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*Full Length Research Paper*

# Evaluating airline's service quality performance in uncertainty

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**The balanced scorecard (BSC) is a multi-criteria evaluation concept that highlights the importance of performance measurement criteria. Although there is an abundance of literature on the BSC framework, there is not much literature on how the framework should be implemented with interdependent relationships and linguistic preferences. To deal with these issues, this study proposes an original approach: the fuzzy network balanced scorecard (FNBSC) method that uses an analytic network process (ANP) to analyze a network's BSC aspects and criteria to evaluate the uncertainty. Four interdependent aspects and forty-four criteria were evaluated for an international airline firm in Taiwan. The empirical result showed that the financial aspect is the most influencing aspect and the three performance measures are the cost of sales, profitability, and company growth versus industry growth. The managerial implications and concluding remarks are also included.**

**Key words:** Analytic network process, balanced scorecard, fuzzy set theory, service quality.

## INTRODUCTION

An international airline needs to provide high-quality service to its passengers because of growing competition in the international airline market. However, international airlines realize that basing a competitive strategy on service quality alone is not promising over the long-term due to the similar levels of service provided by airlines (Park, 2007; Wang, 2007; Tiernan et al., 2008; Lu and Ling, 2008; Tseng, 2009b). This implies that an international airline with a competitive advantage based on service quality alone is not sustainable. Hence, the assessment of an international airline is an on-going process that requires continuous monitoring to maintain a high level of internal evaluation across a number of aspects. In terms of an internal process evaluation, the balanced scorecard (BSC) is a well-known performance measurement tool that can incorporate both financial and non-financial factors; it captures not only a firm's current performance, but also the drivers of its future performance (Banker and Datar, 1989; Dyson, 2000).

However, in the literature, there are few studies of the development and implementation of the BSC in measuring the performance of an airline firm's activities. Yet, such studies do exist concerning other industries, such as banking, textiles, and pharmaceuticals (Neufeld et al., 2001; Li and Dalton, 2003; Bremser and Barsky, 2004; Cebeci, 2009; Wu et al., 2009). The conceptual framework of the BSC has been widely accepted in the business community as the best method for investigating an issue. For instance, Leung et al. (2006) incorporated a wide set of non-financial attributes into the measurement system of a firm by using the analytic hierarchy process (AHP) and one of its variants, the analytic network process (ANP), to facilitate the implementation of the BSC. Yuan and Chiu (2009) used BSC design and proposed a three-level weighting design to enhance case-based reasoning inference performance. A genetic algorithm mechanism has been employed to facilitate weighting for a BSC and to determine the most appropriate three-level feature weights. The approach proposed here is compared with the equal weights approach and the AHP approach. Cebeci (2009) proposed that a decision support system integrated with strategic management might be an alternative to some methods for ERP selection. The enterprise resources plan packages and vendors for textile firm were compared using fuzzy AHP. In view of the interde-pendence complexity, evaluating firms' performances using a BSC might cause multi- dimensional difficulties. Besides,

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some of the qualitative criteria are vague and uncertain in nature, and the quantitative data should be comparable to the qualitative information, which makes a FNBSC evaluation even more challenging (Tseng, 2011).

Nevertheless, the BSC is a model for measuring the performance of all types of organizations, as developed by Kaplan and Norton in 1992. Using a BSC is an important activity that helps firms to make continuous improvements. It engenders multi-dimensional difficulties that involve numerous organizational functions and resource integration among the various departments in a firm (Tseng et al., 2008; Tseng, 2008). Moreover, the BSC categorized evaluation measures four aspects: financial, customer, internal business process, and learning and growth. With the BSC, firms can evaluate their managers in terms of their effectiveness in creating value for customers and developing internal capabilities; then firms can invest in the people and systems that are necessary to improve future performance. Therefore, these considerations imply that there are interdependent relationships in the BSC. Thus, the traditional statistical approach is not suited to evaluate proposed network BSC (NBSC), since the traditional approach assumed that the aspects are always independent. Evaluation related activities have inherent uncertainties and they are difficult to perform accurately with qualitative and quantitative information. This study proposes utilizing the analytical network process (ANP) technique to analyze the proposed NBSC. The ANP developed by Saaty (1996) takes into account both the relationships of feedback and dependence. In addition, the ANP provides a more generalized model for decision-making without making assumptions about the interdependent relationships among the various factors and criteria.

Fuzzy theory can address situations that lack well-defined boundaries of activity or observation sets (Zadeh, 1967; 1975). In many practical cases, human preferences are uncertain and can only be described qualitatively, so it is not easy to assign exact numerical values to describe preferences. Certain 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 theory can express and handle vague or imprecise judgments mathematically (Al-Najjar and Alsyouf, 2003; Tseng and Lin, 2008; Tseng et al., 2009c). A linguistic parameter is a variable with values (namely linguistic values) that the form of phrases or sentences in a natural language (Von Altrock, 1996). In particular, linguistic preferences are used to evaluate the factors or criteria with values that are not numbers but are instead linguistic terms. In practice, linguistic values can be represented by fuzzy numbers, and the triangular fuzzy number (TFN) is commonly used. Moreover, quantitative measures should transform into comparable crisp values to compare all of the qualitative measures. Therefore, this study adopts fuzzy set theory to assess the ability of NBSC to make a performance measurement.

This study addresses two important and related aspects in the implementation of the BSC: handling the dependency between aspects and criteria, especially those of a qualitative nature, and transforming the crisp values so that they can be compared with the qualitative measures. In view of the respective advantages of the available methods, this study develops an hybrid approach, called the “fuzzy network balanced scorecard (FNBSC)” method, to evaluate a performance measurement. The rationale of the proposed approach is to combine fuzzy set theory with ANP method, wherein fuzzy set theory accounts for the linguistic vagueness of qualitative criteria and ANP converts the interdependence relationship in the hierarchical structure into intelligible weights (Tseng et al., 2009c).

Four BSC aspects of an international airline in Taiwan were evaluated: the financial aspect, customer aspect, internal business aspect and learning and growth aspect. Moreover, the uncertainty was mainly due to the rapid changes of marketing information and human perceptions, while there was interdependence between the aspects and criteria.

