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Full Length Research Paper

A hybrid performance evaluation system for notebook computer ODM companies

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The aim of the paper is to fulfill this need by building a conceptual framework for measuring the business performance of notebook computer ODM (Original Design Manufacturer) companies carried out to investigate how performance is understood and to identify the potential dimensions to improvement. In the process, a multiple criteria procedure is used to assess the performance in these companies. We explore the performance-evaluation systems by using fuzzy AHP and VIKOR techniques. The evidence from the investigation showed that supply chain capability and manufacturing capability are the top two indicators for the notebook computer ODM companies' performance. Furthermore, it was found that Quanta and Compal have the relative high business performance among these companies. The research provides evidence which establishes whether benchmarking provides a real and lasting benefit to notebook computer ODM companies. A series of managerial implications are set forth and discussed.

Key words: Performance evaluation, Fuzzy Analytic Hierarchy Process (Fuzzy AHP), VIKOR, Multiple Criteria Decision Making (MCDM).

INTRODUCTION

Neely, Gregory and Platts (1995) define performance measurement as the process of quantifying the effectiveness and efficiency of action. Performance measurement is defined as the construction and use of several, often related, quantifiable measures for different factors (i.e. cost, time, quality, customer satisfaction) that can be employed for the evaluation of the efficiency and effectiveness of the performance and performance capabilities of various objects within a company (i.e. business functions, processes, employees) (Gleich and Brokemper, 1997a). In order to compete in today's competitive environment, many organizations have recognized benchmarking as being of strategic important in the drive for better performance and commitment to achieving a competitive advantage. There are many studies have investigated the method about performance evaluation (Wynn-Williams, 2005; Chalasani and Sounderpandian, 2004; Gleich, Motwani and Wald, 2008; Maiga and Jacobs, 2004). Some literatures identified the different key performance indicators, including tangible and intangible aspect (Mukherjee, Nath and Pal, 2002; Chin, Pun, Lau and Lau, 2001; Himes, 2007; Jones and Kaluarachchi, 2008; Welch and Mann, 2001; Wainwright, Green, Mitchell and Yarrow, 2005; Robson and Prabhu, 2001). It is essential for the application of performance measurement that a company's tangible and intangible targets are defined in a way that is more appropriate to the requirements and objects of this targets and that its strategy is more extensively operationalized, quantified and linked in a mutually supplementing way.

In the literature, there is limited fuzzy logic methods aimed at evaluating the relative performance by multi-dimensions. The main purpose of this paper is to provide practitioners with a fuzzy point of view to traditional performance research for dealing with imprecision and at obtaining the prioritization and the best performance of measurement dimensions. Moreover, we attempt to assist government representatives or industrial analyst in accessing the relative performance. We take the global top four notebook computer ODM companies for pursuing our case purposes. This research invites ten experts that evaluate the performance of global top four notebook computer ODM companies via the proposed fuzzy AHP and VIKOR techniques with MCDM. The fuzzy AHP is used to determine the preference weights of evaluation. Then this research adopts the VIKOR to improve the gaps of alternatives between real performance values and pursuing aspired levels in each dimension and criterion and find out the best alternatives for achieving the aspired/desired levels based on four proposed companies. This research looks forward to provide Taiwan industries and government with some strategic recommendations.

IDENTIFYING THE KEY PERFORMANCE DIMENSIONS

The performance measurement activity has paralleled the strategy activity throughout the period of the grant. This paper applies the focus group research method to get the evaluation relative dimensions. Focus group research is based on facilitating an organized discussion with a group of individuals selected because they were believed to be representative of some class. Discussion is used to bring out insights and understandings in ways which simple questionnaire items may not be able to tap. Focus group research has long been prominent in marketing studies (Morgan, 1988), in part because researchers seek to tap emotional and unconscious motivations not amenable to the structured questions of conventional survey research. The interaction among focus group participants brings out differing perspectives through the language that is used by the discussants. Interaction is the key to successful focus groups. In an interactive setting, discussants draw each other out, sparking new ideas. The reactions of each person spark ideas in others, and one person may fill in a gap left by others (Duric, Rado, Adamovi, 2010).

The host researcher raised a number of issues including: the relative importance of notebook computer ODM companies performance evaluation criteria as recognized by participants, industrial analysts, professors and so on. After thorough discussion, and with the aid of answers to open-ended questionnaires and recording equipment, opinions were integrated and summarized. Finally, six potential evaluation dimensions are determined through the focus group process. They are manufacturing capability, financial capability, innovation capability, supply chain capability, human resource capability and service quality capability.

Manufacturing capability

Manufacturing capability is considered to be an important element in a firm's endeavor to improve firm performance (Jutras, 2006). Manufacturing capability management strategies have reduced inventory and manufacturing cycle times, and more complete and on-time shipments of better quality products (Himes, 2007). The enterprises should focus on reducing costs; they also pay much more attention to building agility and flexibility into their manufacturing processes, seeking better market differentiation. Cost reductions remain the focus of all enterprises and many still struggle with data collection and cultural issues (Wainwright, Green, Mitchell and Yarrow, 2005). The manufacturing capability includes five aspects, such as reducing manufacturing cost, shrinking manufacturing cycle time, improving schedule compliance, satisfying demand for more complete and on-time shipments (Gleich, Motwani and Wald, 2008; Welch and Mann, 2001).

Reducing manufacturing costs increases profitability by making more with what you have or the same with less. It sounds pretty simple but many companies struggle with this. Moreover, increasingly demanding customers and the surge of strong global competition require reduced manufacturing cycle times and increased customization of products and services-all in addition to the traditional allocation challenges of constrained resources. With a real-time manufacturing planning and scheduling solution that simultaneously balances multiple constraints; firm can address these issues while meeting customer service targets.

Financial capability

Financial capability concerns itself with the application of this discipline to the finance function. It deals with how well the finance organizations support a company’s strategic objectives (Maiga and Jacobs, 2004). The majority of empirical studies have found that firm’s cash flow as a measure of internal financial capability is associated with higher levels of performance. The financial capabilities include five aspects, such as liquidity, financial leverage, asset turnover, profitability and market value (Fang, Huang, Huang, 2010).

