

Fuzzy Multiple Attribute Decision Making Theory With The Balanced Scorecard Application In Mobile Industry

Chiu-Hung Su

Department of Electrical Engineering
Hwa-Shia Institute of Technology,
Taipei 235, Taiwan
ritasu@cc.hwh.edu.tw

Ying-Hsun Hung

Department of Information
Management, Hwa-Shia Institute of
Technology, Taipei 235, Taiwan
horninch@gmail.com

Gwo-Hshiung Tzeng

Institute of Management of
Management, National Chiao Tung
University, Hsinchu 300, Taiwan
ghtzeng@cc.nctu.edu.tw

Abstract—this study is the use of fuzzy multi-attribute decision making as a business management application in the balanced scorecard performance assessment. The study expected to help enterprises to establish effective expression of those feelings with subjective indicators of weight value. In order to increase the accuracy of weight and practice, so that more perfect performance of the Balanced Scorecard in the business. The use of the Balanced Scorecard to evaluate the importance of screening criteria in Taiwan mobile industry operators and fuzzy multi attribute decision making through the match with the comparison with the fuzzy multiple criteria decision making, to establish Taiwan's mobile industry business model assessment. Fuzzy multi-attribute decision making can be vague, uncertain or unstructured problems trying to provide a solution to this. Finally, this study found results, the implementation of the model created to operate as a decision-making in Taiwan mobile industry reference, and can understand the fuzzy multiple attribute decision making not only in dealing with the definition of ambiguous or unclear information, as an effective Methods, but in the real world where a lot of created process can easily be used, it will also help assess the performance of the Balanced Scorecard.

Keywords—component; Balanced Scorecard; Multi-attribute decision making; MADM; Fuzzy Linguistic Variables

I. INTRODUCTION

Taiwan's communications industry and the simultaneous development of global industry trends in the case of wireless communications equipment industry accounted for the proportion of the overall communications industry, forecast to 50.7 % from the year 2001 to 2010 grew 79.6 % to 9, 064 million NT Production value, mainly due to smart phones and wireless local area network products, such as the two major types of products.

Recently, wireless communications, the global communications industry and the market has gradually focused on the mobile Internet, in addition to continued improvement related products, Smart mobile phone wireless communication contains (Smartphone) , the new models iPhone, notebook and mini-notebook (Netbook) , TV, Blu-ray players, set-top boxes, Bluetooth, Zigbee low cost and low power , RFID and other video-related consumer electronics products. We can know the

future of wireless communication industry is the star, intense competition and survival, in order to enhance the overall efficiency and effectiveness of operations, in order to pin down opponents in the market in order to grasp the opportunity to ensure their long term competitive advantage. How to give real assistance from the academic point of view as to the task of balance scorecard and fuzzy multi-attribute decision theory to solve performance management and enhancing competitiveness of the push is urgent. The communication devices also show the booming trend. Taiwan's communications industry and the simultaneous development of global industry trends in the case of wireless communications equipment industry accounted for the proportion of the overall communications industry, forecast to 50.7 % from the year 2001 to 2010 grew 79.6 % to 9, 064 million NT Production value, mainly due to smart phones and wireless local area network products, such as the two major types of products.

Based on the above reason, this study was to understand the following issues:

First, explore the use of Balanced Scorecard-based applications in the Mobile Enterprise applicability.

Second, the implementation of the case company Fuzzy multiple attribute decision making problems.

Third, set for enterprise performance management strategy for Mobile program.

Mobile SMEs in an attempt to enterprise applications into the Balanced Scorecard, Balanced Scorecard of the four dimensions with the financial side, customer, internal business process perspective and learning and growth surface indicators to develop a corporate cause and effect Diagram, and to assist with the fuzzy multiple attribute decision making in the case company's balanced scorecard results further explore the issue in depth in order to understand the management decision-making reference for efficiency.