## RESEARCH METHODOLOGY

To determine a performance measurement, there are several 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, we need to generate and establish the evaluation for the current scenario. As discussed earlier, four aspects of a FNBSC are to be considered. Moreover, the criteria cluster has to consider interdependent variables. So, a FNBSC evaluation of a firm can be obtained by:

(i) Assigning weights to the four aspects (AS1, AS2, AS3, AS4) and their associated $x_{ij}$ criteria ($x_{ij}$, i=1, 2, 3, 4; j=1, 2,…, $x_j$).
(ii) Assessing the performance rating of each aspect and its associated criteria.

This study first introduces fuzzy set theory and the ANP technique and discusses the FNBSC approach.

### Hierarchical structure

The hierarchical structure presents the evaluation aspects and criteria for the FNBSC approach. The evaluation framework consists of four aspects with forty-four measurement criteria that are determined from an extensive literature review. In this study, four primary dependence aspects of NBSC were identified and evaluated: the financial aspect, the customer aspect, the internal business aspect and the learning and growth aspect. The hierarchical structure is referred 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 processes aspect) that can deliver value to the market (customer aspect), which will eventually lead to a higher shareholder value (financial aspect). Thus, these aspects are interdependent, which should be considered in the evaluation process.

Financial aspect (AS1): The financial objectives serve as the focus for the objectives and measures of the other criteria. Every measure should be part of interdependent relationships that culminate in long-term, sustainable financial performance. The measures are sales, cost of sales, profitability, prosperity, growth, new products and services and industrial leadership.

Customer aspect (AS2): Financial success is closely linked to customer satisfaction. Satisfied customers lead to referrals and new business, customer retention, customer acquisition, customer profitability, and customer lead-time; these all contribute to the financial results of the firm.

Internal operations aspect (AS3): Customer satisfaction is directly achieved through the operational activities of the firm. The objectives and measures for this aspect thus enable a firm to focus on maintaining and improving the performance of processes that deliver the established objectives that are the keys to satisfying customers, which in turn satisfies the shareholders. The criteria are:

(i) The service processing time.
(ii) The cost of a service quality comparison.
(iii) Finding a low cost provider.
(iv) Reducing service costs.
(v) The facilities utilization rate.
(vi) The safety incident index.

The learning and growth aspect: The ability, flexibility and motivation of the staff to support all of the financial results, customer satisfaction and operational activities measured in the other quadrants of the BSC. The criteria are:

(i) Innovative service measures.
(ii) Breakeven time, the rate at which new services and products are produced per quarter.
(iii) The number of new services and products successfully introduced to the public.
(iv) The annual increase in the number of new services and products.
(v) The employee capabilities.
(vi) The employee satisfaction survey.
(vii) The employee retention.
(viii) The employee productivity.
(ix) The salaries compared to the norm in the local industry.
(x) The percentage of competency deployment matrix filled.
(xi) The number of promotions from within.
(xii)The absenteeism rate.

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

**Determining the quantitative number**

The quantitative (crisp) numbers of criteria (the last three years of data, Table 1) have varying values that cannot be compared; instead, the crisp value number must be normalized. The crisp number is normalized to achieve criteria values that are unit-free and comparable among all criteria. The normalized crisp values of $W_{ij}$ are calculated as expressed in the following equation (Karasak, 2002; Tseng, 2009a).

$$W_{ij}^{crisp} = \frac{W_{ij}^k - \min W_{ij}^k}{\max W_{ij}^k - \min W_{ij}^k}, \quad W_{ij}^{crisp} \in [0,1]; k = 1,2,..n \tag{1}$$

Where $\max W_{ij}^k = \max\{W_{ij}^1, W_{ij}^2, .....W_{ij}^n\}$ and $\min W_{ij}^k = \min\{W_{ij}^1, W_{ij}^2, .....W_{ij}^n\}$

**Determining the qualitative measure**

To determine the qualitative measures, fuzzy set theory can mathematically express and handle vague or imprecise judgments. 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 triangular fuzzy numbers. 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 $\mu_{\tilde{N}}(x)$ is defined as:

$$\mu_{\tilde{N}}(x) \begin{cases} 0, & x \prec l \\ (x - l)/(m - l), & l \le x \le m \\ (u - x)/(u - m), & m \le x \le u \\ 0, & x \succ u \end{cases} \tag{2}$$

Where l, m, and u are real numbers and $l \le m \le u$ (Figure 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, $\tilde{N}_1 \otimes \tilde{N}_2$ approximates a TFN as follows:

$$\tilde{N}_1 \otimes \tilde{N}_2 \cong (l_1 \otimes l_2, m_1 \otimes m_2, u_1 \otimes u_2) \tag{3}$$

To measure the pairwise comparison between criteria C = $\{C_i \mid i$ = 1,2,. . .,n}, a decision group of k experts was asked to make sets of pair-wise comparisons in terms of linguistic preferences. Hence, k fuzzy matrices $\tilde{Z}^{(1)}, \tilde{Z}^{(2)}, \tilde{Z}^{(3)}, ....., \tilde{Z}^{(k)}$, each corresponding to an expert and TFNs, were obtained (Lin and Wu, 2008; Tseng, 2009c). We denote $\tilde{Z}^{(k)}$ as:

$$\tilde{Z}^{(k)} = \begin{pmatrix} 0 & \tilde{Z}_{12}^{(k)} & \cdots & \tilde{Z}_{1n}^{(k)} \\ \tilde{Z}_{21}^{(k)} & 0 & \cdots & \tilde{Z}_{2n}^{(k)} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{Z}_{n1}^{(k)} & \tilde{Z}_{n2}^{(k)} & \cdots & 0 \end{pmatrix} \tag{4}$$

Let $\tilde{Z}_{ij}^{(k)} = \left(\ell_{ij}^{\langle k \rangle}, m_{ij}^{\langle k \rangle}, u_{ij}^{\langle k \rangle}\right)$. Without a loss of generality, $\tilde{Z}_{ii}^{(k)} = (i = 1, 2, ..., n)$ will be regarded as a TFN (0, 0, 0.25)

