.3323, 0.3290, 0.3243)	0.0574 (9)	(0.0558, 0.0559, 0.0560)
Popularity	0.3187	(0.3268, 0.3251, 0.3208)	0.0558 (11)	(0.0549, 0.0552, 0.0554)
Image	0.3533	(0.3408, 0.3459, 0.3549)	0.0618 (3)	(0.0572, 0.0587, 0.0613)
Price Factors	0.1124 (6)	(0.1094, 0.1110, 0.1152)		
Price	0.5456	(0.5209, 0.5263, 0.5296)	0.0613 (4)	(0.0570, 0.0584, 0.0610)
Terms of payment	0.4544	(0.4791, 0.4737, 0.4704)	0.0511 (14)	(0.0524, 0.0526, 0.0542)
Sense Perceptions	0.2219 (2)	(0.2185, 0.2202, 0.2230)		
Car space	0.2532	(0.2524, 0.2509, 0.2491)	0.0562 (10)	(0.0552, 0.0553, 0.0555)
Style appearance	0.2587	(0.2561, 0.2525, 0.2498)	0.0574 (8)	(0.0560, 0.0556, 0.0557)
Comfortableness	0.2676	(0.2582, 0.2604, 0.2595)	0.0594 (7)	(0.0564, 0.0573, 0.0579)
Fashion style	0.2204	(0.2332, 0.2362, 0.2417)	0.0489 (15)	(0.0510, 0.0520, 0.0539)
Service Factors	0.1141 (5)	(0.1102, 0.1128, 0.1138)		
Maintenance points	0.4671	(0.4836, 0.4818, 0.4836)	0.0533 (13)	(0.0533, 0.0544, 0.0551)
Maintenance cost	0.5329	(0.5164, 0.5182, 0.5164)	0.0608 (5)	(0.0569, 0.0585, 0.0588)

These evaluation criteria are independent and interaction, we use the FAHP weights to obtain the weights of key evaluation criteria by FANP method according to Figure 4.4. Because the weights of FAHP include the concept of independence, thus interacts with the FANP method to attain the weights of key evaluation criteria. The weights of evaluation criteria for FANP methods are shown in Table 4.8.

Table 4.8: The weights of key criteria for FANP methods

Key Criteria	*Weights*	
Safety devices	0.1179 (2)	(0.1210, 0.1163, 0.1177)
Interior equipment	0.1092 (6)	(0.1070, 0.1099, 0.1097)
Theft-proof devices	0.1141 (3	(0.1115, 0.1160, 0.1176)
Public praise	0.1063 (8)	(0.0987, 0.1042, 0.1105)
Image	0.1184 (1)	(0.1127, 0.1217, 0.1282)
Price	0.1097 (5)	(0.1090, 0.1090, 0.1105)
Car space	0.1065 (7)	(0.0987, 0.1047, 0.1104)
Comfortableness	0.1043 (9)	(0.1028, 0.1035, 0.1056)
Maintenance cost	0.1135 (4)	(0.1114, 0.1148, 0.1170)

The weights of evaluation criteria in these situations are different from the weights of independent structure. These values obtained are more accurate in the real world since these include two weighted conditions: independent and interaction. Then we rank each alternative by SAW method which is illustrated in Table 4.8. In Table 4.9, there is little difference in each alternative. At the same time, the performance value of Lexus mode is number one but it needs to improve to raise its performance value. In all evaluation dimension and criteria, Lexus ranks the number one high-class automobile in the customer's mind. It is a fact the Lexus sold the highest quantity (6,541 vehicles) in 2005. But the two high-class automobile modes (Lexus and BMW) need to improve its product to get higher performance values.

Table 4.9: The performance value of each alternative

Key Criteria	*Weights*	*Lexus*	*BMW*
Safety devices	0.1179	51.7942	47.5974
Interior equipment	0.1092	76.8837	78.9087
Theft-proof devices	0.1141	84.3593	84.3593
Public praise	0.1063	78.9087	75.6692
Image	0.1184	56.8471	59.1653
Price	0.1097	80.6853	75.6692
Car space	0.1065	67.0631	66.1325
Comfortableness	0.1043	81.8206	79.5657
Maintenance cost	0.1135	76.1004	75.0444
Sales Quantity in 2005		*6,541*	*5,520*
Performance Value		0.3414 (1)	0.3344 (2)

According to the results of empirical studies, we find the independent structure having errors. It lacks the consideration of multi-dimensional and multi- criteria. However, the non-independent structure considers multi-dimensional and multi-criteria, the results of empirical studies are also similar to the real conditions. The results of non-independent structure are more acceptable in the real world. Thus we will build a key success Customers' Choice Behavior Model (CCBM) based on the non-independent structure.