II. RELATED RESEARCH

A. Balanced Scorecard

"Balanced Scorecard" (Balanced Scorecard, referred to as BSC) from the 1990 U.S. Professor David Norton and Robert

S. Kaplan of Harvard University study "Organization of future performance evaluation system ", it is a performance measurement model, which is a strategy; remuneration means a combination of strategic management tool. Emphasis on performance measurement should be achieved: (1) to measure the balance between internal and external: internal measure of emphasis on internal business process implementation and staff learning and growth surface, and an external measure of the emphasis on the financial side and customer side. (2) The results of surface measurement surface to measure the balance and the future: the results of surface Through the Balanced Scorecard applied to SMEs. We learned that the scorecard for small and medium enterprises also is

Eastern Media International Corporation has been building a strategic performance measurement system, and the concept of the Balanced Scorecard into the case company. The company has taken the traditional way of performance evaluation system and flexibility of management by objectives, which, strategy and incentive system has a high degree of association with low correlation of performance evaluation system. Among them, the import of this approach, top managers will need the support and full participation (Yuksel, 2010).

B. Multi-attribute decision making

In general, the term commonly used in decision making, Zeleny (1982) consider multiple criteria (multiple criteria) includes a number of attributes (multiple attributes) and multi-objective (multiple objectives); generally used to describe the four elements of MADM, (1) the alternatives (Alternatives), (2) set of attributes (Attributes), (3) goal set (Objectives) and (4) preference / weight set (Preferences / Weights).

Multi-attribute evaluation criteria is when policy-makers face multiple, even conflicting objectives, the assessment criteria must be choice, and multiple criteria decision making (MCDM) is the number of evaluation criteria used to assess the merits of different alternatives and their implementation the order of the systematic scientific methods. Therefore, the generalized multiple criteria decision making methods can be divided into multiple attribute, multi-objective decision making, covering multiple attribute decision making (Multi-Attribute Decision Making; called MADM), multi-objective decision analysis (Multi-Object Decision Making; referred MODM) generalized deal with the problem.

Multi-attribute decision making is the decision-makers may also consider the number of Conflicts, in a viable alternative, the decision to choose their preferred method (Yoon & Hwang, 1995) . To be addressed include the following four basic elements (Yu, 1995) .

- (1) A fixed set of alternatives (Finite Set of Alternative)
- (2) The set of assessment criteria (Set of Criteria)
- (3) Each program performance value (Performance Rating)
- (4)Decision makers preference structure (Preference Structure of Decision Maker)

The decision makers must decide from a group of action , the trade-offs by considering a variety of property relationship,

try to choose the most appropriate programs to achieve goals in the process, that is, multiple attribute decision making (Multiple Attribute Decision Making, MADM) . Bellman and Zedeh (1970) that the real environmental issues among decision-making occurred, most of the objectives, limitations, and possible options for the results are inaccurate, they are also the first to MADM fuzzy set theory is applied to the field. Therefore, the fuzzy multiple attribute decision making (Fuzzy MADM, FMADM) it will be extended to the fuzzy MADM environment, refers to the attributes in the decision-making process, weights, targets and the nature of restrictions may be vague, fuzzy sets must be said that Or property may be fuzzy linguistic variables.

C. The DEMATEL Method

The original DEMATEL (DEcision-MAking Trial and Evaluation Laboratory) method studied the disjointed and antagonistic phenomena of world and investigated integrated solutions. In 1973, the Battelle Memorial Institute conducted the DEMATEL project through its Geneva Research Centre. In recent years, this method has become very popular in Japan.

It is especially practical and useful for visualizing the structure of complicated causal relationships with matrices or digraphs, which portray the contextual relations between the elements of a system, where a numeral represents the strength of influence. Therefore, the DEMATEL method can convert the relationship between the causes and effects of criteria into an intelligible structural model of the system.

The DEMATEL method has been successfully applied in many fields. For example, Tamura et al. (2002) try to decrease anxiety of people by extracting and analyzing various uneasy factors in order to create future safe, secure and reliable (SSR) society. More recently, Chiu et al. (2005) adopted the method to study marketing strategy based on customer behavior related to LCD-TVs. Also Hori and Shimizu (1999) employed it to design and evaluate the software of a display-screen structure for analyzing a supervisory control system.