Liquidity is particularly interesting to short-term creditors. Liquidity is the availability of credit or the ease with which institutions can borrow or take on leverage. The financial managers are working with banks and other short-term lenders, an understanding of liquidity are essential. Financial leverage takes the form of a loan or other borrowings, the proceeds of which are reinvested with the intent to earn a greater rate of return than the cost of interest. The higher a firm's financial leverage, the riskier the firm's operations are considered to be. The most typical system of determining an acceptable level of financial leverage is by comparing operations to others firms in the same industry. Asset turnover is a financial ratio that measures the efficiency of a company's use of its assets in generating sales revenue or sales income to the company. Profit generally is the making of gain in business activity for the benefit of the owners of the business. Market value is a concept distinct from market price, which is “the price at which one can transact”, while market value is “the true underlying value”.

Innovation capability

It is well known that industrial enlivenment must continually cope with extremely rapid changes which demand an innovative technological and managerial response (Lee, Yu, 2010). Such a response must redefine the firms' organizational assets in order to achieve a satisfactory degree of adaptation to the external environment. Innovation is a necessary condition, not only for increasing the firms' competitiveness, but primarily to ensure their survival (Capaldo, Iandoli, and Zollo, 2003). Innovation is about change, about doing different things, or doing things differently. The ability to innovate is critical to the survival and growth of your business (Liu, Chuang, Huang, Tsai, 2010).

Innovation shows up in the quality and quantity of ideas and the efficiency and effectiveness of implementation of those ideas (Jones and Kaluarachchi, 2008). The second face of R&D is called the absorptive capacity, and it is considered to be crucial particularly for assessing the effective contribution by spillovers from others. Defined as a set of knowledge and competencies, the firm's knowledge base remains a preliminary condition in the assimilation of spillovers from R&D efforts of environment (Chuang, Liu, Tsai, Huang, 2010). R&D activity does not only stimulate innovation, but it also enhances the firms' ability to assimilate outside knowledge.

Supply chain capability

Supply chain management, analysis, and improvement are becoming increasingly important. Managers want to measure the performance of the supply chain and the results of improvement efforts across supplier, company and customer operations (Groznik, Maslaric, 2010). Supply chain management will affect more than costs, and managers must be able to sell the value created to senior executives, trading partners, and shareholders (Pohlen and Coleman, 2005). Everyone agrees that "you can only manage what you measure," but many companies struggle with creating and using effective performance measurement systems for forecasting, purchasing, production and distribution operations (Gupta and Selvaraju, 2006). The challenges may include lack of consistency, inability to share data, or poor buy-in, among others. This course provides a fast-paced overview of a proven approach for identifying measurement needs, developing appropriate metrics and implementing the infrastructure to support them. The course is essential for those who want to use measures to maximize supply chain performance and improvement (Welch and Mann, 2001; Chen, Chen, Lee, 2010).

The entire supply chain's ability to meet end-customer needs through product availability and responsive, on-time delivery. Supply chain performance crosses both functional lines and company boundaries. Functional groups (engineering/R&D, manufacturing, and sales/ marketing) are all instrumental in designing, building, and selling products most efficiently for the supply chain, and traditional company boundaries are changing as companies discover new ways of working together to achieve together to achieve the ultimate supply chain goal: the ability to fill customer orders faster and more efficiently than the competition. Supply Chain capability measures must show not only how well you are providing for customers (service metrics) but also how companies are handling your business (speed, asset/inventory, and financial metrics).

Human resource capability

Successfully managing human resource capability is important for the high tech industry. Management techniques, such as recruit, train, apply, apprise and maintain combine organizational strategies and human resources plans that can effectively carry out human resources development, and directly influence the Taiwanese economy's success or failure (Tai and Wang, 2006). Businesses find success when they can establish clear strategic goals and marshal all resources to achieve those objectives. Human resource performance management is a huge priority for competitive organizations. That's where superior software solutions come in. By automating much of the human resource performance management process, and adding much-needed knowledge and information access to the equation, such solutions can help to make these HR initiatives a source of success. Valued human resource development not only improves professional skills and capabilities, but also solves the problem of measuring the effect of human resources on an organization. We think that HRM as an instrument designed to enhance the labor extraction process and thus improve firm performance.

Human Resource Development is the framework for helping employees develops their personal and organizational skills, knowledge, and abilities. Human Resource Development includes such opportunities as employee training, employee career development, performance management and development, coaching, succession planning, key employee identification, tuition assistance, and organization development.

Service quality capability

SERVQUAL as the most often used approach for measuring service quality has been to compare customers' expectations before a service encounter and their perceptions of the actual service delivered. For Parasuraman, Zeithaml, and Berry (1985, 1988a), service quality is measured in 10 phases: accessibility, communication, capability, courtesy, trustworthiness, reliability, responsiveness, safety, tangibility, and understanding with customers. Parasuraman et al. (1988a, b) also reduced the 10 to 5: tangibility, reliability, responsiveness, assurance, and empathy.

The concept of measuring the difference between expectations and perceptions in the form of the SERVQUAL gap score proved very useful for assessing levels of service quality (Chin, Pun, Lau and Lau, 2001). Parasuraman et al., argue that, with minor modification, SERVQUAL can be adapted to any service organization. They further argue that information on service quality gaps can help managers diagnose where performance improvement can best be targeted (Chen and Hao, 2010) he largest negative gaps, combined with assessment of where expectations are highest, facilitate prioritization of performance improvement. Equally, if gap scores in some aspects of service do turn out to be positive, implying expectations are actually not just being met but exceeded, then this allows managers to review whether they may be "over-supplying" this particular feature of the service and whether there is potential for re-deployment of resources into features which are underperforming (Robson and Prabhu, 2001).

Summary

To sum up, the performance evaluation problem is a group decision-making under multiple criteria. The degree of uncertainty, the number of decision makers and the nature of the criteria those have to be taken into account in solving this problem. We adopt six evaluation dimensions to prioritize the priority to these dimensions. Based on the deductions from the prior literature, the evaluation dimensions in question are manufacturing capability, supply chain capability, innovation capability, financial capability, human resource capability and service quality capability. Based on the six evaluation dimensions, we will evaluate, improve, and select the best alternatives of notebook computer ODM Company for achieving aspiration levels.