**Table 1.** Evaluation aspects and criteria of BSC approach

| | Aspects | Criteria |
|---|---|---|
| Balanced scorecard framework | Financial aspect (AS1) | Sales: annual growth in sales (C11) (last three years data) |
| | | Cost of sales: extent that it remains flat or decreases each year (C12) (last three years data) |
| | | Profitability: economic value added (EVA) or return on total capital employed (C13) (last three years data) |
| | | Prosperity: cash flows (C14) (last three years data) |
| | | Company growth versus industry growth (C15) |
| | | Ratio of international sales to total sales (C16) |
| | | New service/product: gross profit/growth from new services/products (C17) |
| | | Industry leadership: market share (C18) |
| | Customer aspect (AS2) | Market share for target customer segment (C21) |
| | | Customer retention/percentage of growth with existing customers (C22) |
| | | Customer acquisition: number of new customers/total sales to new customers/actual new customers divided by prospective inquiries (C23) |
| | | Customer satisfaction (via satisfaction surveys) (C24) |
| | | Customer profitability (via accounting analyses) (C25) |
| | | Customer lead time (on-time delivery) (C26) |
| | | Service quality: customer complain rates, reworks, percentage of returns (C27) |
| | Internal business aspect (AS3) | Service cycle processing time (C31) |
| | | Cost of service quality comparison (Other international airline) (C32) |
| | | Low cost provider: unit cost versus competitors' unit cost (C33) |
| | | Reduce service costs: service costs as percentage of sales (C34) |
| | | Service output per hour/facilities utilization (C35) (last three years data) |
| | | Safety incident index (C36) (last three years data) |
| | | Innovation of services/products measures (C41) (last three years data) |
| | Learning and growth aspect (AS4) | Breakeven time: the time from the beginning of services/products development work until the services/products has been introduced (C42) |
| | | Rate of new services/products introduction per quarter (C43) |
| | | Number of new services/products with successful introduction to public (C44) |
| | | Annual increase in number of new services/products (C45) |
| | | Employee capabilities (C46) |
| | | Employee satisfaction survey (C47) |
| | | Employee retention: percentage of key staff turnover (C48) |
| | | Employee productivity: revenue per employee (C49) |
| | | Salaries compared to the norm in the local industry (C410) |
| | | Percentage of competency deployment matrix filled (C411) (last three years data) |
| | | Number of promotions from within (C412) (last three years data) |
| | | Absenteeism rate (C413) (last three years data) |

Note: the four aspects are with interdependence relationship and self-feedback; the criteria are also self-feedback

whenever it is necessary. The fuzzy matrix $\tilde{Z}^{(k)}$ is called the initial pairwise comparison fuzzy matrix of expert k. Now we acquire the normalized pairwise comparison fuzzy matrix and let $\tilde{a}_i^{(k)}$ be the TFNs,

$$\tilde{a}_i^{(k)} = \sum_{j=1}^{n} \tilde{Z}_{ij}^{(k)} = \left( \sum_{j=1}^{n} \ell_{ij}^{(k)}, \sum_{j=1}^{n} m_{ij}^{(k)}, \sum_{j=1}^{n} u_{ij}^{(k)} \right) \quad (5)$$

and

$$r^{(k)} = \max_{1 \le i \le n} \left( \sum_{j=1}^{n} u_{ij}^{(k)} \right)$$

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

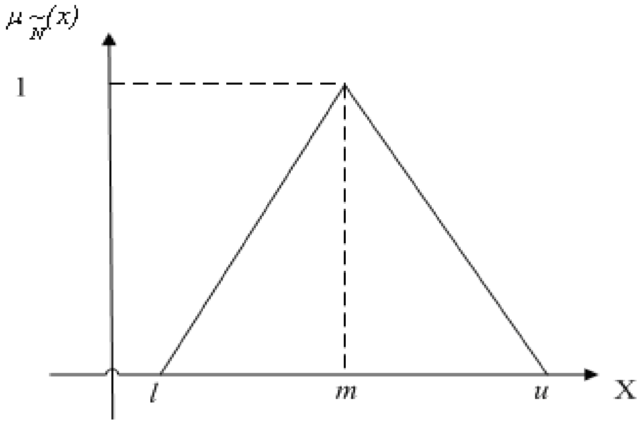


**Figure 1.** A triangular fuzzy number $\tilde{N}$.

normalized pairwise comparison fuzzy matrix of expert k, denoted as $\tilde{X}^{(k)}$, is given by

$$\tilde{X}^{(k)} = \begin{pmatrix} \tilde{X}_{11}^{(k)} & \tilde{X}_{12}^{(k)} & \cdots & \tilde{X}_{1n}^{(k)} \\ \tilde{X}_{21}^{(k)} & \tilde{X}_{22}^{(k)} & \cdots & \tilde{X}_{2n}^{(k)} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{X}_{n1}^{(k)} & \tilde{X}_{n2}^{(k)} & \cdots & \tilde{X}_{nn}^{(k)} \end{pmatrix}; \quad k=1,2,\ldots\ldots\ldots,k \qquad (6)$$

Where,

$$\tilde{X}_{ij}^{\langle k\rangle} = \frac{\tilde{z}_{ij}^{\langle k\rangle}}{r^{\langle k\rangle}} = \left( \frac{\ell_{ij}^{\langle k\rangle}}{r^{\langle k\rangle}}, \frac{m_{ij}^{\langle k\rangle}}{r^{\langle k\rangle}}, \frac{u_{ij}^{\langle k\rangle}}{r^{\langle k\rangle}} \right)$$

Note that we have $\sum_{i=1}^{n} u_{ij}^{\langle k\rangle} < r^{\langle k\rangle}$. Then, we can calculate the average matrix, denoted as $\tilde{X}$, of $\tilde{X}^{(1)}, \tilde{X}^{(2)}, \tilde{X}^{(3)}, \ldots\ldots., \tilde{X}^{(k)}$

$$\tilde{X} = \frac{(\tilde{X}^{(1)}, \tilde{X}^{(2)}, \tilde{X}^{(3)}, \ldots\ldots., \tilde{X}^{(K)})}{k} \qquad (7)$$

and $\tilde{X}$ is defined as:

$$\tilde{X} = \begin{pmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{n1} & \tilde{x}_{n2} & \cdots & \tilde{x}_{nn} \end{pmatrix}; \text{ where } \tilde{X}_{ij} = \frac{\sum_{k=1}^{k} \tilde{X}_{ij}^{(k)}}{k}$$

The fuzzy matrix $\tilde{X}$ is called the normalized pairwise comparison matrix. This study uses the arithmetic mean to aggregate or pool together all of the data from the experts after computing the normalized fuzzy pairwise comparison matrix $\tilde{X}^{\langle k\rangle}$. This approach can make the differences between individuals apparent, which is better than aggregating all of the experts' data after obtaining the initial pairwise comparison matrix $\tilde{Z}^{\langle k\rangle}$.