D. The Fuzzy Number and Linguistic Variables

Since fuzzy set theory was initially proposed by Zadeh, and Bellman and Zadeh (1970) subsequently described the decision-making methods in fuzzy environments, an increasing number of studies have dealt with uncertain fuzzy problems by applying fuzzy set theory. Similarly, this study adopts fuzzy decision-making theory by considering possible fuzzy subjective judgments during the evaluation process of strategic planning for the Balanced Scorecard in mobile industry.

It is very difficult for traditional quantification methods to reasonably express situations that are overtly complex or hard to define; therefore, the notion of linguistic variables is a useful tool in such situations. The theory of linguistic variables is used to represent the imprecision of spatial data and human cognition in terms of the criteria used for the evaluation

process. A linguistic variable is a variable whose values are words or sentences in a natural or artificial language. We use this approach to evaluate criteria represented by linguistic variables in a fuzzy environment as “Very high influence”, “High influence”, “Low influence”, and “No influence” on a four-level fuzzy scale.

The use of linguistic variables is widespread and, in this study, the linguistic values of alternatives are primarily used to assess the linguistic ratings given by decision-makers. Furthermore, linguistic variables are used to measure the performance value of alternatives for each criterion as “no influence”, “low influence”, “high influence”, and “very high influence”. We use triangular fuzzy numbers to express the fuzzy scale, as shown in Step 1 of the evaluation process.

E. The ANP for Calculating Weights of Criteria Based on the NRM

The analytic hierarchy process (AHP) supposes independence among criteria, which is not reasonable in the real world. Saaty (1996) thus extended AHP to ANP to resolve problems with dependence or feedback between criteria, which primarily divides problems into numerous different clusters and every cluster includes multiple criteria. Moreover, there is outer dependence among clusters and inner dependence within the criteria of clusters as illustrated in Fig. 18. In addition, we figured the relative weights of criteria of respective matrices by pair-wise comparison and modifying the weights as eigenvectors. Then we integrated multiple matrices into a super matrix, because the capacity to examine the inner and outer dependence of clusters is the largest benefit of a super matrix.

There are three steps for the decision process of ANP. First, the decision problem and the structure of problem were built to offer an evident depiction of the problem and separate it into a relation network structure as shown in Fig. 1. Second, not only is pair-wise comparison matrix established, but also eigenvalue and eigenvector were figured. Pair-wise comparison is composed of clusters and criteria. Furthermore, the pair-wise comparison of clusters was separated into comparison of criteria within and between clusters. We utilize ratio scale (1 ~ 9) to determine the level of importance of the comparison. In addition, the data deriving from the survey of ANP were combined and transferred into pair-wise comparison matrix by geometric average. After building the

matrix, we received the eigenvector W_{ii} through an equation: $Aw = \lambda_{\max} w$, where A is pair-wise comparison matrix, $w = (w_1, \dots, w_i, \dots, w_n)'$ is the eigenvector, w_i is the eigenvalue, then

$$\lambda_{\max} = \frac{1}{n} \sum_{i=1}^n \frac{(Aw)_i}{w_i}$$

where $(Aw)_i = \sum_{j=1}^n a_{ij} w_j$ and n equals the number of comparative criteria. Third, the super-matrix, tagged W (as shown in Equation 6), was formed. It was constructed by the dependence table obtained from the interrelations among criteria, and the eigenvectors received from the pair-wise comparison matrix served as the weights of it. No inner dependence among criteria or clusters was shown by a blank or zero. By Wu and Lee (2007), the usage of power matrix by W^h (multiplication) and $\lim_{h \rightarrow \infty} W^h$ is a fixed convergence value; therefore, we can acquire weights in every criterion.

III. RESEARCH METHOD

A. Case study

This study adopts a case study (Case Study Research) manner, the main purpose of the concept of Balanced Scorecard framework, supplemented by the method of fuzzy multi-attribute performance evaluation. Therefore, this chapter will be the basic concept of case study method, including its definition, types, design, procedures and applicable time, and case studies to illustrate the causes and processes. Case studies often conducted in a single case, focusing on the depth of discussion and analysis, to programs such as case studies in Table II of the program (Yin, R. K., 1989).