FUZZY ANALYTIC HIERARCHY PROCESS

The Analytic Hierarchical Process (AHP) is one of the methodological approaches that may be applied to resolve highly complex decision making problems involving multiple scenarios, criteria and actors (Pirannejad, Salami, Mollaee Abdolazim, 2010). AHP constructs a ratio scale associated with the priorities for the various items compared. In his initial formulation, The AHP is based on the use of pair-wise comparisons, which lead to the elaboration of a ratio scale. Moreover, the AHP permits to refine the decision-making process while examining the global coherence of the user's preferences, as it can include the calculation of an overall consistency ratio (Cho, SoonHu, 2010). Analytic Hierarchy Process (AHP) is a powerful method to solve complex decision problems (Jun, Cusin, Kiritsis and Xirouchakis, 2007). Any complex problem can be decomposed into several sub-problems using AHP in terms of hierarchical levels where each level represents a set of criteria or attributes relative to each sub-problem (Thawesaengskulthai and Tannock, 2008). The AHP method is a multi-criteria method of analysis based on an additive weighting process, in which several relevant attributes are represented through their relative importance. AHP has been extensively applied by academics and professionals, mainly in engineering applications involving financial decisions associated to non-financial attributes (Malakooti, 1991; Saaty, 1996). Through AHP, the importance of several attributes is obtained from a process of paired comparison, in which the relevance of the attributes or categories of drivers of intangible assets are matched two-on-two in a hierarchic structure (Freed, Doerr and Chang, 2006; Beatriz, José, Rodríguez-Benavides, 2010). The weight of each factor was determined with AHP according to the expert advice. AHP was a systematic analyzing evaluation method to treat the complex and multi-index system quantitatively, which could decompose the complex problem to some layers and some factors, and could compare and calculate as the result of weigh. Due to its ability of assigning proper weights to various factors of complex systems, performance evaluation system was suitable to employ AHP.

However, the pure AHP model has some shortcomings (Yang and Chen, 2004). They pointed out that the AHP method is mainly used in nearly crisp-information decision applications; the AHP method creates and deals with a very unbalanced scale of judgment; the AHP method does not take into account the uncertainty associated with the mapping of human judgment to a number by natural language; the ranking of the AHP method is rather imprecise; and the subjective judgment by perception, evaluation, improvement and selection based on preference of decision-makers have great influence on the AHP results (Ravi, Shankar and Tiwari, 2008; Karsak, 2002, 2006). In order to consider uncertainty and improving imprecision in ranking attributes and/or machine alternatives. The presented approach introduces triangular numbers into traditional AHP method. Adoption of fuzzy numbers allows decisions makers to achieve a better estimation flexibility regarding the overall importance of attributes and real alternatives (Ambe, Badenhorst-Weiss, 2010). To overcome these problems, several researchers integrate fuzzy theory with AHP to improve the uncertainty (Lin, Shih, Lu, Lin, 2010; Mirbagheri, 2010; Nuhodzic, Macura, Bojovic, Milenkovic, 2010). Buckley (1985) used the evolutionary algorithm to calculate the weights with the trapezoidal fuzzy numbers. The fuzzy AHP based on the fuzzy interval arithmetic with triangular fuzzy numbers and confidence index α with interval mean approach to determine the weight for evaluative elements (Ayag and Ozdemlr, 2007).

Building the evaluation hierarchy systems for evaluating the performance of global top four notebook computer ODM companies

This research tries to access the performance of global top four notebook computer ODM companies. After reviewing the related literature, we set six dimensions that building the evaluation hierarchy systems: Manufacturing Capability, Supply Chain Capability, Innovation Capability, Financial Capability, Human Resource Capability and Service Quality Capability. Based on the six evaluation dimensions, this research accesses the performance of global top four notebook computer ODM companies.

Determining the evaluation dimensions weights

This research employs Fuzzy AHP to fuzzify hierarchical analysis by allowing fuzzy numbers for the pair-wise comparisons and find the fuzzy preference-weights. In this Section, we briefly review concepts for fuzzy hierarchical evaluation. Then the following sections will introduce the computational process about Fuzzy AHP in detail.

Establishing fuzzy number

Fuzzy sets are sets whose elements have degrees of membership. Fuzzy sets have been introduced by Zadeh (1965) as an extension of the classical notion of set. In classical set theory, the membership of elements in a set is assessed in binary terms according to a bivalent condition - an element either belongs or does not belong to the set (Li, 2007; Liou, Yen and Tzeng, 2007; Wu and Lee, 2007). The mathematics concept borrowed from Hsieh, Lu and Tzeng (2004) and Ayag (2005; 2007). A fuzzy number $\tilde{A}$ on $\mathbb{R}$ to be a TFN if its membership function $\mu_{\tilde{A}}(x): \mathbb{R} \rightarrow [0,1]$ is equal to following Equation (1):

$$\mu_{\tilde{A}}(x) = \begin{cases} (x-l)/(m-l), & l \le x \le m \\ (u-x)/(u-m), & m \le x \le u \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

From the above Equation (1), l and u mean the lower and upper bounds of the fuzzy number $\tilde{A}$, and m is the modal value for $\tilde{A}$. The TFN can be denoted by $\tilde{A}$ = (l,m,u) (as Figure 1). The operational laws of TFNs $\tilde{A}_1 = (l_1, m_1, u_1)$ and $\tilde{A}_2 = (l_2, m_2, u_2)$ are displayed as following Equations (2) to (5) thus:

1). Addition of the fuzzy number $\oplus$

$$\tilde{A}_1 \oplus \tilde{A}_2 = (l_1, m_1, u_1) \oplus (l_2, m_2, u_2) = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \quad (2)$$

2). Multiplication of the fuzzy number $\otimes$

$$\tilde{A}_1 \otimes \tilde{A}_2 = (l_1, m_1, u_1) \otimes (l_2, m_2, u_2) = (l_1 l_2, m_1 m_2, u_1 u_2) \text{ for } l_1, l_2 > 0;\ m_1, m_2 > 0;\ u_1, u_2 > 0 \quad (3)$$

3). Subtraction of the fuzzy number Θ

$$\tilde{A}_1 \Theta \tilde{A}_2 = (l_1, m_1, u_1) \Theta (l_2, m_2, u_2) = (l_1 - u_2, m_1 - m_2, u_1 - l_2) \quad (4)$$

4). Division of a fuzzy number $\varnothing$

$$\tilde{A}_1 \varnothing \tilde{A}_2 = (l_1, m_1, u_1) \varnothing (l_2, m_2, u_2) = (l_1 / u_2, m_1 / m_2, u_1 / l_2) \text{ for } l_1, l_2 > 0;\ m_1, m_2 > 0;\ u_1, u_2 > 0$$

5). Reciprocal of the fuzzy number

$$\tilde{A}^{-1} = (l_1, m_1, u_1)^{-1} = (1/u_1, 1/m_1, 1/l_1) \text{ for } l_1, l_2 > 0;\ m_1, m_2 > 0;\ u_1, u_2 > 0 \quad (5)$$