Now we compute the total pair-wise comparison matrix $\tilde{T}$ to ensure the convergence of $\lim_{w\to\infty} = \tilde{X}^{w} = 0$ in advance. While computing $\tilde{X}^{w}$, this study applies the approximation in Equation (2) for the multiplication of two TFNs. Hence, the elements of $\tilde{X}^{w}$ are also TFNs. Let $\tilde{X}_{ij} = (\ell_{ij}, m_{ij}, u_{ij})$ and define three crisp matrices, whose elements are extracted from $\tilde{X}$, as follows:

$$X_{\ell} = \begin{pmatrix} 0 & \ell_{12} & \ldots & \ell_{1n} \\ \ell_{21} & 0 & \ldots & \ell_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \ell_{n1} & \ell_{n2} & \ldots & 0 \end{pmatrix},$$

$$X_{m} = \begin{pmatrix} 0 & m_{12} & \cdots & m_{1n} \\ m_{21} & 0 & \cdots & m_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ m_{n1} & m_{n2} & \cdots & 0 \end{pmatrix}, \text{ and}$$

$$X_{u} = \begin{pmatrix} 0 & u_{12} & \cdots & u_{1n} \\ u_{21} & 0 & \cdots & u_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ u_{n1} & u_{n2} & \cdots & 0 \end{pmatrix}$$

The following theorem enables the computation of $\tilde{X}^{w}$ to be executed by the multiplication of crisp matrices. The three matrices are as follows

$$\left[\ell_{ij}^{(w)}\right] = \begin{pmatrix} \ell_{11}^{(w)} & \ell_{12}^{(w)} & \cdots & \ell_{1n}^{(w)} \\ \ell_{21}^{(w)} & \ell_{22}^{(w)} & \cdots & \ell_{2n}^{(w)} \\ \vdots & \vdots & \ddots & \vdots \\ \ell_{n1}^{(w)} & \ell_{n2}^{(w)} & \cdots & \ell_{nn}^{(w)} \end{pmatrix},$$

$$\left[m_{ij}^{(w)}\right] = \begin{pmatrix} m_{11}^{(w)} & m_{12}^{(w)} & \cdots & m_{1n}^{(w)} \\ m_{21}^{(w)} & m_{22}^{(w)} & \cdots & m_{2n}^{(w)} \\ \vdots & \vdots & \ddots & \vdots \\ m_{n1}^{(w)} & m_{n2}^{(w)} & \cdots & m_{nn}^{(w)} \end{pmatrix}, \text{ and}$$

$$\left[u_{ij}^{(w)}\right] = \begin{pmatrix} u_{11}^{(w)} & u_{12}^{(w)} & \cdots & u_{1n}^{(w)} \\ u_{21}^{(w)} & u_{22}^{(w)} & \cdots & u_{2n}^{(w)} \\ \vdots & \vdots & \ddots & \vdots \\ u_{n1}^{(w)} & u_{n2}^{(w)} & \cdots & u_{nn}^{(w)} \end{pmatrix}$$

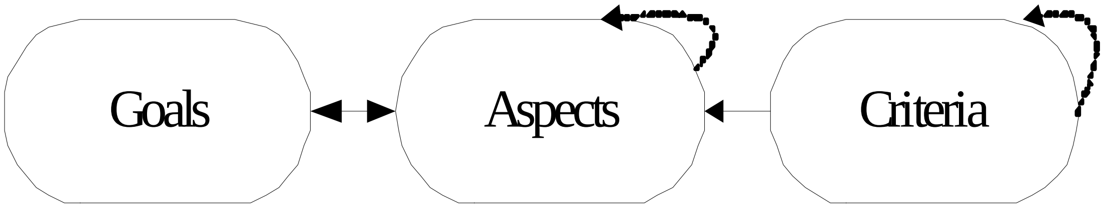


**Figure 2.** The modified feedback system model.

$$\left[\ell_{ij}^{(w)}\right] = X_{\ell}^{w}, \left[m_{ij}^{(w)}\right] = X_{m}^{w}, and \left[u_{ij}^{(w)}\right] = X_{u}^{w} \qquad (8)$$

Let $\rho\left(X_u\right)$ denote the spectral radius of the matrix $X_u$. Then, $\text{limit}_{w\to\infty} X_u^w \to 0$ is a sufficient and necessary condition of $\rho\left(X_u\right) < 1$. According to the crisp case, this study defines the total pair-comparison fuzzy matrix $\tilde{T}$ as

$$\tilde{T} = \text{limit}_{w\to\infty}\left(\tilde{X} + \tilde{X}^2 + \cdots + \tilde{X}^w\right). \qquad (9)$$

Now that $\tilde{T}$ (total- pair comparison matrix) has been acquired as an asymmetric matrix, it is easy to decompose the e-vector via MATLAB, where $\tilde{x}$ is a non-zero e-vector:

$$\tilde{T} = \begin{pmatrix} \tilde{x}_1 \\ \tilde{x}_2 \\ \cdots\cdots \\ \tilde{x}_n \end{pmatrix} \qquad (10)$$

The normalized weight vectors are

$$W = \left(x_1, x_2, \ldots\ldots x_n\right)^T \qquad (11)$$

where, W is a non-fuzzy number

**ANP**

The ANP must satisfy the characteristic of dependence among the criteria before it can proceed to decision making. The ANP, which was 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 attributes. The ANP feedback approach replaces hierarchies with networks where the relationships between levels are not easily defined as higher or lower, dominant or subordinate. Hence, given the problems encountered in reality, a dependence and feedback relationship is usually generated among the evaluation criteria, and this type of interdependent relationship usually becomes more complex as the scope and depth of the decision-making problems increase (Tseng et al., 2008; Tseng, 2008). A two-way arrow among different levels of criteria can graphically represent the interdependencies in an ANP model. If the dependencies are present within the same level of analysis, a "looped arc" may be used to represent such interdependence. Figure 2 gives the inter-dependence structure, which shows the intertwined relationships in the proposed framework. The following descriptions are the equations applied in this approach.

