Computers & Education 55 (2010) 188–201

Contents lists available at ScienceDirect

Computers & Education

journal homepage: www.elsevier.com/locate/compedu

Implementation and performance evaluation using the fuzzy network balanced scorecard

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ARTICLE INFO

Article history:
Received 8 April 2009
Received in revised form 2 January 2010
Accepted 10 January 2010

Keywords:
Evaluation methodologies
Interdisciplinary projects
Analytic network process
DEMATEL
Fuzzy set theory
Balanced scorecard

ABSTRACT

The balanced scorecard (BSC) is a multi-criteria evaluation concept that highlights the importance of performance measurement. However, although there is an abundance of literature on the BSC framework, there is a scarcity of literature regarding how the framework with dependence and interactive relationships should be properly implemented in uncertainty. This study proposes a hybrid approach: the analytic network process (ANP) is used to analyze the dependence aspects, the decision-making trial and evaluation laboratory (DEMATEL) is used to deal with the interactive criteria, and the fuzzy set theory is used to evaluate the uncertainty. The four BSC aspects and 22 criteria are evaluated for a private university of science and technology in Taiwan. The results show that student acquisition is the most influential and weighty criterion, and the annual growth in revenue is the most effective criterion. Managerial implications are also discussed, and concluding remarks are made.

1. Introduction

The performance evaluation of a university is an ongoing process that requires continuous monitoring to maintain a high level of internal process evaluation across a number of aspects of an organization. In terms of internal process evaluation, the balanced scorecard (BSC) is well recognized in the literatures that performance measurement should be incorporated in both of financial and non-financial measures; it captures not only a firm's current performance but also the drivers of its future performance (Banker & Datar, 1989; Dyson, 2000). There are few studies of the development and implementation of the BSC in measuring the performance of university activities, though there are BSC studies on other industries such as banking, textiles, pharmaceuticals (Bremser & Barsky, 2004; Cebeci, 2009; Li & Dalton, 2003; Neufeld, Simeoni, & Taylor, 2001; Wu, Tzeng, & Chen, in press). Even fewer studies deal with the dependent relationships of the BSC with measures in qualitative approaches to measurement activities and implementations in a university.

Hence, although the BSC conceptual framework has been widely accepted in the business community, the proper method of implementing the framework remains an issue. For instance, Leung, Lam, and Cao (2006) incorporated a wider set of non-financial attributes into the measurement system of a firm by using the analytic hierarchy process (AHP) and its variant, the analytic network process (ANP), to facilitate the implementation of the BSC. Yuan and Chiu (2009) used the BSC design and proposed a three-level feature weighting system designed to enhance case-based reasoning inference performance. A genetic algorithm mechanism was employed to facilitate weighting of all levels in the BSC and to determine the most appropriate three-level feature weighting system. The proposed approach is compared with the equal weights approach and the AHP approach. It minimizes the effect of subjective factors that have to be carefully dealt with in the performance evaluation process. Cebeci (2009) proposed that a decision support system integrated with strategic management by using the BSC may be an alternative to some methods of ERP selection. The enterprise resources plan packages and vendors for textile firms were compared using fuzzy AHP. In view of the interdependence complexity, it is anticipated that the evaluation of the BSC in firms' performance measurements and reward systems will result in multi-dimensional difficulties. Besides, some of the qualitative criteria measured in linguistic expression are vague and uncertain in nature, making the evaluation fuzzy network balanced scorecard (FNBSC) even more challenging.

Nevertheless, the BSC is a model for the analysis of performance measurements and reward systems for all types of organizations and was developed by Kaplan and Norton in 1992. The BSC is an important activity that helps organizations make continuous improvements

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doi:10.1016/j.compedu.2010.01.004

due to a great emphasis on performance measurement. It engenders multi-dimensional difficulties that involve numerous organizational functions and resource integration among various departments (Tseng, 2009a; Tseng, Lin, Chiu, & Liao, 2008). Moreover, the BSC categorizes evaluation measures' four aspects: finances, student, internal operations process, and learning and growth. With the BSC, universities can evaluate their management in terms of their effectiveness in creating value for students, developing internal capabilities, and investing in the people and systems that are necessary to improve future performance. This implies that dependence relationships exist in the BSC aspects and criteria. However, the traditional statistical approach is no longer suited to evaluating proposed network BSC (NBSC) due to the traditional approach assumed that the aspects and criteria are always independent. The evaluation-related activities have inherent and high uncertainty and imprecision, and they are difficult to assess accurately with qualitative information.

Previous studies identified the evaluation method using the AHP. For example, the study by Hwang, Huang, and Tseng (2004) proposed several soft computing technologies, including fuzzy theory, the grey system and the group decision method to approach a computer-assisted web site evaluation system that is capable of selecting the proper criteria for an individual web site and achieving greater accuracy when evaluating results. Shee and Wang (2008) proposed a multi-criteria methodology (AHP) to study web-based e-learning systems, including skill training and knowledge acquisition. Lin (in press) presented an empirical evaluation of the relative importance of different online learning experiences using fuzzy AHP. However, none of them consider the dependence and interaction of the aspects and criteria of BSC. This study proposes the utilization of the ANP technique to analyze the proposed NBSC. The ANP developed by Saaty (1996) takes into account the relationship of feedback and dependence. In addition to these merits, ANP provides a more generalized model of decision-making without making assumptions about the independent relationships among the aspects and criteria.

In view of qualitative measures, fuzzy set theory can address situations that lack well-defined boundaries of activity or observation sets (Zadeh, 1965, 1975). In many practical cases, human preferences are uncertain and qualitatively descriptive, and it is not easy to assign exact numerical values to precisely describe the preferences. Linguistic terms have been used for approximate reasoning within the framework of fuzzy set theory to handle the ambiguity of evaluating data and the vagueness of linguistic expression. Hence, fuzzy set theory can express and handle vague or imprecise judgments mathematically (Al-Najjar & Alsyouf, 2003; Tseng, Chiang, & Lan, 2009; Tseng & Lin, 2009). A linguistic preference is a variable whose values (namely linguistic values) have the form of phrases or sentences in a natural language (von Altrock, 1996). In particular, linguistic preferences are used to evaluate aspects or criteria whose values are not numbers but linguistic terms. In practice, linguistic values can be represented by fuzzy numbers, and the triangular fuzzy number (TFN) is commonly used. Moreover, the quantitative measures should transform into comparable crisp values to allow for comparison with all the qualitative measures. Therefore, this study adopts fuzzy set theory to assess NBSC in the assessment of performance measurement and reward systems.

This study addresses two important and related aspects of the implementation of NBSC: (1) the handling of the dependency and interactions of aspects and criteria – especially those of a qualitative nature – and (2) the transformation of the crisp values to compare with the other measures and determine the contribution of the respective aspects and criteria. In view of the respective advantages of the proposed methods, this study attempts to propose an approach, called the "fuzzy network balanced scorecard (FNBSC)" method, to evaluate the assessment of performance measurement. The rationale of the proposed approach is to combine fuzzy set theory, the DEMATEL and the ANP method, wherein fuzzy set theory accounts for the linguistic vagueness of qualitative criteria, DEMATEL analyzes the interaction among the criteria, and ANP converts the dependence relationship in the hierarchical structure into intelligible weights (Tseng, 2009a; Tseng et al., 2009; Wu & Lee, 2007).

Therefore, the aim of this study is to propose FNBSC as a performance evaluation method when the aspects and criteria are dependent and interaction is uncertain. In the case study, four aspects of BSC for a private university of science and technology in Taiwan will be evaluated: the financial aspect, student aspect, internal operations aspect and learning and growth aspect. Moreover, the uncertainty is mainly due to the rapid changes of marketing information and human perceptions, while the dependence and interaction are mainly due to the aspects and criteria. The remainder of this study is organized as follows. Section 2 presents the proposed approach – the FNBSC. Section 3 subsequently applies the proposed approach to evaluating a case firm. This is followed by managerial implications in Section 4 and conclusions in Section 5.