Determining the linguistic variables

Linguistic variables take on values defined in its term set: its set of linguistic terms. Linguistic terms are subjective categories for the linguistic variables. A linguistic variable is a variable whose values are words or sentences in a natural or artificial language. Here, we use this kind of expression to compare two building notebook computer ODM companies evaluation dimension by nine basic linguistic terms, as "Perfect," "Absolute," "Very good," "Fairly good," "Good," "Preferable," "Not Bad," "Weak advantage" and "Equal" with respect to a fuzzy nine level scale. In this paper, the computational technique is based on the following fuzzy numbers defined by Gumus (2008) in Table 1. Here each membership function (scale of fuzzy number) is defined by three parameters of the symmetric triangular fuzzy number, the left point, middle point and right point of the range over which the function is defined. The use of linguistic variables is currently widespread and the linguistic effect values of notebook computer companies alternatives found in this study are primarily used to assess the linguistic ratings given by the evaluators.

Fuzzy AHP

Then we will briefly introduce that how to carry out the fuzzy AHP in the following sections.

Step 1: Construct pair-wise comparison matrices among all the elements/criteria in the dimensions of the hierarchy system. Assign linguistic terms to the pair-wise comparisons by asking which is the more important of each two dimensions, as following matrix $\tilde{\boldsymbol{A}}$

$$\tilde{\boldsymbol{A}} = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{\boldsymbol{m}\mathbf{1}} & \tilde{a}_{n2} & \cdots & 1 \end{bmatrix} = \begin{bmatrix} 1 & \tilde{a}_{\mathbf{12}} & \cdots & \tilde{a}_{\mathbf{1}\boldsymbol{m}} \\ 1/\tilde{a}_{\mathbf{12}} & 1 & \cdots & \tilde{a}_{\mathbf{2}\boldsymbol{m}} \\ \vdots & \vdots & \ddots & \vdots \\ 1/\tilde{a}_{\mathbf{1}\boldsymbol{m}} & 1/\tilde{a}_{\mathbf{2}\boldsymbol{n}} & \cdots & 1 \end{bmatrix} \quad (6)$$

where $\tilde{a}_{ij} =$

$$\begin{cases} \tilde{9}^{-1}, \tilde{8}^{-1}, \tilde{7}^{-1}, \tilde{6}^{-1}, \tilde{5}^{-1}, \tilde{4}^{-1}, \tilde{3}^{-1}, \tilde{2}^{-1}, \tilde{1}^{-1}, \tilde{1}, \tilde{2}, \tilde{3}, \tilde{4}, \tilde{5}, \tilde{6}, \tilde{7}, \tilde{8}, \tilde{9}, & i \ne j \\ 1, & i = j \end{cases} \quad (7)$$

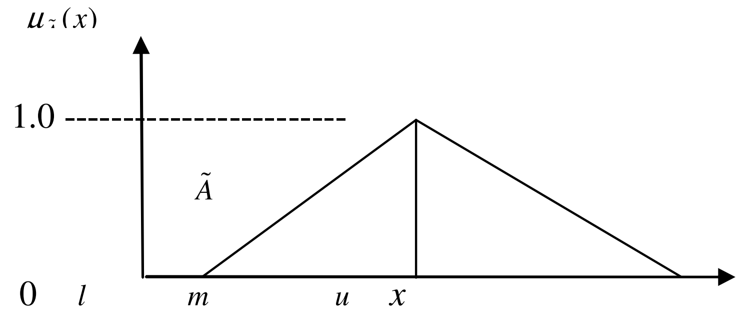

Figure 1. The membership functions of the triangular fuzzy number.

Table 1. Membership function of linguistic scale (example).

Fuzzy number	Linguistic	Scale of fuzzy number
9	Perfect	(8,9,10)
8	Absolute	(7,8,9)
7	Very good	(6,7,8)
6	Fairly good	(5,6,7)
5	Good	(4,5,6)
4	Preferable	(3,4,5)
3	Not Bad	(2,3,4)
2	Weak advantage	(1,2,3)
1	Equal	(1,1,1)

where $\tilde{a}_{ij} = \begin{cases} \tilde{9}^{-1},\tilde{8}^{-1},\tilde{7}^{-1},\tilde{6}^{-1},\tilde{5}^{-1},\tilde{4}^{-1},\tilde{3}^{-1},\tilde{2}^{-1},\tilde{1}^{-1},\tilde{1},\tilde{2},\tilde{3},\tilde{4},\tilde{5},\tilde{6},\tilde{7},\tilde{8},\tilde{9}, & i \neq j \\ 1, & i = j \end{cases}$ (7)

Step 2: To use geometric mean technique to define the fuzzy geometric mean and fuzzy weights of each criterion by Hsieh et al. (2004).

$$\tilde{r}_i = (\tilde{a}_{i1} \otimes \cdots \otimes \tilde{a}_{ij} \otimes \cdots \otimes \tilde{a}_{in})^{1/n}$$
$$\tilde{w}_i = \tilde{r}_i \otimes [\tilde{r}_1 \oplus \cdots \oplus \tilde{r}_i \oplus \cdots \oplus \tilde{r}_n]^{-1} \quad (8)$$

where $\tilde{a}_{ij}$ is fuzzy comparison value of dimension i to criterion j, thus, $\tilde{r}_i$ is a geometric mean of fuzzy comparison value of criterion i to each criterion j and $j = 1,2,...,n$, $\tilde{w}_i$ is the fuzzy weight of the i-th criterion and $i = 1,2,...,n$, can be indicated by a TFN, $\tilde{w}_i = (lw_i, mw_i, uw_i)$. The lw_i, mw_i and uw_i stand for the lower, middle and upper values of the fuzzy weight of the i-th dimension respectively.

There are numerous studies that apply fuzzy AHP method to solve different managerial problems. Huang, Chu and Chiang (2008) adopt a fuzzy analytic hierarchy process method and utilize crisp judgment matrix to evaluate subjective expert judgments made. Pan (2008) applied fuzzy AHP model for selecting the suitable bridge construction method. Cakir and Canbolat (2008) propose an inventory classification system based on the fuzzy analytic hierarchy process. Wang and Chen (2008) applied fuzzy linguistic preference relations to construct a pairwise comparison matrix with additive reciprocal property and consistency.