ANP uses a supermatrix to deal with the 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 value would no longer equal zero and an unweighted supermatrix M can be obtained. If the matrix does not conform to the principle of a 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* based on Equation (12) can be obtained, allowing for the gradual convergence of the interdependence relationship to obtain the accurate relative weights among the criteria:

$$M^* = \lim_{k\to\infty} M^k \qquad (12)$$

Moreover, the ANP is a mathematical theory that can deal with all kinds of dependences systematically (Saaty, 1996). The ANP has been successfully applied in many fields (Shang et al., 2004; Yurdakul, 2004). Messey (2008) studied multi-objective resource allocation of shared resources for group decision making and combined analytic and qualitative modeling, where the subsequent phases of the qualitative and the analytic solution of a multi-objective cooperative resource allocation problem were applied within the group decision-making framework of defense requirements capability-based planning. The merits of ANP in group decision-making are as follows (Dyer and Forman, 1992; Tseng, 2008; Tseng et al., 2008; 2009a; 2009b):

(i) Both tangibles and intangibles, individual values, and shared values can be included in the decision process.
(ii) The discussion in a group can be focused on objectives rather than alternatives.
(iii) The discussion can be structured so that every factor relevant to the decision is considered.
(iv) In a structured analysis, the discussion continues until the relevant information from each individual member in the group is considered and a consensus is achieved.

**Proposed approach**

To achieve a favorable solution, group decision-making is usually important to any organization. This is because the process of arriving at a consensus should be based upon the reaction of multiple individuals, whereby an acceptable judgment may be obtained. To deal with problems of uncertainty, an effective fuzzy aggregation method is required. Any fuzzy aggregation method must always contain a defuzzification method, because the results of human judgments with fuzzy linguistic variables are fuzzy

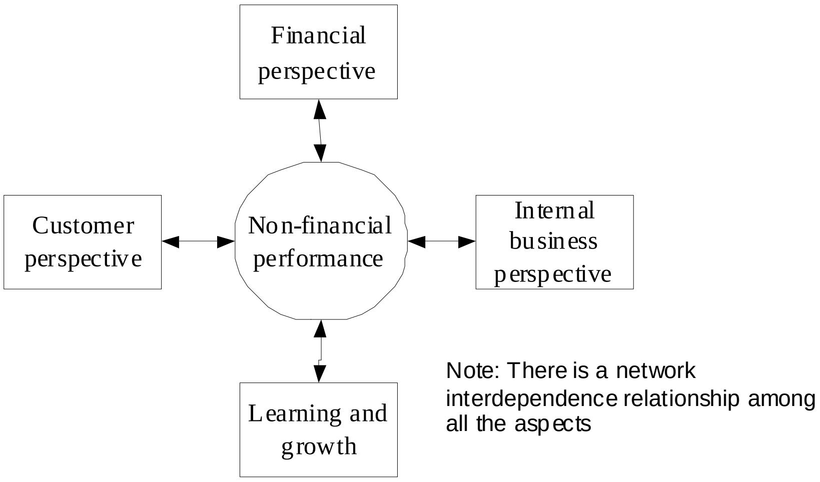


**Figure 3.** Network BSC framework.

numbers (Tseng, 2009b). In summary, to combine the proposed FNBSC method in this study, the following procedure was formulated:

1. Identify the BSC measures and gather the relevant information to evaluate the advantages and disadvantages, and monitor the results to ensure that the objective can be achieved. For this step, it is necessary to form an expert committee for a performance evaluation.
2. Use the evaluation criteria to develop the criteria for the survey instrument; the aspects and criteria can have interdependent relationships. To analyze the BSC model with qualitative and quantitative measures, the ANP techniques and fuzzy set theory are applied. It is necessary to consult a group of experts to confirm reliable information of the criteria description.
3. To measure the qualitative and quantitative criteria, the qualitative measures use a pairwise comparison between the criteria. The comparisons given by an expert and with the TFNs were obtained. In addition, we transformed the quantitative data into comparable with quantitative measures using Equation (1). The TFNs definitions are given by Equations (2) and (3). Equation (4) is used to translate the linguistic preferences using linguistic values (TFNs). The normalized pairwise comparison is calculated as expressed by Equation (5). To interpret the linguistic information into a fuzzy linguistic scale using linguistic information to convert fuzzy numbers into pair-wise comparison matrix, the fuzzy assessments given in Equations (6) through (9) are defuzzified and aggregated as total-pair comparison matrix $\tilde{T}$. Then we decomposed the $\tilde{T}$ for each pair comparison matrix to obtain the eigenvectors using Equation (10). Equation (11) is then used to normalize the e-vector.
4. Analyze the proposed approach using decision objectives, where the e-vectors are used to form the unweighted supermatrix based on the dependence relationships, as presented in Figure 1.
5. Equation (12) gives the normalized and unweighted supermatrix of the multiplied result and raises it to limiting powers to acquire the overall weights.

## A CASE STUDY

This study attempts to apply the proposed FNBSC approach to evaluate a firm. The data gathering technique and the results are presented here.

### The case study of an international airline firm in Taiwan

An international airline firm in Taiwan was used to evaluate the performance measurement. This international airline has been continuously developing its service in recent years. To enhance its competitiveness and fully satisfying the market and customer demands, this firm can use a systematic BSC evaluation.