4.2 Discussions

In Figure 4.1, we can see more clearly that these dimensions- equipment factors (D_1), technological factors (D_2), brand factors (D_3), price factors (D_4), sense perceptions (D_5), and service factors (D_6) are not independent. In the past, it assumes that dimensions are independent. However, we prove that they have relationships (as Figure 4.1 shows).

In Figure 4.1, the equipment factors (D_1) is affecting other dimensions- technological factors (D_2), brand factors (D_3), price factors (D_4), sense perceptions (D_5), and service factors (D_6); visibly showing that the equipment factors (D_1) plays an important role in dimensions. In other words, any one of dimensions has to been developed based on the equipment factors (D_1). At the same time, the equipment factors (D_1) is also influenced by three dimensions: technological factors (D_2), brand factors (D_3), price factors (D_4). We divide dimensions into six parts. These six parts have three dimensions relating with the equipment factors (D_1). Furthermore, the equipment factors (D_1) may affect itself, showing that the equipment factors (D_1) is quite important. The criteria of the dimension for equipment factors (D_1) must have complex relationships. Later, we will illustrate in a more detailed matter. The technological product has to connect with the equipment, brand, and price. The good technological product needs to have a well-known brand, so it can give reassurance for customers to purchase. By the same token, the price has to be reasonable as well. Therefore, they have certain relationships among new technological product, equipment, brand, and price. We also shows that the technological factors (D_2) affects equipment factors (D_1), brand factors (D_3), and price factors (D_4) in Figure 4.1, and it is also influenced by equipment factors (D_1) and price factors (D_4).

People often consider the brand while purchasing. It is evident to see the importance of brand. It means that branded equipments can attract more customers. We show that the equipment factors (D_1), technological factors (D_2), and price factors (D_4) influences the brand factors (D_3), which affects equipment factors (D_1), and price factors (D_4) in Figure 4.1. Evidently, the brand is related to the price. Customers must pay higher cost to acquire famous-branded products. The price factors (D_4) dispatches the four dimensions, equipment factors (D_1), technological factors (D_2), brand factors (D_3), and price factors (D_4). Additionally, the price factors (D_4) is influenced by equipment factors (D_1), new technological factors (D_2), brand factors (D_3), price factors (D_4), and service factors (D_6). The price factors (D_4) is another important role in the dimensions, having a situation similar with the equipment factors (D_1) -having feedback. Dimensions in them affect them. In the high-class automobile case, the sense perceptions (D_5) are other considered-dimensions to customers. The vehicle space for high-class automobile truly affects the customers' sensation. Since the vehicle space is a kind of equipment, the sense perceptions and equipment are related. People who regard themselves as elites usually buy a high-class automobile to look stylish. Therefore, we show that the sense perceptions (D_5) are influenced by equipment factors (D_1). Service is important to customers. During the recent years, customers consider more and more the after-sales service. In the last dimension, we would discuss the service factors (D_6), and how it influences the others. We show that the equipment factors (D_1) influences the service factors (D_6), which affect the price factors (D_4).

After analyzing the dimensions, we would illustrate the considered-criteria in each dimension. According to the results, we illustrate the impact-digraph-map of criteria in Figure 4.2. It is more visible hat these criteria- safety devices (C_1), interior equipment (C_2), theft-proof devices (C_4), public praise (C8), image (C_{10}), price (C_{11}), car space (C_{13}), comfortableness (C_{15}), and maintenance cost (C_{18}) are key criteria. That means customers consider these nine criteria while purchasing high-class automobile.

In customer-considered criteria aspect (as Figure 4.2), "safety devices (C_1)" is a very powerful criteria affecting other factors. "Image (C_{10})" is the criteria that is intensely affected by the others. Because of their value $\left(d_i + r_j = d_i + r_i\right)$ and the value $\left(d_i - r_j = d_i - r_i\right)$ is very significant, the $d_i + r_j \left(= d_i + r_i\right)$ value of safety devices (C_1) is 15.507 and the $d_i - r_j \left(= d_i - r_i\right)$ value of image (C_{10}) is -0.830.