Sambasivan and Fei (2008) evaluate the factors and sub-factors critical to the successful implementation of ISO 14001-based environmental management system and benefits. Sharma, Moon and Bae (2008) used AHP methodology to optimize the selection of delivery network design followed by relevant choices for decision making of Home plus distribution center. Costa and Vansnick (2008) discussed the meaning of the priority vector derived from the principal eigenvalue method used in AHP. Firouzabadi, Henson and Barnes (2008) presented a decision support methodology for strategic selection decisions used a combination of Analytic Hierarchy Process and Zero-One Goal Programming to address the selection problem from the point of view of an individual stakeholder. Wang, Luo and Hua (2008) showed by examples that the priority vectors determined by the Analytic Hierarchy Process method. Gumus (2008) evaluate hazardous waste transportation firms containing the methods of fuzzy-AHP and TOPSIS. Armillotta (2008) described a computer-based tool for the selection of techniques used in the manufacture of prototypes and limited production runs of industrial products. The underlying decision model based on the AHP methodology, Dagdeviren and Yuksel (2008) presented fuzzy AHP approach to determine the level of faulty behavior risk in work systems.

Chen, Tzeng and Ding (2008) used fuzzy analytic hierarchy process to determine the weighting of subjective/perceptive judgments for each criterion and to derive fuzzy synthetic utility values of alternatives in a fuzzy multi-criteria decision-making environment. Lin, Wang, Chen and Chang (2008) proposed a framework that integrates the analytical hierarchy process and the technique for order preference by similarity to ideal solution to assist designers in identifying customer requirements and design characteristics, and help achieve an effective evaluation of the final design solution.

VIKOR METHOD

This study uses VIKOR (VIseKriterijumska Optimizacija I Kompromisno Resenje) method to evaluate the performance of global top four notebook computer ODM alternatives and rank the priority for them accordingly. The VIKOR method began with the form of L_p-$metric$, which was used as an aggregating function in a compromise programming method and developed into the multi-criteria measure for compromise ranking. The form of L_p-$metric$ was introduced by Opricovic and Tzeng (2004; 2007). We assume the alternatives are denoted as $A_1, A_2, ..., A_i, ..., A_m$, w_i is the weight of the i th criterion, expressing the relative importance of the dimensions, where $i = 1, 2, ..., n$, and n is the number of dimensions. The rating (performance score) of the i th criterion is denoted by f_{ki} for alternative A_k.

Step 1: Determine the best f_i^* and the worst f_i^- values. Because each project is ranked according to its own dimensions, an ideal point and non-ideal point, as in the VIKOR method ($f_i^* = \max_k f_{ki}$ and $f_i^- = \min_k f_{ki}$; setting the aspired/desired level f_i^* and the worst value f_i^- by decision-maker), can be set. Therefore, the benefit or cost must be reset according to the expectation of the decision maker for each criterion of each project, and we call the best f_{ki}^* the aspired level and the worst f_{ki}^- the tolerable level; these functions are expressed as follows:

$f_{ki}^* = aspired\ f_{ki}$ or $f_{ki}^* = aspired\ level$),

$f_{ki}^- = tolerable\ f_{ki}$ or $f_{ki}^- = tolerable\ level$).

We propose an original rating matrix and a normalized weight-rating matrix as follows:

$$\begin{array}{c} criteria \\ \begin{array}{cc} & \begin{array}{ccccc} c_1 & \cdots & c_i & \cdots & c_n \end{array} \\ \begin{array}{c} A_1 \\ \vdots \\ A_k \\ \vdots \\ A_m \end{array} & \begin{bmatrix} f_{11} & \cdots & f_{1i} & \cdots & f_{1n} \\ \vdots & & \vdots & & \vdots \\ f_{i1} & \cdots & f_{ki} & \cdots & f_{kn} \\ \vdots & & \vdots & & \vdots \\ f_{m1} & \cdots & f_{mi} & \cdots & f_{mn} \end{bmatrix} \\ & \begin{array}{ccccc} f_1^* & \cdots & f_i^* & \cdots & f_n^* \\ f_1^- & \cdots & f_i^- & \cdots & f_n^- \end{array} \end{array} \end{array} \quad \begin{array}{c} normalized \\ gaps \\ \Rightarrow \\ \times w_i \end{array} \quad \begin{array}{c} criteria \\ \begin{array}{cc} & \begin{array}{ccccc} c_1 & \cdots & c_i & \cdots & c_n \end{array} \\ \begin{array}{c} A_1 \\ \vdots \\ A_k \\ \vdots \\ A_m \end{array} & \begin{bmatrix} w_1 r_{11} & \cdots & w_i r_{1i} & \cdots & w_n r_{1n} \\ \vdots & & \vdots & & \vdots \\ w_1 r_{i1} & \cdots & w_i r_{ki} & \cdots & w_n r_{kn} \\ \vdots & & \vdots & & \vdots \\ w_1 r_{m1} & \cdots & w_i r_{mi} & \cdots & w_n r_{mn} \end{bmatrix} \end{array} \end{array}$$

alternatives

(Original data) (Normalized data)

where, $r_{ki} = (|\, f_i^* - f_{ki} \,|) / (|\, f_i^* - f_i^- \,|)$, f_i^* is the aspired/desired level and f_i^- is tolerable level for each criterion.

Before we formally introduce the basic concept of the solutions, let us define a class of distance functions by Yu (1973).

$$d_k^p = \left\{ \sum_{i=1}^{n} [w_i (|\, f_i^* - f_{ki} \,|) / (|\, f_i^* - f_i^- \,|)]^p \right\}^{1/p} \tag{9}$$

$$= \left\{ \sum_{i=1}^{n} [w_i r_{ki}]^p \right\}^{1/p}, \quad p \geq 1$$

Step 2: Compute the values S_k and Q_k, $k = 1, 2, \cdots, m$, using the relations

$$S_k = \sum_{i=1}^{n} w_i r_{ki}, \tag{10}$$

$$Q_k = \max_i \{ r_{ki} \mid i = 1, 2, ..., n \}, \tag{11}$$

Where, S_k shows the average gap for achieving the aspired/desired level; Q_k shows the maximal degree of regret for prior improvement of gap criterion.

Step 3: Compute the index values R_k, $k = 1, 2, \cdots, m$, using the relation

$$R_k = v(S_k - S^*)/(S^- - S^*) + (1-v)(Q_k - Q^*)/(Q^- - Q^*) \tag{12}$$

$S^* = \min_k S_k$, $S^- = \max_k S_k$

$Q^* = \min_k Q_k$, $Q^- = \max_k Q_k$

where $S^* = \min_i S_i$ (showing the minimal gap is the best), $S^- = \max_i S_i$, $Q^* = \min_i Q_i$ (showing the minimal degree of regret is the best), $Q^- = \max_i Q_i$.