Therefore, this firm used the proposed analytical approach, which combined ANP and fuzzy set theory. An expert team was then formed, which contained one professor and six management professionals with extensive experience. After a long interview with these experts, the expert group was sure that they fully understood the use of ANP and fuzzy set theory to analyze the BSC of a weighting process.

Figure 3 shows the BSC evaluation framework for this case study.

### Study problem

The international airline firm decided to develop and determine the weights of the BSC aspects and criteria in an effort to restructure their organization. Any team of experts that attempts this task should be familiar with performing an evaluation of performance measurement. The expert term also needs to know the computational approach used for the FNBSC. Therefore, the FNBSC expert team consisted of one academic and five professionals. The role of this team was to act as a system integrator by developing a total approach solution.

**Table 2.** Linguistic scales for the importance weight.

| Linguistic preference | Linguistic values |
|---|---|
| Extreme importance (EI) | (0.75, 1.0, 1.0) |
| Demonstrated importance (DI) | (0.5, 0.75, 1.0) |
| Strong importance (SI) | (0.25, 0.5, 0.75) |
| Moderate importance (MI) | (0, 0.25, 0.5) |
| Equal importance (EI) | (0, 0, 0.25) |

## The results

For this study, we used the five steps of the proposed FNBSC approach to measure the data from the experts.

1. The decision objective is aimed at gathering the relevant information to monitor the results and the post-survey discussion is used to ensure that the study objective can be achieved. The BSC measures are presented in Table 1.
2. For this case study, the goal, four aspects and forty-four criteria were defined. The goal is to measure the non-financial performance using BSC, ANP and fuzzy set theory. The four aspects are the financial aspect, customer aspect, internal business aspect and learning and growth aspect. Also, the aspects and criteria have interdependent relationships. To evaluate the interdependent relationships, the ANP can be applied. Moreover, the fuzzy set theory is able to handle the linguistic preferences. The TFNs are shown in Table 2.
3. This step measured the defuzzified pairwise comparison between aspects. This study interprets the linguistic information using a fuzzy linguistic scale. The definition of the fuzzy set theory presented in Equation (2). Table 3 presents the initial input data from the experts.

Using Equations (4) through (9), we can find a defuzzified and aggregated total pair comparison matrix $\tilde{T}$. To convert the linguistic preferences into a pairwise comparison matrix, the linguistic terms need to be defuzzified and aggregated into a total-pair comparison matrix $\tilde{T}$. We decomposed the $\tilde{T}$ for each pair comparison matrix to acquire the e-vectors. Table 4 presents the pairwise comparison matrix of the four aspects of the goal. Equations (10) and (11) are used to normalize the e-vector. The decomposed e-vector is (0.210, 0.454, 0.534, 0.682) and the normalized e-vector is (0.112, 0.241, 0.284, 0.363).
4. This step repeated all of the computational procedures used to find the total pair comparison matrices. The final result can be represented as an unweighted supermatrix. Hence, to compose the unweighted supermatrix, the notation of Table 5 was used to transform the supermatrix so that it would satisfy the column stochastic requirement.

This study assumes that all of the clusters are of equal importance. Two adjustments need to be included to convert the supermatrix into a column-stochastic matrix. Firstly, the influences on the goal by the aspects and criteria clusters need to be considered; since there are two clusters, each sub-matrix (A and B) is multiplied by 0.5. Secondly, the influences of aspects to aspects and criteria need to be multiplied by 0.5 as well, which is given by the sub-matrices C and D. The adjusted column stochastic supermatrix is shown in Table 6. The table presents the e-vectors decomposed from each defuzzified total-pair comparison matrix and composed to an unweighted supermatrix based on the interdependence relationships.
5. The analytical result obtained from the unweighted supermatrix and the multiplied result is raised to limiting powers to acquire the overall weights. Using Equation (12), the converged supermatrix calculations can be solved using the Microsoft Excel, as shown in Table 7. The NBSC aspect's ranking order is:

(1) Internal business aspect (AS3).
(2) Financial aspect (AS1).
(3) Customer aspect (AS2).
(4) Learning and growth aspect (AS4) with relative importance values of 0.0634, 0.0602, 0.0598 and 0.0472. The internal business aspect is the most influential aspect.

The top-three criteria for each aspect are as follows. The top-three weighted financial criteria are:

(1) The cost of sales (C12).
(2) Profitability, or the economic value added or returned on the total capital employed (C13).
(3) The company growth versus industry growth (C15).

These criteria have relative importance values of 0.0575, 0.0596 and 0.0517, respectively. The top-three weighted customer criteria are:

(1) Customer satisfaction (via satisfaction surveys) (C24).
(2) Customer acquisition, or the number of new customers or total sales divided by the prospective inquiries (C23).
(3) Customer profitability (C25).