Scholars Yin (1989) that the conditions for case study three:

- (1) When the type of research question is “How” and “Why”
- (2) The researchers studied no significant control over the event, or no control.
- (3) The focus of the present rather than past events.

Therefore, when the case study focuses on contemporary issues and problems of control is small, the use of case study research is a better strategy. In early studies, the administration should be carefully considered for the problem through the “how” and “why” of deep thinking, and determine the reach of a valid target. Scholars Yin (1994) has decided that the research methods to be used, Ke Yi in the form of research questions, study the need for behavioral control, the focus of research is focused on current events upper three dimensions, as the choice of reference.

This study investigated the balanced scorecard and fuzzy multiple attribute decision making using of the Mobile industry. The relevant departments of the operation of field observations case, the case company looking to read all relevant information, interviews, related departments, etc., the case company's strategy, processes, performance evaluation, balanced scorecard to understand, to the line of the contents into a follow-up questions Explore the implementation problems encountered and possible improvements made under the direction of the results in order to enhance the case competition in IT services. This chapter will explore the case study approach, the use of case study of the theory and process of this study.

B. Balanced Scorecard

This study investigated the balanced scorecard and fuzzy multiple attribute decision making using of the Mobile industry. From the second half of 2010, gradually forming. The relevant departments of the operation of field observations case, the case company looking to read all relevant information, interviews, related departments, etc., the case company's strategy, processes, performance evaluation, balanced scorecard to understand, to the line of the contents into a follow-up questions Explore the implementation problems encountered and possible improvements made under the direction of the results in order to enhance the case competition in IT services. This chapter will explore the case study A case in order to understand the reason of the company began promoting promote the balanced scorecard, the researchers before the interview in advance cases to understand the company's corporate mission, vision and help the goal of:

Detailed planning steps are as follows:

- Stage one, the case company executives to Balanced Scorecard Introduction
- Phase II, the case company to collect the significant information to determine the executive structure to implement the Balanced Scorecard
- Stage III, the company announced the Balanced Scorecard to determine
- Phase IV, the case company teams at all levels About the Balanced Scorecard
- Stage five, the real implementation group set up developing develop with the four factors of corporate structure chart
- Phase VI, the first interview
- Phase VII, the first discussion
- Stage eight, the second interview
- Stage nine, the second talk
- Stage ten, received fuzzy multiple attribute decision making to establish meters for the case company helping help , the use of case study of the system and process of this study.

Avoid combining SI and CGS units, such as current in amperes and magnetic field in oersteds. This often leads to confusion because equations do not balance dimensionally. If you must use mixed units, clearly state the units for each quantity that you use in an equation.

TABLE I. BSC AND THE CASE COMPANY AND ITS MEASURE OF CORPORATE STRATEGY TABLE

Dimensions	Policy Topics	Measure
Customer Perspective	Customer Loyalty	1. Loyalty 2. Satisfaction 3. partner satisfaction
Financial Perspective	Stable earnings growth	1. Orders 2. renewal rate 3. revenue 4. Gross profit / profit / profit contribution

Process dimension	Reduce operating costs Continuous improvement process Internal employee satisfaction	1. operating cost control 2. time and commitment to customers 3. whether to solve the problem on the spot
Learning and growth perspective	Understanding of a shared vision Improving the Quality of Human Performance Evaluation and Rewards	1.employees aware of their responsibilities 2. formal staff turnover rate

C. Multi-attribute decision making

Step one: to define the various sectors of the property assessment indicators

The company implemented the Balanced Scorecard will be the case in four dimensions will be the key indicators of performance evaluation

It can be easily and clearly by a clear definition into two categories, one for the clear definition of a clear assessment can be the key performance index assessment, two values for the oral assessment can be the key performance indicators, the relationship these two categories.

Step Two: Setting fuzzy linguistic variables and fuzzy numbers

Step three: assess the performance of various departments

Step Four: Collect "key performance index of the weight "

D. The Fuzzy DEMATEL Method Procedure

A unique characteristic of this method is that it shows the relationships between Balanced Scorecard items with certain scores by using matrix operations. The relationship is that of "cause and effect". Another important characteristic is that it grasps both the direct effects, and the indirect effects of competing components.