Besides safety devices (C_1) and Image (C_{10}), we also find the other main criteria in view of the causal diagram of total relation. There are interior equipment (C_2), theft-proof devices (C_4), public praise (C_8), price (C_{11}), car space (C_{13}), comfortableness (C_{15}), and maintenance cost (C_{18}). Thus, the CCBM is produced composing of these nine key criteria. Managers have to pay attention to these nine key criteria. In Figure 4.2, it shows that the "safety devices (C_1)" is a key and powerful factor that plays an important role; the "safety devices (C_1)" dispatches many criteria. The "safety devices (C_1)" would affect the interior equipment (C_2), theft-proof devices (C_4), public praise (C_8), image (C_{10}), price (C_{11}), car space (C_{13}), and maintenance cost (C_{18}); the criteria (C_1), (C_2), (C_4), and (C_{18}) have an interaction. Its effect, having multi-criteria considerations, is important. Generally, customers usually consider multi-criteria while making purchasing decisions. It shows safety devices (C_1), interior equipment (C_2), theft-proof devices (C_4), and maintenance cost (C_{18}) could have a reciprocal effect.

These findings are important to managers. If these four criteria are good, then the dimensions of "equipment factors (D_1)" and "service factors (D_6)" can be considered to be good. For this reason, these four criteria are the bases on how to develop the whole CCBM. The "theft-proof devices (C_4)" is also developed, based upon safety devices (C_1), image (C_{10}), price (C_{11}), and maintenance cost (C_{18}). Based on these results, it is necessary to establish good equipment to combine price with high-class automobile and to develop a good management model. Many people want to have a better thing rather than a cheaper price. Hence, the dimension of equipment factors (D_1) and the dimension of price factors (D_4) are deeply related. Furthermore, the "interior equipment (C_2)" is influenced by safety devices (C_1), it can be seen that the safety devices (C_1), interior equipment (C_2), and theft-proof devices ($C4$) are quite critical in eighteen criteria. These three criteria- safety devices (C_1), interior equipment (C_2), and theft-proof devices (C_4) are included in the dimension of equipment factors (D_1); the equipment factors (D_1) will be the core to develop the other dimensions. As far as the brand factors (D_3) is concerned; it is a powerful dimension. The "public praise (C_8)" and "image (C_{10})" is significant in the dimension of brand factors (D_3). The "public praise (C_8)" is influenced by the safety devices ($C1$). On the other hand, "image (C_{10})" is negatively influenced by the other criteria, because the value of $\left(d_i - r_j = d_i - r_i\right)$ is negative and it is also significant. The image (C_{10}) affects the attraction for customers in safety devices (C_1), interior equipment (C_2), theft-proof devices (C_4), comfortableness (C_{15}), and maintenance cost (C_{18}). Furthermore, the image (C_{10}) increases trust in the high-class automobile and discourages fraudulent of the customers. The "price (C_{11})" is special characteristics of high-class automobile. Customers generally want to maximize their utility and minimize the price they have to pay for it. We have shown that the "price (C_{11})" is important to customers. If the price of the high-class automobile is low and the safety devices (C_1) and theft-proof devices (C_4) are good, the customers are more likely to purchase the high-class automobile. Thus, the pricing strategy is successful. We show that the "price (C_{11})" is influenced by the safety devices (C_1) and theft-proof devices (C_4).

In Figure 4.1, the dimension of sense perceptions (D_5) is also weakly important. In the sense perceptions (D_5), there are car space (C_{13}), style appearance (C_{14}), and comfortableness (C_{15}). The $d_i + r_j\left(= d_i + r_i\right)$ value and $d_i - r_j\left(= d_i - r_i\right)$ value of style appearance (C_{14}) is not significant; we skip it. The "car space (C_{13})" is influenced by safety devices (C_1), and the "comfortableness (C_{15})" affects the safety devices (C_1) and image (C_{10}). These two are the most important criteria for customers. The safety devices (C_1) and theft-proof devices (C_4) influence the "maintenance cost (C_{18})", which affects the safety devices (C_1) and image (C_{10}).

Realizing the relationships of dimensions and criteria, and understanding which dimension is the key status, which criterion is an important role, the CCBM of high-class automobile market is proposed through our study. Managers have to know what the CCBM of high-class automobile market is, so that firms can make right marketing strategies to increase their market share.

5. Conclusions

The Decision Making Trial and Evaluation Laboratory approach (DEMATEL) is proposed in 1973. Fuzzy theory is presented in 1965. These two were the approaches to access the high-class automobile market. The evaluated criteria are uncertain in the real world; previous studies lack this consideration of multi- dimensions or multi-criteria. Due to the precious studies' deficiency, an approach of combining the DEMATEL method and fuzzy theory is introduced. In order for a company to verify management strategies and satisfy customer's needs, we identify the customers' choice behaviors among decision criteria of high-class automobile market. We take two high-class automobile modes as test cases, and proposed Fuzzy DEMATEL approach combined with FMCDM to demonstrate the non-independent structure problem. Through our study, the novel hybrid method (Fuzzy DEMATEL approach combined with FMCDM) is found as a useful or effective assessment for businesses to meet customer's needs.

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