2. Research method

Let us define the FNBSC by first saying that there are multiple evaluation criteria that are frequently structured into multi-level hierarchies. Hence, the first phase is to define the decision objectives. After defining the decision objectives, what is required is to generate and establish evaluation objectives in the current scenario, which is similar to a chain of determinants-aspects and criteria. As discussed in the previous section, four aspects of FNBSC are to be considered. Overall, FNBSC evaluation can be obtained by (i) assigning weights to four aspects ($AS1$, $AS2$, $AS3$, $AS4$) and their associated x_{ij} criteria (x_{ij}, $i = 1, 2, 3, 4$; $j = 1, 2, \ldots, x_j$) and (ii) assessing the performance rating of each aspect and its associated criteria. This section introduces the FNBSC approach, the fuzzy set theory, the ANP technique, and the DEMATEL method, and it is followed by the proposed analytical procedures.

2.1. NBSC hierarchical structure

This section presents the evaluation aspects and criteria for the FNBSC approach. The evaluation framework consists of four aspects with 22 criteria, which were determined from an extensive literature review. In this study, four primary dependence aspects of NBSC were identified and evaluated: the financial aspect, student aspect, internal operations aspect, and learning and growth aspect. The hierarchical structure is derived from Kaplan and Norton (1992), Kaplan and Atkinson (1998), and Leung et al. (2006). Kaplan and Norton (1996) also emphasized that the BSC is only a template and must be customized for the specific elements of an organization or industry. The BSC presents the knowledge, skills, and systems that the employees will need (learning and growth aspect) to innovate and build the right strategic capabilities and efficiencies (internal operations aspect) that deliver specific value to the university student population (student aspect), eventually leading to a higher shareholder value (financial aspect). It has even been proven that dependence relationships exist in the evaluation process.

Financial aspect (*AS*1): financial objectives serve as the focus for the objectives and measures of the other criteria. Every measure should be part of dependence relationships culminating in long-term and sustainable financial performance. The measures are sales, cost of revenue, profit margin, and new educational department/services. Student aspect (*AS*2): financial success is closely linked to student satisfaction. Satisfied students mean repeat business, referrals and new services, student retention, student acquisition, student complaints, student satisfaction, and they thereby contribute to the financial results of the university. Internal operations aspect (*AS*3): student satisfaction is directly achieved through the operational activities. The objectives and measures for this aspect thus enable a university to focus on maintaining and improving the performance of processes that deliver the established objectives that are keys to satisfying students, which in turn satisfy shareholders. The criteria are service processing time, cost of service quality comparison, reduction of service cost, facility utilization rate and environmental safety incident index. Learning and growth aspect (*AS*4): the ability, flexibility, and motivation of staff support all of the financial results. Student satisfaction and operational activities are measured in the other quadrants of the BSC. The criteria of this aspect are rate of new services/educational department introduction per year, number of new services/educational department with successful introduction to the public, faculty/employee satisfaction survey, faculty/employee retention, number of promotions from within, and absenteeism rate.

The BSC shows how the overall strategic objectives of a university are translated into the performance measurement drivers that the university has identified as critical success factors (criteria). The performance drivers are translated into more tangible measures that allow the university to quantify the performance measurement drivers. It should be noted that this study considers the collective evaluation results; thus, the information of one aspect may be subsumed by that of another aspect. Table 1 presents the evaluation aspects and criteria for a university's BSC, narrated in detail as follows.

2.2. Fuzzy set theory

To determine the qualitative measures, fuzzy set theory can express and handle vague or imprecise judgments mathematically. In fuzzy set theory, each number between 0 and 1 indicates a partial truth, whereas crisp sets correspond to binary logic [0, 1]. In particular, to tackle the ambiguities involved in the process of linguistic estimation, it is beneficial to convert these linguistic terms into TFNs. This study builds on some important definitions and notations of fuzzy set theory from Chen (1996) and Cheng and Lin (2002). Some definitions are as follows:

Definition 1. A TFN $\tilde{N}$ can be defined as a triplet (*l, m, u*), and the membership function $\mu_{\underset{N}{\sim}}(x)$ is defined as:

$$\mu_{\underset{N}{\sim}}(x)\begin{cases} 0, & x \prec l \\ (x-l)/(m-l), & l \leqslant x \leqslant m \\ (u-x)/(u-m), & m \leqslant x \leqslant u \\ 0, & x \succ u \end{cases} \tag{1}$$

where l, m, and u are real numbers and $l \leqslant m \leqslant u$. See Fig. 1.

Definition 2. Let $\tilde{N}_1 = (l_1, m_1, u_1)$ and $\tilde{N}_2 = (l_2, m_2, u_2)$ be two TFNs. The multiplication of $\tilde{N}_1$ and $\tilde{N}_2$ is denoted by $\tilde{N}_1 \otimes \tilde{N}_2$. Two positive TFNs, $\tilde{N}_1 \otimes \tilde{N}_2$, approximate a TFN as follows:

$$\tilde{N}_1 \otimes \tilde{N}_2 \cong (l_1 \otimes l_2, m_1 \otimes m_2, u_1 \otimes u_2) \tag{2}$$

Table 1
Evaluation aspects and criteria of BSC approach.

Aspects	Criteria
Financial aspect (AS1)	Annual growth in revenue (C1) Cost of revenue: extent that it remains flat or decreases each year (C2) Profit margin: return on total capital employed (C3) Growth from new services/educational departments (C4) Industry leadership: market share (C5)
Student aspect (AS2)	Student retention/percentage of growth with existing students (C6) Student acquisition: number of new students/total revenue to new students (C7) Student satisfaction (via satisfaction surveys) (C8) Student profitability (via accounting analyses) (C9) Service quality: student complain rates (C10)
Internal operations aspect (AS3)	Service cycle processing time (C11) Cost of service quality comparison (Other institutions) (C12) Reduce service costs: service costs as percentage of revenue(C13) Service output per hour/facilities utilization (C14) Environmental safety incident index (C15)
Learning and growth aspect (AS4)	Innovation of services/products measures (C16) Rate of new services/educational package introduction per year (C17) Faculties/employee capabilities (C18) Faculties/employee satisfaction survey (C19) Faculties/employee retention: percentage of key staff turnover (C20) Number of promotions from within (C21) Absenteeism rate (C22)

Note: The four aspects are with dependence relationship and self-feedback; the criteria are interactive.

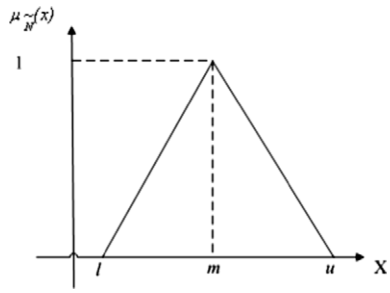


Fig. 1. A triangular fuzzy number $\tilde{N}$.

The criteria consist of four aspects and 22 measures and were determined from an extensive literature review and an expert team. Two triangular fuzzy membership functions (Tables 2 and 3) can accommodate the qualitative data while the evaluators process the evaluation in linguistic information. This proposed framework allows experts to identify options using linguistic expressions. The unique point of this study involved qualitative measures in linguistic terms that were presented by TFNs and defuzzified into a crisp value for analysis in a cause and effect model. The following tables present the application of TFNs for the ANP and DEMATEL techniques.

Furthermore, in achieving a favorable solution, group decision-making is usually important in any organization. This is because the process of arriving at a consensus should be based upon the reaction of multiple individuals, from which an acceptable judgment may be obtained. To deal with the problems of uncertainty, an effective fuzzy aggregation method is required. Any fuzzy aggregation method always needs to contain a defuzzification method because the results of human judgments with fuzzy linguistic variables are fuzzy numbers. The defuzzification refers to the selection of a specific crisp element based on the output fuzzy set, which converts fuzzy numbers into crisp value. This study applied the converted fuzzy data into crisp scores. As developed by Opricovic and Tzeng (2003), the main procedure of determining the left and right scores by fuzzy minimum and maximum involves determining the total score as a weighted average according to the membership functions.