We use triangular fuzzy numbers (TFN) with fuzzy DEMATEL to establish fuzzy weights for the Balanced Scorecard components and to determine the relative importance of the criteria. Then, the performance value of each criterion can be derived by the decision-makers. After the synthetic utility values are derived, we rank the alternatives based on the best non-fuzzy performances (BNP). The procedures of the DEMATEL method and the evaluation methods can be summarized as follows:

Step 1: Producing the direct-relation matrix

Comparison scale of the DEMATEL method

Numeral	Definition
0	No influence
1	Low influence

2	High influence
3	Very high influence

Step 2: Normalizing the direct-relation matrix

On the basis of the direct-relation matrix A , the normalized direct-relation matrix X can be obtained through formulas (2) and (3):

$$X = k \cdot A \quad (2)$$

$$k = \frac{1}{\max_{1 \leq i \leq n} \sum_{j=1}^n a_{ij}}, \quad i, j = 1, 2, \dots, n. \quad (3)$$

Step 3: obtaining the total-relation matrix

Once the normalized direct-relation matrix X has been obtained, the total-relation matrix T can be derived by using formula (4), in which the I denotes the identity matrix.

$$T = X + X^2 + X^3 + \dots$$

$$T = X + X^2 + X^3 + \dots = X(I + X + X^2 + \dots)$$

$$= X \left(\frac{I - X^n}{I - X} \right)$$

$$= X(I - X)^{-1}, \text{ when } n \rightarrow \infty, X^n = 0$$

$$T = X(I - X)^{-1} \quad (4)$$

Step 4: Analyzing the results

In this step, the sum of rows and the sum of columns are used to derive vector S and vector R respectively, as shown in formulas (5), (6), and (7). Then, the horizontal axis vector ($S + R$), called “Prominence”, is formed by adding S to R , which indicates the level of importance of the criterion. Similarly, the vertical axis ($S - R$) called “Relation”, is formed by subtracting S from R , which may divide criteria into a cause group and an effect group. When ($S - R$) is positive, the criterion belongs to the cause group; otherwise, it belongs to the effect group. Therefore, the causal diagram can be derived by mapping the dataset of ($S + R, S - R$), which provides valuable insights for making decisions.

$$T = [t_{ij}]_{n \times n}, \quad i, j = 1, 2, \dots, n \quad (5)$$

$$s = \left[\sum_{j=1}^n t_{ij} \right]_{n \times 1} = [t_{i \cdot}]_{n \times 1} \quad (6)$$

$$r = \left[\sum_{i=1}^n t_{ij} \right]_{1 \times n} = [t_{\cdot j}]_{1 \times n}, \quad (7)$$

where vector S and vector R respectively denote the sum of rows and the sum of columns from the total-relation matrix $T = [t_{ij}]_{n \times n}$.

IV. CONCLUSION AND FINDINGS

We have proposed an approach for Balanced Scorecard evaluation in mobile industry based on effective group decision-making from the perspective of fuzzy multi-attribute decision making. The fuzzy DEMATEL method is used to establish fuzzy weights for Balanced Scorecard evaluation components.

The contribution of our approach is that it overcomes the limitations of traditional methods used to evaluate performance of mobile industry by Balanced Scorecard perspectives, as it does not have to accurately estimate the considered criteria in terms of numerical values for the anticipated alternatives. Applying fuzziness and the DEMATEL method for Balanced Scorecard evaluation allows practitioners to select components according to their organizations' priorities, and gather meaningful knowledge that captures the causal relationships between criteria.

The development of performance evaluation management system: the assessment of the case company does not have too many management systems, is not quantitative assessment of the project and assess the data. The purpose of daily operations, risk factors, such as timeliness and independent evaluation of the program flow is not related to each other. Data can not be automatically collected, the data obtained did not plan, can not understand the true value of the information, no relevant department or person responsible for data collection, resulting in missing data timeliness.

Structural organization of interdepartmental communication and consensus: The case company can provide the same services many companies are all competitors, the department of civil servants between the prevailing mindset, can not actively create the company with the best chance of combining customer service, real cause for concern.