**Table 3.** Initial input data from experts.

| | Aspects | Criteria | No.1 | No.2 | No.3 | No.4 | No.5 | No.6 |
|---|---|---|---|---|---|---|---|---|
| Balanced scorecard framework | | C11 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 |
| | | C12 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 |
| | | C13 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 |
| | Financial aspect (AS1) | C14 | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 |
| | | C15 | (0.25, 0.5, 0.75) | (0.5, 0.75, 1.0) | (0.75, 1.0, 1.0) | (0.5, 0.75, 1.0) | (0.75, 1.0, 1.0) | (0, 0.25, 0.5) |
| | | C16 | (0.75, 1.0, 1.0) | (0.25, 0.5, 0.75) | (0, 0.25, 0.5) | (0.5, 0.75, 1.0) | (0.5, 0.75, 1.0) | (0.75, 1.0, 1.0) |
| | | C17 | (0.75, 1.0, 1.0) | (0.5, 0.75, 1.0) | (0.25, 0.5, 0.75) | (0.25, 0.5, 0.75) | (0.25, 0.5, 0.75) | (0.5, 0.75, 1.0) |
| | | C18 | (0.5, 0.75, 1.0) | (0.75, 1.0, 1.0) | (0.5, 0.75, 1.0) | (0.5, 0.75, 1.0) | (0.5, 0.75, 1.0) | (0, 0.25, 0.5) |
| | | C21 | (0.75, 1.0, 1.0) | (0.5, 0.75, 1.0) | (0.75, 1.0, 1.0) | (0.5, 0.75, 1.0) | (0.5, 0.75, 1.0) | (0, 0.25, 0.5) |
| | | C22 | (0.25, 0.5, 0.75) | (0.25, 0.5, 0.75) | (0.25, 0.5, 0.75) | (0.5, 0.75, 1.0) | (0.5, 0.75, 1.0) | (0.5, 0.75, 1.0) |
| | | C23 | (0.5, 0.75, 1.0) | (0, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.25, 0.5, 0.75) | (0, 0.25, 0.5) | (0, 0.25, 0.5) |
| | Customer aspect (AS2) | C24 | (0, 0.25, 0.5) | (0.5, 0.75, 1.0) | (0, 0.25, 0.5) | (0, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.5, 0.75, 1.0) |
| | | C25 | (0.5, 0.75, 1.0) | (0.25, 0.5, 0.75) | (0.25, 0.5, 0.75) | (0.25, 0.5, 0.75) | (0.5, 0.75, 1.0) | (0.75, 1.0, 1.0) |
| | | C26 | (0.5, 0.75, 1.0) | (0.25, 0.5, 0.75) | (0.25, 0.5, 0.75) | (0.25, 0.5, 0.75) | (0.75, 1.0, 1.0) | (0.5, 0.75, 1.0) |
| | | C27 | (0.5, 0.75, 1.0) | (0.5, 0.75, 1.0) | (0.5, 0.75, 1.0) | (0.5, 0.75, 1.0) | (0.5, 0.75, 1.0) | (0.5, 0.75, 1.0) |
| | | C31 | (0.25, 0.5, 0.75) | (0.25, 0.5, 0.75) | (0.25, 0.5, 0.75) | (0.75, 1.0, 1.0) | (0.5, 0.75, 1.0) | (0.5, 0.75, 1.0) |
| | | C32 | (0.75, 1.0, 1.0) | (0.25, 0.5, 0.75) | (0, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.75, 1.0, 1.0) | (0.5, 0.75, 1.0) |
| | Internal business aspect (AS3) | C33 | (0.5, 0.75, 1.0) | (0.5, 0.75, 1.0) | (0.5, 0.75, 1.0) | (0, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.25, 0.5, 0.75) |
| | | C34 | (0.75, 1.0, 1.0) | (0.5, 0.75, 1.0) | (0.25, 0.5, 0.75) | (0.25, 0.5, 0.75) | (0, 0.25, 0.5) | (0.5, 0.75, 1.0) |
| | | C35 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 |
| | | C36 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| | | C41 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 |
| | | C42 | (0.5, 0.75, 1.0) | (0.25, 0.5, 0.75) | (0.25, 0.5, 0.75) | (0.25, 0.5, 0.75) | (0.5, 0.75, 1.0) | (0.75, 1.0, 1.0) |
| | | C43 | (0.5, 0.75, 1.0) | (0.25, 0.5, 0.75) | (0.25, 0.5, 0.75) | (0.25, 0.5, 0.75) | (0.75, 1.0, 1.0) | (0.75, 1.0, 1.0) |
| | | C44 | (0, 0.25, 0.5) | (0.5, 0.75, 1.0) | (0.5, 0.75, 1.0) | (0.25, 0.5, 0.75) | (0.25, 0.5, 0.75) | (0.25, 0.5, 0.75) |
| | | C45 | (0.5, 0.75, 1.0) | (0.5, 0.75, 1.0) | (0, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.25, 0.5, 0.75) | (0, 0.25, 0.5) |
| | | C46 | (0.5, 0.75, 1.0) | (0, 0.25, 0.5) | (0.5, 0.75, 1.0) | (0.25, 0.5, 0.75) | (0.75, 1.0, 1.0) | (0.25, 0.5, 0.75) |
| | Learning and growth aspect (AS4) | C47 | (0, 0.25, 0.5) | (0.75, 1.0, 1.0) | (0.25, 0.5, 0.75) | (0.75, 1.0, 1.0) | (0.5, 0.75, 1.0) | (0.5, 0.75, 1.0) |
| | | C48 | (0.5, 0.75, 1.0) | (0.25, 0.5, 0.75) | (0.25, 0.5, 0.75) | (0.25, 0.5, 0.75) | (0, 0.25, 0.5) | (0.5, 0.75, 1.0) |
| | | C49 | (0.75, 1.0, 1.0) | (0.25, 0.5, 0.75) | (0, 0.25, 0.5) | (0.25, 0.5, 0.75) | (0.5, 0.75, 1.0) | (0.5, 0.75, 1.0) |
| | | C410 | (0.25, 0.5, 0.75) | (0.75, 1.0, 1.0) | (0.25, 0.5, 0.75) | (0.75, 1.0, 1.0) | (0, 0.25, 0.5) | (0.75, 1.0, 1.0) |
| | | C411 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 |
| | | C412 | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 |
| | | C413 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |

**Table 4.** Defuzzification of linguistic preferences for criteria in goal.

| Goal | AS1 | AS2 | AS3 | AS4 | E-vector | Weights |
|---|---|---|---|---|---|---|
| AS1 | 1.000 | 0.5806 | 0.683 | 0.481 | 0.719 | 0.563 |
| AS2 | 0.175 | 1.000 | 0.531 | 0.2 | 0.219 | 0.172 |
| AS3 | 0.456 | 0.6333 | 1.000 | 0.328 | 0.253 | 0.198 |
| AS4 | 0.115 | 0.225 | 0.403 | 1.000 | 0.085 | 0.067 |

**Table 5.** Submatrix notation for supermatrix composition.

| | Goal | Aspects | Criteria |
|---|---|---|---|
| Goal | A | | |
| Aspects | B | C | |
| Criteria | | D | E |

These criteria have relative important values of 0.0318, 0.0288 and 0.0238, respectively. The top-three internal business criteria are:

(1) The cost of a service quality comparison (C32).
(2) The service cycle processing time (C31).
(3) The service output per hour that the facility is utilized (C35).