In addition, $0 \le v \le 1$; when $v > 0.5$, this indicates *S* is emphasized more than *Q* in Equation (12), whereas when $v < 0.5$ this indicates *Q* is emphasized more than *S* in Equation (12). More specifically, when $v = 1$, it represents a decision-making process that could use the strategy of maximum group utility; whereas when $v = 0$, it represents a decision-making process that could use the strategy of minimum individual regret, which is ob-tained among maximum individual regrets/gaps of lower level dimensions of each project (or aspects/ objectives). The weight (v) would affect the ranking order of the projects/aspects/objectives and it is usually determined by the experts or decision making.

Step 4: Rank the alternatives, sorting by the value of {S_k, Q_k and $R_k \mid i = 1, 2, ..., m$}, in decreasing order. Propose as a compromise the alternative which is ranked first by the measure $\min\{R_k \mid k = 1, 2, ..., m\}$ if the following two conditions are satisfied:

C1: *Acceptable advantage*: [illegible], where $A^{(2)}$ is the alternative with second position in the ranking list by R; m is the number of alternatives.

C2: *Acceptable stability in decision making*: Alternative $A^{(1)}$ must also be the best ranked by {S_k or/and $Q_k \mid k = 1, 2, ..., m\}$.

If one of the conditions is not satisfied, then a set of compromise solutions is proposed, which consists of:

(i) Alternatives $A^{(1)}$ and $A^{(2)}$ if only condition C2 is not satisfied.

(ii) Alternatives $A^{(1)}, A^{(2)}, ..., A^{(M)}$ if condition C1 is not satisfied. $A^{(M)}$ is determined by the relation $R(A^{(M)}) - R(A^{(1)}) < 1/(m-1)$ for maximum *M* (the positions of these alternatives are close.

The compromise solution is determined by the compromise-ranking method; the obtained compromise solution could be accepted by the decision makers because it provides maximum group utility of the majority, and minimum individual regret of the opponent. The VIKOR algorithm determines the weight stability intervals for the obtained compromise solution with the input weights given by the experts.

There are also many researches adopt the VIKOR model to investigate the complex managerial problems. Sayadi, Heydari and Shahanaghi (2008) extended the VIKOR method for decision making problems with interval number. Büyüközkan, Feyzioğlu, and Nebol (2007) applied VIKOR method to evaluate of software development projects. Chu, Shyu, Tzeng, and Khosla (2007) to demonstrate the anticipated achievements of knowledge communities (KC) through simple average weight (SAW), “Technique for Order Preference by Similarity to an Ideal Solution” (TOPSIS) and “VIseKriterijumska Optimizacija I Kompromisno Resenje” (VIKOR). Opricovic and Tzeng (2004) compared with four multicriteria decision making methods: TOPSIS, PROMETHEE, ELECTRE, and VIKOR and find out the best method evaluation method is VIKOR. Opricovic and Tzeng (2007) tried to reveal and to compare the procedural basis of these two MCDM methods, TOPSIS and VIKOR.

EMPIRICAL EVIDENCE FOR EVALUATING THE PERFORMANCE OF GLOBAL TOP FOUR NOTEBOOK COMPUTER ODM COMPANIES

The hierarchical structure of this decision problem is shown in Figure 2. The whole hierarchy of accessing the performance of global top four notebook computer ODM companies can be easily visualized from Figure 2. After

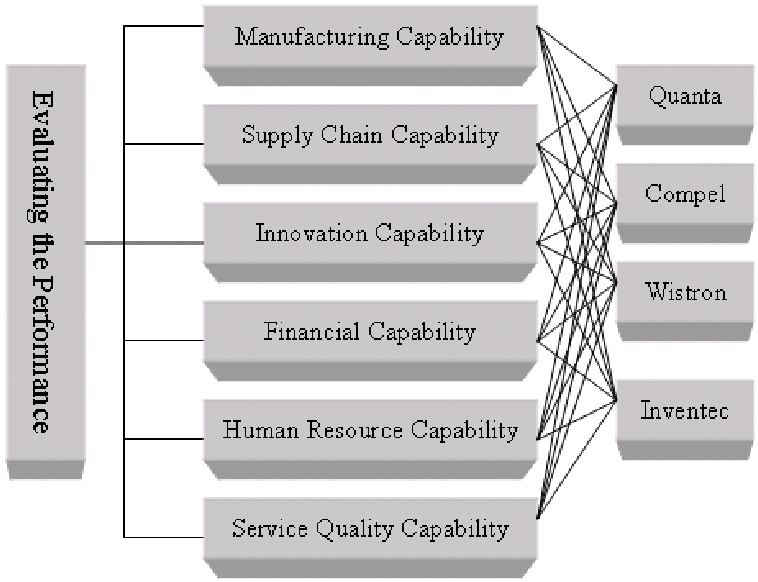

Figure 2. Research framework.

the construction of the hierarchy the different priority weights of each criteria, attributes and alternatives are calculated using the Fuzzy AHP and VIKOR approaches. The comparison of the importance or preference of one criterion, attribute or alternative over another can be done with the help of the questionnaire. The method of calculating priority weights of the different decision alternatives is discussed below.

The weights of evaluation dimensions

We adopt Fuzzy AHP method to evaluate the weights of different dimensions for the performance of notebook computer ODM companies. Following the construction of Fuzzy AHP model, it is extremely important that experts fill the judgment matrix. The following section demonstrates the computational procedure of the weights of dimensions. (1). According to the committee with ten representatives about the relative important of dimension, then the pair-wise comparison matrices of dimensions will be obtained. We apply the fuzzy numbers defined in Table 1. We transfer the linguistic scales to the corresponding fuzzy numbers (as Appendix I).