Assume $\tilde{X}$ to be an arbitrary convex and bounded fuzzy number. The assessed values of qualitative criteria metrics for NBSC are $\tilde{X} = ({}_{L}x_{ij}, {}_{m}x_{ij}, {}_{R}x_{ij})$, $i = 1, 2, 3, 4$, and $j = 1, 2, 3, \ldots, 7$ in this study. $\tilde{X} = ({}_{L}x_{ij}, {}_{m}x_{ij}, {}_{R}x_{ij})$ are the TFNs; x_{ij} presents at the left, middle and right positions; ${}_{L}x_{ij}^{k}, {}_{m}x_{ij}^{k}, {}_{R}x_{ij}^{k}$ represent overall average ratings of aspect ith, criterion jth over kth evaluators; and x_{ij}^{p}, $p = 1, 2, \ldots, k$, are fuzzy numbers for each evaluator. The normalization of TFNs is as follows:

$$\begin{cases} z_{L}x_{ij}^{p} = \left({}_{L}x_{ij}^{k} - min_{L}x_{ij}^{k}\right) \Big/ \delta_{min}^{max} \\ z_{m}x_{ij}^{p} = \left({}_{m}x_{ij}^{k} - min_{m}x_{ij}^{k}\right) \Big/ \delta_{min}^{max}; \quad \text{where } \delta_{min}^{max} = max_{R}x_{ij}^{k} - min_{L}x_{ij}^{k} \\ z_{R}x_{ij}^{k} = \left({}_{R}x_{ij}^{k} - min_{R}x_{ij}^{k}\right) \Big/ \delta_{min}^{max} \end{cases} \tag{3}$$

Compute the left (ls) and right (rs) normalized value

$$\begin{cases} zls_{ij}^{p} = z_{m}x_{ij}^{k} \Big/ \left(1 + {}_{m}x_{ij}^{k} - {}_{L}x_{ij}^{k}\right) \\ zrs_{ij}^{p} = z_{R}x_{ij}^{k} \Big/ \left(1 + {}_{R}x_{ij}^{k} - {}_{m}x_{ij}^{k}\right) \end{cases} \tag{4}$$

Compute the total normalized crisp value

$$y_{ij}^{k} = \left[zls_{ij}^{p}\left(1 - zls_{ij}^{p}\right) + zrs_{ij}^{k} zrs_{ij}^{k}\right] \Big/ \left[1 - zls_{ij}^{p} + zrs_{ij}^{p}\right] \tag{5}$$

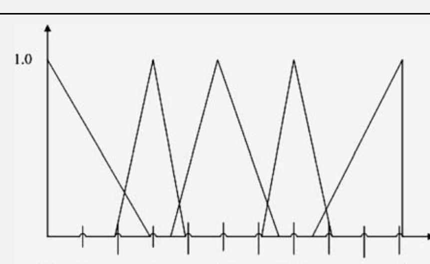
Compute crisp values:

$$w_{ij}^{k} = min_{L}x_{ij}^{k} + y_{ij}^{k}\delta_{min}^{max} \tag{6}$$

To integrate the different opinions of evaluators, this study adopts the synthetic value notation to aggregate the subjective judgment for k evaluators, given by

Table 2
Linguistic scales/model for the importance weight of aspects for ANP.

Linguistic variable	(TFNs)
Equal importance	(0, 0, 0.3)
Moderate importance	(0.2, 0.3, 0.4)
Strong importance	(0.35, 0.5, 0.65)
Demonstrated importance	(0.6, 0.7, 0.8)
Extreme importance	(0.75, 1.0, 1.0)

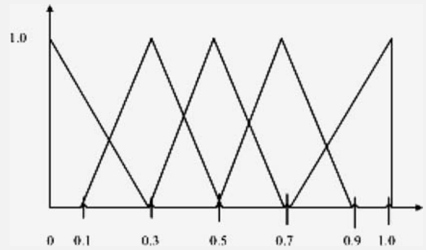


Triangular fuzzy membership functions

Note: This table is the linguistic scale and their corresponding TFNs defined by Wang, Lu, and Chen (2008).

Table 3
Linguistic scales/model for the importance weight of criteria for DEMATEL.

Linguistic variable	(TFNs)
No influence	(0, 0.1, 0.3)
Very low influence	(0.2, 0.3, 0.5)
Low influence	(0.3, 0.5, 0.7)
High influence	(0.5, 0.7, 0.9)
Very high influence	(0.7, 0.9, 1.0)



Triangular fuzzy membership functions

Note: This table is the linguistic scale and their corresponding TFNs defined by Wang and Chang (1995) and used in Chen (2000).

$$\tilde{w} = \frac{1}{k}\left(\tilde{w}_{ij}^1 + \tilde{w}_{ij}^2 + \tilde{w}_{ij}^3 + \cdots + \tilde{w}_{ij}^k\right) \tag{7}$$

2.3. Dematel

The DEMATEL method is especially practical and useful for visualizing the structure of complicated causal relationships with matrices or digraphs (Fontela, Gabus, & DEMATEL, 1976). The matrices or digraphs portray a contextual relation between the elements of the system, in which a numeral represents the strength of influence. Hence, 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 (Hori & Shimizu, 1999; Sankar & Prabhu, 2001; Seyed-Hosseini, Safaei, & Asgharpour, 2006; Tseng, 2010, 2009c). The essentials of the DEMATEL method suppose that a system contains a set of criteria $C = \{C_1, C_2, \ldots, C_n\}$, and the particular pairwise relations are determined for modeling with respect to a mathematical relation. The solving steps are as follows.

2.3.1. Generating the direct-relation matrix

The initial data can be obtained as the direct-relation matrix that is a $n \times n$ matrix A, in which a_{ij} is denoted as the degree to which criterion i affects criterion j.

2.3.2. Normalizing the direct-relation matrix

On the basis of the direct-relation matrix A, the normalized direct-relation matrix X can be obtained through the following formulas:

$$X = k \cdot A \tag{8}$$

$$k = \frac{1}{\max\limits_{1 \leqslant i \leqslant n} \sum_{j=1}^{n} a_{ij}}, \quad i,j = 1,2,\ldots,n \tag{9}$$

2.3.3. Obtaining the total-relation matrix

Once the normalized direct-relation matrix X is obtained, the total-relation matrix T can be acquired by using Eq. (10), in which I is denoted as the identity matrix:

$$T = X(I - X)^{-1} \tag{10}$$

2.3.4. Producing a causal diagram

The sum of rows and the sum of columns are separately denoted as vector D and vector R, respectively, through Eqs. (8)–(13).

$$T = [t_{ij}]_{nxn}, \quad i,j = 1,2,\ldots,n \tag{11}$$

$$D = \left[\sum_{i=1}^{n} t_{ij}\right]_{nx1} = [t_i]_{nx1} \tag{12}$$

$$R = \left[\sum_{j=1}^{n} t_{ij}\right]_{1xn} = [t_j]_{1xn} \tag{13}$$

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

2.3.5. Obtaining the dependence matrix

In this step, the sum of each column in the total-relation matrix is equal to 1 by the normalization method, and then the dependence matrix can be acquired.

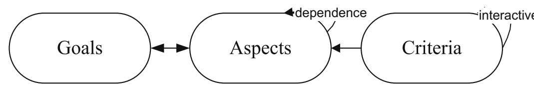


Fig. 2. The modified feedback system model.

2.4. ANP

The ANP, also introduced by Saaty (1996), is a generalization of the analytical hierarchical process (AHP). While the AHP represents a framework with a unidirectional hierarchical AHP relationship, the ANP allows for complex interrelationships among decision levels and criteria. The ANP feedback approach replaces hierarchies with networks in which the relationships between levels are not easily represented as higher or lower, dominant or subordinate. Hence, given the problems encountered in reality, a dependent and feedback relationship is usually generated among the evaluation criteria, and such an interdependent relationship usually becomes more complex with the change in scope and depth of the decision-making problems. A two-way arrow among different levels of criteria may graphically represent the dependencies in an ANP model. If dependencies are present within the same level of analysis, a ‘‘looped arc” may be used to represent such interdependence. Fig. 2 shows the dependence structure with an intertwined relationship of the proposed framework. The following descriptions are the equations applied in this approach.