Will promote the implementation of company strategy into the details: a positive vision combined with staff training / education, coupled with effective processes, customer satisfaction goals, and create a win-win target company shareholders and employees.

When we understand the theory and the four Balanced Scorecard dimensions, the dimensions will have to quantify these indicators, we must first determine through internal discussion and consensus on which indicators must be considered, and these indicators may be due to industry Different or change the company's vision, not necessarily take into account each company will have the same index.

In terms of strategic planning for the company, whether long or short, shall be convened by the company executives in charge of all a consensus on a common resolution. According to Company the specific action plan launched by the various

units in the company's goal to complete the year. The planning process of the balanced scorecard and corporate strategy, the company's specific action plan must take into account top-down driven; the results of the implementation level, is the bottom-up implementation, the company must develop a pragmatic Dimension in the four short-term goals can achieve. Therefore, measure of all sectors of the setting is very important because it is a business process assessment standard.

For important work, that is as soon as possible to assess the use of quantitative indicators. But the focus, it is not too much. For non-focused work, it can take fuzzy judgments, qualitative or quantitative management approach to determine. So the work can be focused, but also the employees ignore the non-priority work. Based on this concept, seven departments of the key indicators of performance evaluation, divided into two, one for the quantitative indicators, indicators of non-fuzzy, two non-quantitative indicators, and the fuzzy index, and the theory of multiple fuzzy attribute decision making Sector performance evaluation, in order to understand the applicability of the model, and the advantages and disadvantages of the operation in practice. Based on this concept, seven departments of the key indicators of performance evaluation, divided into two, one for the quantitative indicators, indicators of non-fuzzy, two non-quantitative indicators, and the fuzzy index, and the theory of multiple fuzzy attribute decision making Sector performance evaluation, in order to understand the applicability of the model, and the advantages and disadvantages of the operation in practice.