(2). Computing the elements of synthetic pair-wise comparison matrix by using the geometric mean method suggested by Buckley (1985) that is:

$\tilde{a}_{ij} = (\tilde{a}_{ij}^{1} \otimes \tilde{a}_{ij}^{2} \otimes \ldots \otimes \tilde{a}_{ij}^{10})$, for $\tilde{a}_{12}$ as the example:

$$\begin{aligned}\tilde{a}_{12} &= (1,1,1) \otimes (1,1,1) \otimes \cdots \otimes (2,3,4)^{1/10} \\ &= ((1\times 1\times \cdots \times 2)^{1/10}, (1\times 1\times \cdots \times 3)^{1/10}, (1\times 1 \cdots \times 4)^{1/10}) \\ &= (0.88,1.14,1.37)\end{aligned}$$

It can be obtained the other matrix elements by the same computational procedure, therefore, the synthetic pair-wise comparison matrices of the five representatives will be constructed as follows matrix $\boldsymbol{A}$:

$$\boldsymbol{A} = \begin{array}{c} \\ D_1 \\ D_2 \\ D_3 \\ D_4 \\ D_5 \\ D_6 \end{array} \begin{array}{c} \begin{array}{cccccc} D_1 & D_2 & D_3 & D_4 & D_5 & D_6 \end{array} \\ \begin{bmatrix} 1 & (0.88,1.14,1.37) & (1.21,1.49,1.74) & (0.87,0.98,1.07) & (2.14,2.93,3.79) & (1.06,1.28,1.55) \\ (0.73,0.88,1.14) & 1 & (1.14,1.55,1.91) & (1.76,1.94,2.09) & (2.65,3.36,3.98) & (2.14,2.70,3.19) \\ (0.58,0.67,0.83) & (0.52,0.64,0.88) & 1 & (1.40,1.63,1.93) & (1.56,2.22,\ 2.91) & (1.67,2.13,2.56) \\ (0.93,1.02,1.15) & (0.48,0.52,0.57) & (0.52,0.61,0.71) & 1 & (1.92,2.48,2.96) & (1.64,2.24,2.75) \\ (0.26,0.34,0.47) & (0.25,0.30,0.38) & (0.34,0.45,0.69) & (0.34,0.40,0.52) & 1 & (0.95,1.12,1.25) \\ (0.65,0.78,0.95) & (0.31,0.37,0.47) & (0.39,0.47,0.60) & (0.36,0.45,0.61) & (0.80,0.90,1.06) & 1 \end{bmatrix} \end{array}$$

To calculate the fuzzy weights of dimensions, the computational procedures are displayed as following parts.

$$\begin{aligned}\tilde{r}_1 &= (\tilde{a}_{11} \otimes \tilde{a}_{12} \otimes \tilde{a}_{13} \otimes \tilde{a}_{14} \otimes \tilde{a}_{15} \otimes \tilde{a}_{16})^{1/6} \\ &= ((1\times 0.88\times \cdots \times 1.06)^{1/6},\ (1\times 1.14\times \cdots \times 1.28)^{1/6},\ (1\times 1.37\times \cdots \times 1.55)^{1/6}) \\ &= (1.130,1.358,1.571)\end{aligned}$$

Similarly, we can obtain the remaining $\tilde{r}_i$, there are:

$\tilde{r}_2 = (1.423, 1.699, 1.966)$
$\tilde{r}_3 = (1.017, 1.222, 1.478)$
$\tilde{r}_4 = (0.949, 1.101, 1.248)$
$\tilde{r}_5 = (0.440, 0.524, 0.655)$
$\tilde{r}_6 = (0.533, 0.615, 0.745)$

For the weight of each dimension, they can be done as follows:

$$\begin{aligned}\tilde{w}_1 &= \tilde{r}_1 \otimes (\tilde{r}_1 \oplus \tilde{r}_2 \oplus \tilde{r}_3 \oplus \tilde{r}_4 \oplus \tilde{r}_5 \oplus \tilde{r}_6)^{-1} \\ &= (1.130, 1.358, 1.571) \otimes (1/(1.571+\cdots+0.745), 1/(1.358+\cdots+0.615), \\ &\quad 1/(1.130+\cdots+0.533)) \\ &= (0.147, 0.208, 0.286)\end{aligned}$$

We also can calculate the remaining $\tilde{w}_i$, there are:

$\tilde{w}_2 = (0.186, 0.261, 0.358)$
$\tilde{w}_3 = (0.133, 0.187, 0.269)$
$\tilde{w}_4 = (0.124, 0.169, 0.227)$
$\tilde{w}_5 = (0.057, 0.080, 0.119)$
$\tilde{w}_6 = (0.070, 0.094, 0.136)$

(3). To apply the COA method to compute the BNP value of the fuzzy weights of each dimension: To take the BNP value of the weight of D_1 (Manufacturing Capability) as an example, the calculation process is as follows.

$$\begin{aligned}BNP_{w_1} &= \left[(U_{w_1} - L_{w_1}) + (M_{w_1} - L_{w_1})\right]/3 + L_{w_1} \\ &= \left[(0.286 - 0.147) + (0.208 - 0.147)\right]/3 + 0.147 \\ &= 0.20\end{aligned}$$

Then, the weights for the remaining dimensions can be found as shown in Table 2. Table 2 shows the relative weight of six dimensions of the evaluation of notebook computer companies, which obtained by AHP method. The weights for each dimension are: Manufacturing Capability (0.20), Supply Chain Capability (0.26), Innovation Capability (0.19), Financial Capability (0.17), Human Resource Capability (0.08) and Service Quality Capability (0.10). From the Fuzzy AHP results, we can understand the first two important dimensions for the evaluation of notebook computer companies are Supply Chain Capability (0.26) and Manufacturing Capability (0.2). Moreover, the less important dimension is Human Resource Capability (0.08).

Estimating the performance and ranking the alternatives

This paper focuses on evaluating the performance of global four notebook computer ODM companies; so, we assume that questionnaire have collected completely and will start with building dataset that are collected. We had been collected 10 experts in the sample, and then we can undertake to construct dataset with VIKOR method. As mentioned previously, the experts express their preference for criteria weights and alternatives linguistically. The consensus weights of criteria identified through the fuzzy AHP methodology are shown in Table 2 and each expert's evaluation of alternatives are given as Table 3. In addition, this research calculates the normalized value and the results are shown in Table 4.

Compute the values S_k and Q_k, using Equations (9) and (10) to obtain S_k and Q_k. The value of S_k and Q_k are shown in Table 5.

Compute the values R_k, using Equation (12), where $S^* = best\_S = 0$, $S^- = worse\_S = 1$, $Q^* = best\_Q = 0$, $Q^- = worse\_Q = 1$, v = 0 or 0.5 or 1. In this case, we set up the values S^* and Q^* as 0, the values S^- and Q^- as 1, so as to obtain the absolute relations for the index values R_k.