ANP uses a supermatrix to deal with the relationship of feedback and interdependence among the criteria. If no interdependent relationship exists among the criteria, then the pairwise comparison value would be 0. If an interdependent and feedback relationship exists among the criteria, then such a value would no longer be 0, and an unweighted supermatrix M would be obtained. If the matrix does not conform to the principle of column stochastic, the decision-maker can provide the weights to adjust it into a supermatrix that conforms to the principle of column stochastic, and it will become a weighted supermatrix M. Then, the limited weighted supermatrix M^* is obtained based on Eq. (14), and a gradual convergence of the interdependence relationship results in the obtaining of the accurate relative weights among the criteria:

$$M^* = \lim_{k\to\infty} M^k \tag{14}$$

Moreover, the ANP is the mathematical theory that can deal with all kinds of dependences systematically. The ANP has been successfully applied in many fields (Shang, Tjader, & Ding, 2004; Yurdakul, 2004). Lee and Heller (1997) proposed the hierarchical organization of the feedback system and the possible system paths to evaluate an interactive computer system in a museum setting. Messey (2008) showed that multi-objective resource allocation of shared resources by group decision-making can combine analytic and qualitative modeling. Additionally, Messey (2008) showed that the subsequent phases of the qualitative and analytic solutions of a multi-objective cooperative resource allocation problem can be applied within the group decision-making framework of capability-based planning defense requirements. The merits of ANP in group decision-making are as follows (Dyer & Forman, 1992; Tseng et al., 2008): (i) tangibles and intangibles and individual and shared values can be included in the decision process; (ii) the discussion in a group can be focused on objectives rather than on alternatives; (iii) the discussion can be structured so that every factor relevant to the decision is considered; and (iv) in a structured analysis, the discussion continues until relevant information from each individual member in the group is considered and a consensus is achieved.

2.5. Proposed approach

In order to improve the performance of previous methods, this study proposes the following steps in the new approach:

1. Identify decision objectives, gather the relevant information to evaluate the advantages and disadvantages of the decision, and monitor the results to ensure the objective is achievable. This is necessary to forming an expert committee and having group knowledge achieve the evaluation goal.
2. Develop evaluation BSC aspects and criteria and a survey instrument. This is important for establishing a set of aspects and criteria for evaluation. However, the aspects and criteria have the nature of complicated relationships within the cluster of criteria. To deal with the problem of dependence and interaction, the ANP and DAMATEL methods can be applied. Acquire the responded instruments to check the relations among the evaluation criteria. It is necessary to consult with a group of experts to confirm reliable information regarding the criteria influences and directions.
3. Normalize the crisp value number to achieve criteria values that are comparable among all criteria. Interpret the linguistic preferences into TFNs and convert the fuzzy numbers into crisp value, the fuzzy assessments using the definition in Eq. (1) and (2) and applies the Eqs. (3)–(7) are defuzzified and aggregated as a crisp value ($\tilde{w}$).
4. Compose the crisp value from the unweighted supermatrix. The interactive matrix is determined from the DEMATEL method using Eqs. (8)–(13).
5. Compose the unweighted supermatrix from the several DEMATEL interactive matrices and ANP dependence matrix results. The supermatrix is a partitioned matrix, where each submatrix is composed of a set of relations of feedback or dependency. The final result can obtain the normalized unweighted supermatrix from the multiplied result and raises the limiting powers to calculate the overall priority weights, using Eq. (14).

3. A case study

This study attempts to apply the proposed FNBSC approach to evaluate the case study. The data and results are addressed in this section.

3.1. A case study

A university of science and technology in Taiwan wished to evaluate its performance measurement competencies by initiating the BSC. To enhance competitiveness and fully satisfy the market demands, a systematic FNBSC evaluation was developed. Since the FNBSC can take into consideration four aspects, the management tried to understand the performance measurement evaluation. The first of its difficulties stemmed from the fact that the criteria in the BSC model are not quantitative. This study first presented this analytical approach to NCS using ANP, DEMATEL, and fuzzy set theory to analyze the BSC framework. An expert team was then formed, which contained one professor and five management professionals with extensive experience consulting in this study. After a long interview with these experts, the expert group was sure that they somehow understood the ANP, DEMATEL, and fuzzy set theory needed to analyze the BSC for a weighting process. Fig. 3 is the BSC evaluation framework for this case study.

3.2. Study problem

Thus the university decided to develop and determine the weights of BSC aspects and criteria in the solution of their restructured organization. However, these were its reasons: first, the private university continued to improve internal operations processes and faced a challenge regarding how to manage the four aspects in the competitive environment. Second, the university had to sustain reform as its performance measurement in order to deal with intensive market competition. The management was thinking of evaluating the performance measurement using FNBSC. The management expected that FNBSC can help the university resolve their performance measurement, as it requires promoting FNBSC core competence to survive in furious market competitions. The expert team had to be familiarized with the evaluation system of the case institute evaluating performance measurement. The expert team also needed to know the computational approach to the FNBSC. The role of the specialist team was to act as a system integrator by developing a total approach solution.

3.3. The results

This study follows the five steps of the proposed FNBSC approach to measure the data from the experts. This study followed the proposed solution with the five-phase procedures:

1. The relevant information was gathered to evaluate the advantages and disadvantages, and the results were monitored to ensure the objective was achievable. This is necessary to form an expert committee for group knowledge to achieve the study goal.
2. The experts each had over five years of experience in the university. These participants were requested to complete a questionnaire using subjective judgment about the importance of each criterion for the hierarchical structure of the study framework. The qualitative aspects and criteria were based on the TFNs to transform the linguistic preferences into comparable crisp scores; the TFNs are presented in Tables 2 and 3. The fuzzy set theory definitions applied in this study are presented in Eqs. (1) and (2).
3. The linguistic preferences were interpreted into TFNs so that TFNs could be converted into crisp scores, and the defuzzification assessments were made using Eqs. (3)–(7) to acquire the crisp value. Table 4 presents the defuzzification linguistic preferences into each crisp value.
4. The proposed method was analyzed in terms of decision objectives, and the crisp value was composed of the unweighted supermatrix. The dependence matrices were acquired using Eqs. (8)–(13). The dependency matrix is shown in Table 5. In addition, the prominence and relation axis are presented in Table 6, and the cause and effect diagram in terms of the "criteria" cluster was acquired as shown in Fig. 2. By mapping a dataset of $(D + R, D - R)$, it is clear that evaluation criteria are visually divided into the causal group, including C4, C7, C9, C10, C11, C12, C13, C16, C19, and C21, while the effect group is composed of such criteria as C1, C2, C3, C5, C6, C8, C14, C15, C17, C18, C20, and C22 (see Fig. 4).
5. The unweighted supermatrix (Table 7) was formed from the composition of an unweighted supermatrix using Eq. (14). The converged supermatrix results are shown in Table 8.

The result presented shows that the criteria weights to goal as follows (C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12, C13, C14, C15, C16, C17, C18, C19, C20, C21, C22) = (0.0471, 0.0444, 0.0385, 0.0526, 0.0439, 0.0445, 0.0566, 0.0429, 0.0457, 0.0505, 0.0465, 0.0532, 0.0511, 0.0387, 0.0418, 0.0452, 0.0453, 0.0366, 0.0482, 0.0411, 0.0442, 0.0414). The ranking result is C7 > C12 > C4 > C13 > C10 > C19 > C1 > C11 > C9 > C17 > C16 > C6 > C2 > C21 > C5 > C8 > C15 > C22 > C20 > C14 > C3 > C18. The top three most considered criteria

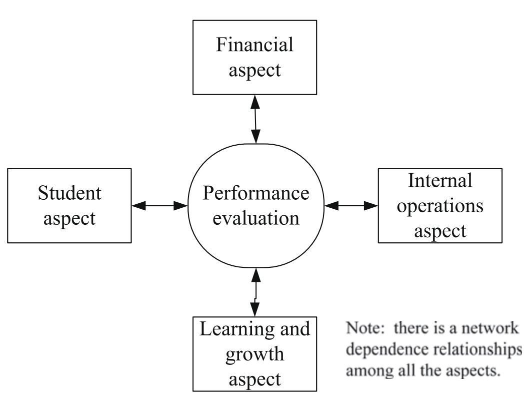


Fig. 3. NBSC framework.

Table 4
Defuzzification crisp values from interactive relationships.