REFERENCES

- [1] Kiran Jude Fernandes, Vinesh Raja, Andrew Whalley, "Lessons from implementing the balanced scorecard in a small and medium size manufacturing organization," *Technovation*, vol.26, no.5, 2006, pp. 623-634
- [2] Kaplan, R. S. & D. P. Norton, *The Balanced Scorecard: Translating Strategic Into Action*. Boston, *Harvard Business School Press*, 1996
- [3] Robert S. Kaplan and David P. Norton, "The balanced scorecard : Measures that drive performance," *Harvard Business Review*, Jan – Feb., 1992, pp.71-79.
- [4] Yin, R. K., *Case Study Research: Design and Methods*, Sage Publications, 1989, pp.17.
- [5] Zairi, M., "Synchronisation of TQM. The TQM Magazine, 2002, pp5-6.
- [6] Ihsan Yuksel, Metin Dagdeviren, Using the fuzzy analytic network process (ANP) for Balanced Scorecard (BSC): A case study for a manufacturing firm," *Expert Systems with Applications*, vol.37, no.2, 2010, pp. 1270-1278
- [7] Zeleny, M., "Multiple Criteria Decision-making," McGraw-Hill, New York, 1982.
- [8] Hwang & Yoon, *Multiple Decision Making : Method and Applications*, 1981.
- [9] Mobile Industry Report. Taipei: Market Intelligence & Consulting Institute, 2009, MIC.
- [10] Bellman, R. E., and Zadeh, L. A., "Decision-making in a fuzzy environment," *Management Science*, vol 17, 1970, pp. 141-164.
- [11] Chiu, Y. J., Chen, H. C., Tzeng, G. H., and Shyu, J. Z., "Marketing strategy based on customer behaviour for the LCD-TV," *International Journal of Management and Decision Making*, vol. 7, no.2, 2006, pp. 143-165.
- [12] Hori, S., Shimizu, Y., "Designing methods of human interface for supervisory control systems," *Control Engineering Practice* vol. 7, 1999, pp. 1413-1419.
- [13] Tsai, W. H., and Chou, W. C. "Selecting management systems for sustainable development in SMEs: A novel hybrid model based on DEMATEL, ANP, and ZOGP," *Expert Systems with Applications*, vol.36, no.2, 2009, pp. 1444-1458.
- [14] Tzeng, G. H., Chiang, C. H., and Li, C. W. "Evaluating intertwined effects in e-learning programs: a novel hybrid MCDM model based on factor analysis and DEMATEL," *Expert Systems with Applications*, vol.32, no.4, 2007, pp. 1028-1044.
- [15] Ou Yang, Y. P., Shieh, H. M., Leu, J. D., and Tzeng, G. H. "A novel hybrid MCDM model combined with DEMATEL and ANP with applications," *International Journal of Operations Research*, vol.5 no.3, 2008, pp.160-168.
- [16] Y.-C. Chen, H.-P. Lien, G.-H. Tzeng, "Measures and evaluation for environment watershed plans using a novel hybrid MCDM model," *Expert systems with applications* vol.37, no.2, 2010, pp.926-938.
- [17] J.-J. Huang, G.-H. Tzeng, C.-S. Ong, "Multidimensional data in multidimensional scaling using the analytic network process," *Pattern Recognition Letters* vol.26, no. 6, 2005, pp.755-767.
- [18] J. Jones, D. Hunter, "Qualitative research: consensus methods for medical and health services research," *British Medical Journal*, vol.311, no. 7001, 1995, pp. 376-380.
- [19] C.-L. Lin, G.-H. Tzeng, "A value-created system of science (technology) park by using DEMATEL," *Expert Systems with Applications*, vol.36, no.6, 2009, pp.9683-9697.
- [20] J.-H. Liou, G.-H. Tzeng, H.-C. Chang, "Airline safety measurement using a hybrid model," *Journal of Air Transport Management*, vol.13, no.4, 2007, pp. 243-249.
- [21] Y.-P. Ou-Yang, J.-D. Leu, G.-H. Tzeng, "A VIKOR-Based Multiple Criteria Decision Method for Improving Information Security Risk," *International Journal of Information Technology and Decision Making* vol.18, no.2, 2009, pp.1-21.
- [22] S. Opricovic, "Multicriteria Optimization of Civil Engineering Systems," Faculty of Civil Engineering, Belgrade, 1998.
- [23] S. Opricovic, G.-H. Tzeng, "Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS," *European Journal of Operational Research*, vol.156, no.2, 2004, pp. 445-455.
- [24] T.L. Saaty, *Decision making with dependence and feedback: The analytic network process*. Pittsburgh: RWS Publications, 1996.
- [25] T.L. Saaty, *Fundamentals of the analytic network process*. Japan: University of Pittsburgh, ISHP, 1999. pp. 1-14.
- [26] T.L. Saaty, "Rank from comparisons and from ratings in the analytic hierarchy/network processes," *European Journal of Operational Research* vol.168, no.2, 2006, pp. 557-570.
- [27] G.-H. Tzeng, C.-H. Chiang, C.-W. Li, "Evaluating intertwined effects in e-learning programs: A novel hybrid MCDM model based on factor analysis and DEMATEL," *Expert Systems with Applications* vol.32, no.4, 2007, pp.1028-1044.
- [28] G.-H. Tzeng, S.-H. Tsaur, Y.-D. Lai, S. Opricovic, "Multicriteria Analysis of Environmental Quality in Taipei : Public Preferences and Improvement Strategies," *Journal of Environmental Management* vol.65, no.2, 2002, pp.109-120.
- [29] P.-L. Wei, J.-H. Huang, G.-H. Tzeng, S.-I. Wu, "Causal modeling of web-advertising effects by improving SEM based on DEMATEL technique," *International Journal of Information Technology and Decision Making*, vol.9, no.5, 2010, pp.799-829.
- [30] W.-W. Wu, "Choosing knowledge management strategies by using a combined ANP and DEMATEL approach," *Expert Systems with Applications*, vol.35, no.3, 2008, pp.828-835.
- [31] C. Yang, G.-L. Fu, G.-H. Tzeng, "Multicriteria Analysis of the Strategies to Open Taiwan's Mobile Virtual Network Operators Services," *International Journal of Information Technology and Decision Making*, vol.6, no.1, 2007, pp.85-112.