In order to understand how the R_k of each objective is affected by v ($0 \le v \le 1$), $R_k = v(S_k - S^*)/(S^- - S^*) + (1-v)(Q_k - Q^*)/(Q^- - Q^*)$, this study respectively adopts v = 0, v = 0.5, v = 1 to compare these index values R_k for the control objectives before and after implementation and presents them in Table 5.

DISCUSSION AND MANAGERIAL IMPLICATIONS

The purpose of this study is aimed at determining the best notebook computer ODM company alternative by using an integrated VIKOR-AHP methodology. From the proposed method, Fuzzy AHP and Fuzzy VIKOR, we find out the first two important dimensions for notebook computer ODM companies are supply chain capability and manufacturing capability. We established six dimensions (Manufacturing Capability, Supply Chain Capability, Innovation Capability, Financial Capability, Human Resource Capability and Service Quality Capability) and a total of seventeen factors using fussy AHP in order to formulate an effective dissemination program and appraise it. Then this study employs the VIKOR method, which is a compromise ranking method used for Multi-Criteria Decision Making (MCDM), to optimize the

Table 3. Aspired value and worst value of four notebook computer ODM companies.

		Alternative			
		A1	**A2**	**A3**	**A4**
Dimension	**D1**	4.0	3.7	3.7	2.8
	D2	4.1	3.8	3.4	2.8
	D3	3.8	3.3	3.5	3.0
	D4	4.3	3.9	3.8	3.1
	D5	3.9	3.5	3.4	2.8
	D6	4.0	3.7	3.6	2.7
Aspired level (f_i^*)		5.0	5.0	5.0	5.0
Worst level (f_i^-)		0.0	0.0	0.0	0.0

Table 4. Normalized gap-values of four notebook computer ODM companies ($r_{ki} = (|f_i^* - f_{ki}|)/(|f_i^* - f_i^-|)$).

		Alternative				Weighting
		A1	**A2**	**A3**	**A4**	
Dimension	**D1**	0.20	0.26	0.26	0.44	0.20
	D2	0.18	0.24	0.32	0.44	0.26
	D3	0.24	0.34	0.30	0.40	0.19
	D4	0.14	0.22	0.24	0.38	0.17
	D5	0.22	0.30	0.32	0.44	0.08
	D6	0.20	0.26	0.28	0.46	0.10

Note: Boldface means the max value of r_{ki} for each alternative.

Table 5. Comparison of value R_k of four notebook computer ODM companies according to (v=0), (v=0.5), (v=1).

		Average gap-value S_k ($v=1$)	**Compromise gap-value** ($S_k + Q_k$)/2 ($v=0.5$)	**Max gap-value** Q_k ($v=0$)
Alternative	**A1**	0.19 (1)	0.21 (1)	0.22 (1)
	A2	0.27 (2)	0.30 (2)	0.34 (3)
	A3	0.29 (3)	0.31 (3)	0.32 (2)
	A4	0.42 (4)	0.44 (4)	0.46 (4)

Note: "( )" mean the ranking orders of each notebook computer ODM company.

multi-response process. The proposed method considers both the mean and the variation of quality losses associated with several multiple responses, and ensures a small variation in quality losses among the responses, along with a small overall average loss.

Moreover, the research obtains different ranking orders of R_k according to (v=0), (v=0.5) and (v=1). When the strategy of maximum group utility is adopted and the individual regret ignored, (v=1) can be selected for the calculation, whereas when the individual regret is considered and the strategy of maximum group utility ignored, (v=0) can be selected. Generally speaking, when decision makers simultaneously are concern about the strategy of maximum group utility and the minimum individual regret, then v = 0.5 should be selected. This selection is decided based on the preference (concern) of the decision makers. In this case, we can understand that the Quanta and Compel rank the best two companies (based on $v = 0.5$).

Better manufacturing ability could predict resource capacities and competing resource requirements provides more accurate forecasts of production lead time. This ability comes from the acuity gained through improved communication, scanning, and analysis. Then greater responsiveness provides flexibility to react to schedule variations and changes. Competing in the marketplace on the basis of cost efficiency requires striving for low cost production. In order to keep manufacturing costs competitive, managers must address materials, labor, overhead, and other costs. Inventories have long been the focus of cost reduction in factories and are one of the justifications of the JIT system. Therefore, inventory and inventory-related items, such as improving vendor's quality, reducing waste of purchased materials, are considered as the indicators of the cost capability. Realizing low inventory level, decreasing labor cost, and reducing machine time are all positive factors of the cost efficiency construct (Demir and Bostanci, 2010).

In addition, online tool launched to help companies improve supply chain capability. The web-based information system could provide sufficient detail and richness to steer supply chain performance. Then the enterprises should design the demand planning, manufacturing planning and transportation and logistics planning. Demand planning can gain advanced fore-casting capabilities to more accurately predict and shape customer demand while sufficiently preparing for a multitude of unforeseen changes capable of both positively and negatively affecting demand. Manufacturing planning could help ensure maximized efficiency throughout entire supply chain by streamlining each of manufacturing process to make the most of valuable assets while reducing total costs. Transportation and logistics planning could overcome the complex challenges of optimally coordinating pick-up and delivery times across multiple worldwide locations, while adhering to a growing number of international regulations to ensure customers consistently receive the right goods at the right time.

CONCLUSIONS AND REMARKS

The aim of this research is to construct a Fuzzy AHP and VIKOR model to evaluate different notebook computer ODM companies. In the evolution step six evaluation dimensions were taken into consideration. The results of the multi-criteria decision analysis suggest that the Quanta is the best notebook computer ODM company alternative In the performance evaluation for the notebook computer ODM companies including manufacturing capability, financial capability, innovation capability, supply chain capability, human resource capability and service quality capability. These factors are to generate a final evaluation ranking for priority among these notebook computer ODM companies of the proposed model. The importance of the dimensions is evaluated by experts, and the uncertainty of human decision-making is taken into account through the fuzzy concept in fuzzy environment. From the proposed method, Fuzzy AHP and VIKOR, we find out the first two important dimensions for the competitive advantages of notebook computer ODM Company are supply chain capability and manufacturing capability. On the other hand, human resource capability and service quality capability rank last priorities among these dimensions. Moreover, the Quanta and Compel rank the first two performances for these companies.

The further research can explore that how to improve the gaps in each criteria based on Network Relationship Map (NRM) and capture the complex relationships among these evaluation criteria. The NRM is not only to find out the most important criteria for the competitive advantages of notebook computer ODM Company but also to measure the relationships among these evaluation criteria.

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