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
C1	0.000	0.457	0.585	0.375	0.582	0.432	0.798	0.464	0.376	0.481	0.583	0.490	0.488	0.328	0.529	0.569	0.488	0.378	0.468	0.401	0.521	0.496
C2	0.517	0.000	0.576	0.478	0.435	0.209	0.145	0.197	0.180	0.367	0.408	0.467	0.812	0.986	0.200	0.658	0.760	0.162	0.477	0.418	0.678	0.719
C3	0.643	0.428	0.000	0.4S2	0.410	0.327	0.410	0.194	0.202	0.317	0.295	0.202	0.887	0.324	0.417	0.450	0.229	0.486	0.503	0.284	0.450	0.450
C4	0.702	0.432	0.425	0.000	0.447	0.504	0.621	0.783	0.837	0.765	0.632	0.700	0.437	0.329	0.545	0.331	0.752	0.102	0.633	0.658	0.418	0.418
C5	0.642	0.455	0.482	0.485	0.000	0.708	0.640	0.362	0.275	0.388	0.391	0.682	0.546	0.395	0.351	0.504	0.351	0.290	0.361	0.387	0.449	0.402
C6	0.675	0.368	0.488	0.368	0.455	0.000	0.198	0.298	0.648	0.419	0.313	0.102	0.691	0.420	0.291	0.638	0.478	0.577	0.460	0.520	0.668	0.873
C7	0.659	0.390	0.657	0.443	0.498	0.390	0.000	0.781	0.281	0.844	0.588	0.289	0.654	0.853	0.837	0.552	0.671	0.812	0.634	0.564	0.694	0.694
C8	0.658	0.576	0.422	0.587	0.512	0.207	0.757	0.000	0.676	0.293	0.733	0.802	0.162	0.352	0.311	0.152	0.360	0.075	0.548	0.418	0.297	0.297
C9	0.627	0.478	0.489	0.698	0.543	0.882	0.492	0.659	0.000	0.209	0.164	0.456	0.487	0.267	0.289	0.118	0.398	0.602	0.399	0.460	0.711	0.711
C10	0.682	0.484	0.477	0.701	0.546	0.238	0.543	0.783	0.855	0.000	0.399	0.815	0.573	0.764	0.573	0.389	0.298	0.459	0.382	0.642	0.270	0.270
C11	0.660	0.482	0.533	0.621	0.578	0.775	0.391	0.765	0.481	0.375	0.000	0.522	0.504	0.289	0.504	0.683	0.515	0.532	0.302	0.313	0.230	0.230
C12	0.591	0.578	0.678	0.605	0.598	0.433	0.207	0.633	0.236	0.284	0.342	0.000	0.624	0.598	0.624	0.264	0.770	0.540	0.944	0.588	0.931	0.931
C13	0.692	0.601	0.477	0.587	0.623	0.570	0.882	0.629	0.332	0.852	0.347	0.162	0.000	0.553	0.568	0.559	0.620	0.464	0.503	0.733	0.274	0.274
C14	0.642	0.562	0.510	0.542	0.634	0.433	0.358	0.455	0.393	0.268	0.159	0.394	0.234	0.000	0.093	0.548	0.559	0.394	0.234	0.602	0.275	0.275
C15	0.654	0.451	0.539	0.210	0.564	0.390	0.638	0.375	0.206	0.884	0.523	0.214	0.127	0.375	0.000	0.884	0.523	0.449	0.127	0.586	0.267	0.267
C16	0.618	0.481	0.536	0.632	0.602	0.783	0.230	0.540	0.297	0.374	0.221	0.880	0.521	0.540	0.297	0.000	0.423	0.880	0.521	0.314	0.143	0.178
C17	0.647	0.495	0.492	0.345	0.612	0.626	0.642	0.734	0.404	0.165	0.498	0.200	0.844	0.734	0.404	0.556	0.000	0.200	0.119	0.689	0.314	0.345
C18	0.643	0.512	0.482	0.555	0.630	0.396	0.238	0.128	0.276	0.248	0.219	0.334	0.187	0.300	0.555	0.472	0.442	0.000	0.508	0.597	0.165	0.215
C19	0.617	0.540	0.567	0.518	0.651	0.513	0.400	0.605	0.360	0.745	0.358	0.817	0.458	0.238	0.812	0.397	0.313	0.576	0.000	0.379	0.391	0.378
C20	0.631	0.476	0.555	0.512	0.633	0.765	0.709	0.183	0.109	0.596	0.287	0.426	0.239	0.126	0.475	0.237	0.588	0.331	0.461	0.000	0.207	0.397
C21	0.614	0.699	0.690	0.407	0.452	0.626	0.531	0.765	0.455	0.490	0.236	0.207	0.216	0.536	0.602	0.294	0.733	0.413	0.090	0.353	0.000	0.534
C22	0.827	0.733	0.546	0.375	0.375	0.523	0.433	0.410	0.367	0.412	0.376	0.256	0.328	0.432	0.555	0.315	0.654	0.343	0.106	0.348	0.487	0.000

Table 5
The dependence matrix from DEMATEL result.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
C1	0.039	0.046	0.048	0.045	0.047	0.046	0.052	0.046	0.047	0.047	0.051	0.048	0.047	0.045	0.048	0.049	0.047	0.046	0.048	0.046	0.049	0.048
C2	0.043	0.037	0.046	0.045	0.043	0.041	0.040	0.040	0.041	0.043	0.045	0.045	0.050	0.053	0.040	0.048	0.049	0.040	0.045	0.044	0.049	0.049
C3	0.040	0.039	0.032	0.040	0.038	0.037	0.039	0.035	0.036	0.038	0.038	0.036	0.046	0.038	0.039	0.040	0.036	0.041	0.041	0.037	0.040	0.040
C4	0.052	0.050	0.050	0.044	0.050	0.052	0.054	0.056	0.060	0.056	0.057	0.056	0.051	0.049	0.053	0.049	0.055	0.046	0.055	0.054	0.052	0.051
C5	0.044	0.044	0.044	0.044	0.037	0.047	0.047	0.042	0.042	0.043	0.044	0.048	0.046	0.043	0.043	0.045	0.042	0.042	0.044	0.043	0.045	0.044
C6	0.045	0.043	0.044	0.043	0.044	0.038	0.041	0.042	0.050	0.044	0.043	0.039	0.048	0.044	0.042	0.048	0.044	0.048	0.045	0.045	0.049	0.052
C7	0.055	0.054	0.057	0.054	0.055	0.053	0.04S	0.059	0.053	0.061	0.059	0.053	0.057	0.061	0.061	0.057	0.057	0.062	0.059	0.056	0.059	0.059
C8	0.043	0.044	0.042	0.045	0.043	0.039	0.047	0.036	0.049	0.041	0.050	0.050	0.039	0.042	0.041	0.038	0.041	0.037	0.046	0.042	0.042	0.042
C9	0.046	0.046	0.045	0.049	0.046	0.051	0.046	0.048	0.039	0.042	0.042	0.046	0.046	0.043	0.043	0.040	0.045	0.049	0.046	0.046	0.052	0.051
C10	0.050	0.050	0.049	0.053	0.050	0.046	0.051	0.054	0.059	0.042	0.050	0.056	0.051	0.055	0.052	0.048	0.047	0.050	0.050	0.052	0.048	0.047
C11	0.047	0.046	0.047	0.049	0.047	0.051	0.045	0.050	0.049	0.045	0.039	0.048	0.047	0.044	0.047	0.050	0.047	0.049	0.045	0.044	0.043	0.043
C12	0.052	0.054	0.054	0.054	0.053	0.051	0.04S	0.054	0.049	0.050	0.052	0.044	0.054	0.054	0.055	0.049	0.056	0.054	0.061	0.054	0.061	0.060
C13	0.051	0.052	0.050	0.052	0.052	0.051	0.057	0.052	0.050	0.057	0.050	0.046	0.043	0.052	0.052	0.052	0.052	0.051	0.052	0.054	0.048	0.047
C14	0.040	0.041	0.040	0.041	0.041	0.039	0.038	0.039	0.040	0.037	0.036	0.040	0.037	0.032	0.034	0.041	0.041	0.039	0.037	0.042	0.038	0.038
C15	0.043	0.042	0.043	0.039	0.043	0.041	0.045	0.041	0.039	0.049	0.045	0.039	0.038	0.042	0.035	0.050	0.043	0.044	0.038	0.044	0.040	0.039
C16	0.045	0.045	0.046	0.048	0.047	0.049	0.041	0.046	0.044	0.044	0.042	0.053	0.046	0.047	0.043	0.038	0.044	0.053	0.048	0.043	0.041	0.041
C17	0.046	0.046	0.045	0.043	0.047	0.048	0.04S	0.049	0.046	0.041	0.048	0.041	0.051	0.050	0.044	0.048	0.038	0.042	0.040	0.049	0.044	0.044
C18	0.038	0.038	0.038	0.039	0.040	0.037	0.035	0.032	0.036	0.035	0.035	0.037	0.034	0.036	0.040	0.039	0.037	0.031	0.040	0.040	0.034	0.035
C19	0.048	0.049	0.049	0.048	0.050	0.048	0.047	0.049	0.048	0.053	0.048	0.054	0.048	0.044	0.054	0.047	0.045	0.051	0.041	0.046	0.048	0.047
C20	0.042	0.041	0.042	0.042	0.043	0.046	0.045	0.037	0.037	0.045	0.041	0.042	0.039	0.037	0.043	0.039	0.043	0.041	0.043	0.034	0.039	0.042
C21	0.045	0.048	0.047	0.043	0.044	0.046	0.046	0.048	0.046	0.045	0.042	0.041	0.041	0.046	0.047	0.042	0.048	0.044	0.039	0.043	0.037	0.047
C22	0.045	0.046	0.043	0.040	0.040	0.043	0.042	0.041	0.042	0.041	0.042	0.039	0.040	0.042	0.044	0.040	0.045	0.041	0.037	0.040	0.044	0.035

Table 6
The prominence and relation axis for cause and effect group.

Criteria	D (sum)	R (sum)	$(D+R)$	$(D-R)$
C1	5.062	6.580	5.062	1.518
C2	4.795	5.179	4.795	0.384
C3	4.149	5.450	4.149	1.300
C4	5.658	5.091	5.658	0.567
C5	4.734	5.526	4.734	0.792
C6	4.806	5.174	4.806	0.368
C7	6.129	5.091	6.129	1.038
C8	4.608	5.185	4.608	0.577
C9	4.944	4.053	4.944	0.891
C10	5.453	4.797	5.453	0.656
C11	5.031	4.048	5.031	0.983
C12	5.763	4.606	5.763	1.157
C13	5.530	4.963	5.530	0.566
C14	4.191	4.792	4.191	0.601
C15	4.525	4.787	4.525	0.262
C16	4.888	4.729	4.888	0.159
C17	4.905	5.311	4.905	0.407
C18	3.966	4.387	3.966	0.421
C19	5.209	4.341	5.209	0.868
C20	4.440	5.014	4.440	0.573
C21	4.802	4.365	4.802	0.437
C22	4.485	4.604	4.485	0.119

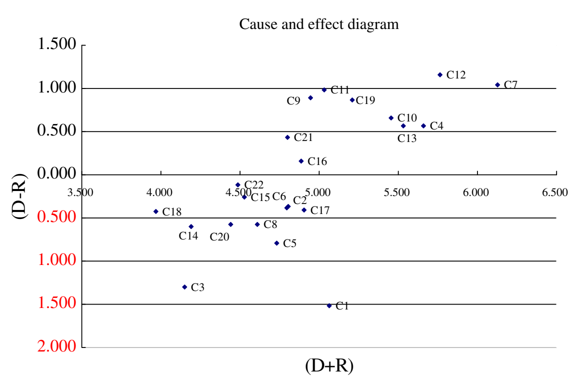


Fig. 4. Cause and effect diagram.

are: first, student acquisition: number of new students/total revenue to new students (C7); second, cost of service quality comparison (other universities) (C12); and third, growth from new services/educational departments (C4).

3.4. Post-survey

In order to assess the effectiveness of the proposed solution, this study conducted a post-survey discussion with the experts. The results were as follows.

First, it is a common understanding that BSC often emphasizes the expectation of improving performance. However, the results showed student acquisition (C7) to be the most important cause criteria due to the DEMATEL method, with the result that the important effect criterion is annual growth in revenue (C1). Student acquisition is the major cause of annual growth in revenue.

Second, although many works on performance measures for a university suggested that a sound performance measurement should be a hybrid model that can integrate the cause criteria with the effect criteria, in practice "student acquisition" will be the most favorable solution for improving the performance measurement.

Third, with the growth from new services or educational departments, it is implied that the new service or educational departments offered should conform to the social expectation. In addition, the expert group remarked on the merits and drawbacks of the proposed solutions. Unlike a traditional hierarchical model based on the linear and piecemeal approach, this proposed FNBSC approach is simple. It can easily justify the complex dependence and interactive relationships among aspects and criteria. In sum, it is favorable to use the FNBSC approach to handling the problems with dependence and interactive relationships, since it can provide more valuable information for decision-making.

4. Managerial implications

In order to assess the evaluation in an effective way, several managerial implications on management can be derived from the results. Valuable cues can also be drawn from the causal and effect diagram (Fig. 2) and the converged supermatrix to identify insightful decisions.

Table 7
The unweighted supermatrix.

	Goal	AS1	AS2	AS3	AS4	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
Goal	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AS1	0.363	0.269	0.119	0.366	0.121	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AS2	0.172	0.167	0.336	0.092	0.237	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AS3	0.198	0.461	0.347	0.086	0.298	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AS4	0.067	0.104	0.199	0.456	0.324	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C1	0.000	0.141	0.000	0.000	0.000	0.039	0.046	0.048	0.045	0.047	0.046	0.052	0.046	0.047	0.047	0.051	0.048	0.047	0.045	0.048	0.049	0.047	0.046	0.048	0.046	0.049	0.048
C2	0.000	0.189	0.000	0.000	0.000	0.043	0.037	0.046	0.045	0.043	0.041	0.040	0.040	0.041	0.043	0.045	0.045	0.050	0.053	0.040	0.048	0.049	0.040	0.045	0.044	0.049	0.049
C3	0.000	0.241	0.000	0.000	0.000	0.040	0.039	0.032	0.040	0.038	0.037	0.039	0.035	0.036	0.038	0.038	0.036	0.046	0.038	0.039	0.040	0.036	0.041	0.041	0.037	0.040	0.040
C4	0.000	0.213	0.000	0.000	0.000	0.032	0.050	0.050	0.044	0.050	0.052	0.054	0.056	0.060	0.056	0.057	0.056	0.051	0.049	0.053	0.049	0.055	0.046	0.055	0.054	0.052	0.051
C5	0.000	0.216	0.000	0.000	0.000	0.044	0.044	0.044	0.044	0.037	0.047	0.047	0.042	0.042	0.043	0.044	0.048	0.046	0.043	0.043	0.045	0.042	0.042	0.044	0.043	0.045	0.044
C6	0.000	0.000	0.347	0.000	0.000	0.045	0.043	0.044	0.043	0.044	0.038	0.041	0.042	0.050	0.044	0.043	0.039	0.048	0.044	0.042	0.048	0.044	0.048	0.045	0.045	0.049	0.052
C7	0.000	0.000	0.172	0.000	0.000	0.055	0.054	0.057	0.054	0.055	0.053	0.048	0.059	0.053	0.061	0.059	0.053	0.057	0.061	0.061	0.057	0.057	0.062	0.059	0.056	0.059	0.059
C8	0.000	0.000	0.130	0.000	0.000	0.043	0.044	0.042	0.045	0.043	0.039	0.047	0.036	0.049	0.041	0.050	0.050	0.039	0.042	0.041	0.038	0.041	0.037	0.046	0.042	0.042	0.042
C9	0.000	0.000	0.249	0.000	0.000	0.046	0.046	0.045	0.049	0.046	0.051	0.046	0.048	0.039	0.042	0.042	0.046	0.046	0.043	0.043	0.040	0.045	0.049	0.046	0.046	0.052	0.051
C10	0.000	0.000	0.102	0.000	0.000	0.050	0.050	0.049	0.053	0.050	0.046	0.051	0.054	0.059	0.042	0.050	0.056	0.051	0.055	0.052	0.048	0.047	0.050	0.050	0.052	0.048	0.047
C11	0.000	0.000	0.000	0.288	0.000	0.047	0.046	0.047	0.049	0.047	0.051	0.045	0.050	0.049	0.045	0.039	0.048	0.047	0.044	0.047	0.050	0.047	0.049	0.045	0.044	0.043	0.043
C12	0.000	0.000	0.000	0.153	0.000	0.052	0.054	0.054	0.054	0.053	0.051	0.048	0.054	0.049	0.050	0.052	0.044	0.054	0.054	0.055	0.049	0.056	0.054	0.061	0.054	0.061	0.060
C13	0.000	0.000	0.000	0.129	0.000	0.051	0.052	0.050	0.052	0.052	0.051	0.057	0.052	0.050	0.057	0.050	0.046	0.043	0.052	0.052	0.052	0.052	0.051	0.052	0.054	0.048	0.047
C14	0.000	0.000	0.000	0.213	0.000	0.040	0.041	0.040	0.041	0.041	0.039	0.038	0.039	0.040	0.037	0.036	0.040	0.037	0.032	0.034	0.041	0.041	0.039	0.037	0.042	0.038	0.038
C15	0.000	0.000	0.000	0.213	0.000	0.043	0.042	0.043	0.039	0.043	0.041	0.045	0.041	0.039	0.049	0.045	0.039	0.038	0.042	0.035	0.050	0.043	0.044	0.038	0.044	0.040	0.039
C16	0.000	0.000	0.000	0.000	0.213	0.045	0.045	0.046	0.048	0.047	0.049	0.041	0.046	0.044	0.044	0.042	0.053	0.046	0.047	0.043	0.038	0.044	0.053	0.048	0.043	0.041	0.041
C17	0.000	0.000	0.000	0.000	0.108	0.046	0.046	0.045	0.043	0.047	0.048	0.048	0.049	0.046	0.041	0.048	0.041	0.051	0.050	0.044	0.048	0.038	0.042	0.040	0.049	0.044	0.044
C18	0.000	0.000	0.000	0.000	0.116	0.038	0.038	0.038	0.039	0.040	0.037	0.035	0.032	0.036	0.035	0.035	0.037	0.034	0.036	0.040	0.039	0.037	0.031	0.040	0.040	0.034	0.035
C19	0.000	0.000	0.000	0.000	0.133	0.048	0.049	0.049	0.048	0.050	0.048	0.047	0.049	0.048	0.053	0.048	0.054	0.048	0.044	0.054	0.047	0.045	0.051	0.041	0.046	0.048	0.047
C20	0.000	0.000	0.000	0.000	0.211	0.042	0.041	0.042	0.042	0.043	0.046	0.045	0.037	0.037	0.045	0.041	0.042	0.039	0.037	0.043	0.039	0.043	0.041	0.043	0.034	0.039	0.042
C21	0.000	0.000	0.000	0.000	0.121	0.045	0.045	0.047	0.043	0.044	0.046	0.046	0.048	0.046	0.045	0.042	0.041	0.041	0.046	0.047	0.042	0.048	0.044	0.039	0.043	0.037	0.047
C22	0.000	0.000	0.000	0.000	0.098	0.045	0.046	0.043	0.040	0.040	0.043	0.042	0.041	0.042	0.041	0.042	0.039	0.040	0.042	0.044	0.040	0.045	0.041	0.037	0.040	0.044	0.035

Table 8
The converged supermatrix.

Ranking	Criteria	Goal	AS1	A32	AS3	AS4	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
	Goal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0 0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0 0000	0.0000	0.0000	0.0000	0.0000
	AS1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0 0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0 0000	0.0000	0.0000	0.0000	0.0000
	AS2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0 0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0 0000	0.0000	0.0000	0.0000	0.0000
	AS3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0 0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0 0000	0.0000	0.0000	0.0000	0.0000
	AS4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0 0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0 0000	0.0000	0.0000	0.0000	0.0000
7	C1	0.0471	0.0471	0.0471	0.0471	0.0471	0.0471	0.0471	0.0471	0.0471	00471	0.0471	0.0471	0.0471	0.0471	0.0471	0.0471	0.0471	0.0471	0.0471	0.0471	0.0471	0.0471	00471	0.0471	0.0471	0.0471	0.0471
13	C2	0.0444	0.0444	0.0444	0.0444	0.0444	0.0444	0.0444	0.0444	0.0444	0 0444	0.0444	0.0444	0.0444	0.0444	0.0444	0.0444	0.0444	0.0444	0.0444	0.0444	0.0444	0.0444	0 0444	0.0444	0.0444	0.0444	0.0444
21	C3	0.038:5	0.0385	0.0385	0.0385	0.0385	0.0385	0.0385	0.0385	0.0385	0 0385	0.0385	0.0385	0.0385	0.0385	0.0385	0.0385	0.0385	0.0385	0.0385	0.0385	0.0385	0.0385	0 0385	0.0385	0.0385	0.0385	0.0385
3	C4	0.0326	0.0326	0.0526	0.0526	0.0526	0.0526	0.0526	0.0526	0.0526	0 0526	0.0526	0.0526	0.0526	0.0526	0.0526	0.0526	0.0526	0.0526	0.0526	0.0526	0.0526	0.0526	0 0526	0.0526	0.0526	0.0526	0.0526
15	C5	0.0439	0.0439	0.0439	0.0439	0.0439	0.0439	0.0439	0.0439	0.0439	0 0439	0.0439	0.0439	0.0439	0.0439	0.0439	0.0439	0.0439	0.0439	0.0439	0.0439	0.0439	0.0439	0 0439	0.0439	0.0439	0.0439	0.0439
12	C6	0.0443	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445	0 0445	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445	0.0445	0 0445	0.0445	0.0445	0.0445	0.0445
1	C7	*0.0566*	0.0566	0.0566	0.0566	0.0566	0.0566	0.0566	0.0566	0.0566	0 0566	0.0566	0.0566	0.0566	0.0566	0.0566	0.0566	0.0566	0.0566	0.0566	0.0566	0.0566	0.0566	0 0566	0.0566	0.0566	0.0566	0.0566
16	C8	0.0429	0.0429	0.0429	0.0430	0.0429	0.0429	0.0429	0.0429	0.0429	0 0429	0.0429	0.0429	0.0429	0.0429	0.0429	0.0429	0.0429	0.0429	0.0429	0.0429	0.0429	0.0429	0 0429	0.0429	0.0429	0.0429	0.0429
9	C9	0.0457	0.0457	0.0457	0.0457	0.0457	0.0457	0.0457	0.0457	0.0457	0 0457	0.0457	0.0457	0.0457	0.0457	0.0457	0.0457	0.0457	0.0457	0.0457	0.0457	0.0457	0.0457	0 0457	0.0457	0.0457	0.0457	0.0457
5	C10	0.0303	0.0505	0.0505	0.0506	0.0505	0.0505	0.0505	0.0505	0.0505	0 0505	0.0505	0.0505	0.0505	0.0505	0.0505	0.0505	0.0505	0.0505	0.0505	0.0505	0.0505	0.0505	0 0505	0.0505	0.0505	0.0505	0.0505
8	C11	0.0463	0.0465	0.0465	0.0465	0.0465	0.0465	0.0465	0.0465	0.0465	0 0465	0.0465	0.0465	0.0465	0.0465	0.0465	0.0465	0.0465	0.0465	0.0465	0.0465	0.0465	0.0465	0 0465	0.0465	0.0465	0.0465	0.0465
2	C12	0.0332	0.0532	0.0532	0.0532	0.0532	0.0532	0.0532	0.0532	0.0532	0 0532	0.0532	0.0532	0.0532	0.0532	0.0532	0.0532	0.0532	0.0532	0.0532	0.0532	0.0532	0.0532	0 0532	0.0532	0.0532	0.0532	0.0532
4	C13	0.0311	0.0511	0.0511	0.0511	0.0511	0.0511	0.0511	0.0511	0.0511	00511	0.0511	0.0511	0.0511	0.0511	0.0511	0.0511	0.0511	0.0511	0.0511	0.0511	0.0511	0.0511	00511	0.0511	0.0511	0.0511	0.0511
20	C14	0.0387	0.0387	0.0387	0.0387	0.0387	0.0387	0.0387	0.0387	0.0387	0 0387	0.0387	0.0387	0.0387	0.0387	0.0387	0.0387	0.0387	0.0387	0.0387	0.0387	0.0387	0.0387	0 0387	0.0387	0.0387	0.0387	0.0387
17	C15	0.0418	0.0418	0.0418	0.0418	0.0418	0.0418	0.0418	0.0418	0.0418	0 0418	0.0418	0.0418	0.0418	0.0418	0.0418	0.0418	0.0418	0.0418	0.0418	0.0418	0.0418	0.0418	0 0418	0.0418	0.0418	0.0418	0.0418
11	C16	0.0452	0.0452	0.0452	0.0452	0.0452	0.0452	0.0452	0.0452	0.0452	0 0452	0.0452	0.0452	0.0452	0.0452	0.0452	0.0452	0.0452	0.0452	0.0452	0.0452	0.0452	0.0452	0 0452	0.0452	0.0452	0.0452	0.0452
10	C17	0.0453	0.0453	0.0453	0.0453	0.0453	0.0453	0.0453	0.0453	0.0453	0 0453	0.0453	0.0453	0.0453	0.0453	0.0453	0.0453	0.0453	0.0453	0.0453	0.0453	0.0453	0.0453	0 0453	0.0453	0.0453	0.0453	0.0453
22	C18	0.0365	0.0366	0.0366	0.0366	0.0366	0.0366	0.0366	0.0366	0.0366	0 0366	0.0366	0.0366	0.0366	0.0366	0.0366	0.0366	0.0366	0.0366	0.0366	0.0366	0.0366	0.0366	0 0366	0.0366	0.0366	0.0366	0.0366
6	C19	0.0482	0.0482	0.0482	0.0482	0.0482	0.0482	0.0482	0.0482	0.0482	0 0482	0.0482	0.0482	0.0482	0.0482	0.0482	0.0482	0.0482	0.0482	0.0482	0.0482	0.0482	0.0482	0 0482	0.0482	0.0482	0.0482	0.0482
19	C20	0.0411	0.0411	0.0411	0.0411	0.0411	0.0411	0.0411	0.0411	0.0411	0.0411	0.0411	0.0411	0.0411	0.0411	0.0411	0 0411	0 0411	0 0411	0.0411	0 0411	0.0411	0.0411	0 0411	0.0411	0 0411	0 0411	0 0411
14	C21	0.0442	0.0442	0.0442	0.0442	0.0442	0.0442	0.0442	0.0442	0.0442	0 0442	0.0442	0.0442	0.0442	0.0442	0.0442	0.0442	0.0442	0.0442	0.0442	0.0442	0.0442	0.0442	0 0442	0.0442	0.0442	0.0442	0.0442
18	C22	0.0414	0.0414	0.0414	0.0414	0.0414	0.0414	0.0414	0.0414	0.0414	0 0414	0.0414	0.0414	0.0414	0.0414	0.0414	0.0414	0.0414	0.0414	0.0414	0.0414	0.0414	0.0414	0 0414	0.0414	0.0414	0.0414	0.0414

First, if the university wishes to obtain high performance in the "effect criteria," it would be necessary to control and pay more attention to the "cause criteria" beforehand. This is because the cause criteria imply the meaning of the influencing criteria, whereas the effect criteria denote the meaning of the influenced criteria (Fontela & Gabus, 1976). The effect criteria (C1, C2, C3, C5, C6, C8, C14, C15, C17, C18, C20 and C22) of the case firm are more difficult to change than the cause criteria (C4, C7, C9, C10, C11, C12, C13, C16, C19 and C21). In other words, the cause criteria can be regarded as the critical criteria in guiding the right benchmark for other universities. It should be noted that the cause criteria are difficult to move, while the effect criteria can be easily moved. The criteria of C4, C7, C9, C10, C11, C12, C13, C16, C19, and C21 have the positive $(D - R)$ values in the visual diagram.

Second, it is found that student acquisition (C7) is the most important among these 22 criteria because it has the highest intensity of relation to other criteria. Moreover, the annual growth in revenue (C1) is the most influential criteria. The implications are as follows. First, the marketing aspect has the highest positive $(D + R)$ values, suggesting that it is the largest net generator of effects and has played the most important role in the university. These net initiators affect other criteria much more than the other criteria do, implying that they should be a priority for improvement.

Third, it can be suggested that in cases where the criteria having high $(D + R)$ values but $(D - R)$ values ranging from nearly zero to negative, the criteria have large effects on the FNBSC but are also affected by other criteria. They are the net receivers and should be ranked as lower managerial priorities. In the broader sense, the framework can be used as an analytical and monitoring tool to develop and construct an overall performance evaluation. For the practice of university management, FNBSC is sufficient for the management to greatly understand the evaluation aspects and criteria. Moreover, the management may apply the proposed NBSC framework (aspects and criteria) for assessment of the relative performance evaluation.

5. Concluding remarks

The study aspects and criteria serve as bridging mechanisms that are helpful in FNBSC performance evaluations. The literature has contributed to identifying the aspects and criteria influencing the performance evaluation of a university. The main contributions of this study are twofold. First, the evaluation of performance evaluation can be considered as a decision-making problem of complex dependences and interactions. This study conducted a review of the literature to generate 22 criteria along with four BSC aspects to measure performance evaluations of universities. Second, this study integrated TFNs, DEMATEL, and ANPs to develop a FNBSC evaluation model that prioritizes the relative weights of BSC aspects and criteria. The proposed method can be used not only as a way to handle the interaction and dependence within a set of aspects and criteria but also as a way of producing more valuable information to build a visual cause and effect diagram for decision-making on performance evaluation. The study findings indicated that there are solid results with regard to the evaluation. Analysis of the evaluation results provides guidance to university management in identifying the key criteria facilitating performance evaluation and in finding the best direction for improving current university management.

From a management perspective, the findings provide suggestions to the managers of a university. First, since student acquisition is generally considered most weighted in the performance evaluation of a university, an enhanced cost of service quality comparison can increase student acquisition by enhancing the growth from new service/education departments and reduce service costs. In terms of student acquisition, the management should actively maintain and improve service quality to satisfy student needs, and such service quality should promptly and accurately present satisfying content and subjects while also being sufficient to help management enhance their internal operations aspect. Second, to cater to the performance evaluation of a university that presents the top four cause criteria, i.e., student acquisition, cost of service quality comparison, service cycle processing time, and faculty/employee satisfaction, it is necessary to strongly emphasize the aspects of internal operations and learning and growth. Thus, the management should improve the internal service quality to provide effective internal processing time and should provide satisfaction surveys of faculty and employees from students' point of view. Third, to cater to perceptions of cost of service quality comparison, the internal process design should provide an effective process and a shorter waiting time in the internal operations aspect.

There are several limitations to this study that require further examination. First, this study was conducted with relatively expert sample groups. A larger sample that brought more explanatory power would have allowed more sophisticated evaluation analysis. The study findings thus should be verified with a larger sample to increase generalizability. Second, this study uses FNBSC to develop an evaluation model that helps management understand the critical criteria in implementing performance evaluations. Future studies can adopt additional fuzzy multi-criteria approaches (such as fuzzy TOPSIS and VIKOR and fuzzy outranking methods) to estimate the relative weights of the influences on BSC performance evaluation. The results of future studies can then be compared with the results presented here. Third, the evaluation criteria were selected from a review of the literatures on BSC performance evaluation, a review that excluded some possible influences on BSC performance evaluation. Future studies can use different methodologies, such as longitudinal studies and interviews, to identify other criteria. Finally, to provide more objective information on applicability of the proposed FNBSC evaluation model, future studies need to be undertaken using case studies of particular performance evaluations, thus proving the practicality of the FNBSC evaluation procedure proposed by this study.

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