These criteria have relative importance values of 0.0.0499, 0.0494 and 0.0484, respectively. Lastly, the top-three weighted learning and growth criteria are:

(1) Innovation of services/products measures (C41).
(2) Absenteeism rate (C413).
(3) Salaries compared to the norm in the local industry (C410).

These criteria have relative importance values of 0.0150, 0.0135 and 0.0124, respectively.

### Managerial implications

The results show that the desired goal was to obtain a performance measurement. The implications for management are as follows.

First, it is well-known that the BSC often emphasizes improving a performance measurement. However, the evaluation process is dependent on aspects and criteria that are both qualitative and quantitative in nature. In this study, we found that profitability (C13) was the most important criteria. The cost of sales (C12) and company growth versus industrial growth (C15) were found to be the next most important criteria. This is because profitability is the most important for a firm's survival in today's marketplace. Besides, the firms' growth versus industrial growth is also important to the firm studied here.

Many studies on using a BSC measure for a firm suggested that a sound FNBSC should be a hybrid model that can integrate the aspects and criteria and indicate how to obtain customer satisfaction. According to the converged weights, a FNBSC that can indicate that the overall top five ranking order are as following:

(1) Internal business aspect (AS3).
(2) Financial aspect (AS1).
(3) Customer aspect (AS2).
(4) Profitability: economic value added (EVA) or return on total capital employed (C13).
(5) Goal: The internal business aspect will be the most favorable performance aspects.

Additionally, the expert group remarked on the merits and drawbacks of the proposed approach. Unlike a traditional hierarchical model based on the linear and piecemeal approach, this proposed FNBSC approach is simple. It can easily justify the complex interdependent relationships among aspects and criteria. In sum, it is favorable to use the FNBSC approach to handle problems with interdependences, since it can provide valuable information for decision-making.

Lastly, the management should recognize the benefits of implementing a BSC and pay close attention to internal business aspects. Moreover, future studies should consider that the knowledge of the management could be included in the internal business aspect by providing the related information and knowledge for preparing documents and retains previous knowledge and experience learned from past experiences.

## CONCLUDING REMARKS

A BSC can be used to capture, organize and share data to enable an accurate performance measurement. Although numerous creditable works have been devoted

**Table 6.** Column stochastic supermatrix

| | Goal | AS1 | AS2 | AS3 | AS4 | C11 | C12 | C13 | C14 | C15 | C16 | C17 | C18 | C21 | C22 | C23 | C24 | C25 | C26 | C27 | C31 | C32 | C33 | C34 | C35 | C36 | C41 | C42 | C43 | C44 | C45 | C46 | C47 | C48 | C49 | C410 | C411 | C412 | C413 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Goal | 0.500 | 0.000 | 0.000 | 0.000 | 0.000 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 |
| AS1 | 0.282 | 0.134 | 0.059 | 0.183 | 0.060 | 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 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| AS2 | 0.086 | 0.084 | 0.168 | 0.046 | 0.129 | 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 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| AS3 | 0.099 | 0.230 | 0.173 | 0.043 | 0.149 | 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 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| AS4 | 0.033 | 0.052 | 0.099 | 0.228 | 0.162 | 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 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| C11 | 0.000 | 0.071 | 0.000 | 0.000 | 0.000 | 0.008 | 0.071 | 0.048 | 0.064 | 0.076 | 0.059 | 0.035 | 0.103 | 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 |
| C12 | 0.000 | 0.039 | 0.000 | 0.000 | 0.000 | 0.057 | 0.049 | 0.079 | 0.054 | 0.087 | 0.059 | 0.112 | 0.078 | 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 |
| C13 | 0.000 | 0.121 | 0.000 | 0.000 | 0.000 | 0.077 | 0.073 | 0.093 | 0.048 | 0.079 | 0.091 | 0.090 | 0.029 | 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 |
| C14 | 0.000 | 0.068 | 0.000 | 0.000 | 0.000 | 0.046 | 0.112 | 0.049 | 0.039 | 0.061 | 0.036 | 0.054 | 0.088 | 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 |
| C15 | 0.000 | 0.082 | 0.000 | 0.000 | 0.000 | 0.062 | 0.039 | 0.091 | 0.077 | 0.048 | 0.070 | 0.077 | 0.043 | 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 |
| C16 | 0.000 | 0.025 | 0.000 | 0.000 | 0.000 | 0.056 | 0.093 | 0.088 | 0.075 | 0.055 | 0.028 | 0.047 | 0.053 | 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 |
| C17 | 0.000 | 0.031 | 0.000 | 0.000 | 0.000 | 0.089 | 0.050 | 0.028 | 0.093 | 0.051 | 0.066 | 0.058 | 0.051 | 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 |
| C18 | 0.000 | 0.065 | 0.000 | 0.000 | 0.000 | 0.108 | 0.015 | 0.027 | 0.053 | 0.045 | 0.091 | 0.029 | 0.057 | 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 |
| C21 | 0.000 | 0.000 | 0.045 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.077 | 0.120 | 0.086 | 0.072 | 0.115 | 0.108 | 0.076 | 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 |
| C22 | 0.000 | 0.000 | 0.051 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.114 | 0.026 | 0.077 | 0.026 | 0.056 | 0.055 | 0.077 | 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 |
| C23 | 0.000 | 0.000 | 0.048 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.053 | 0.092 | 0.091 | 0.099 | 0.090 | 0.043 | 0.091 | 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 |
| C24 | 0.000 | 0.000 | 0.077 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.107 | 0.065 | 0.086 | 0.126 | 0.053 | 0.102 | 0.055 | 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 |
| C25 | 0.000 | 0.000 | 0.065 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.051 | 0.055 | 0.092 | 0.052 | 0.051 | 0.077 | 0.098 | 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 |
| C26 | 0.000 | 0.000 | 0.108 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.052 | 0.101 | 0.048 | 0.062 | 0.026 | 0.052 | 0.068 | 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 |
| C27 | 0.000 | 0.000 | 0.108 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.048 | 0.043 | 0.021 | 0.064 | 0.111 | 0.065 | 0.036 | 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 |
| C31 | 0.000 | 0.000 | 0.000 | 0.107 | 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 | 0.061 | 0.102 | 0.109 | 0.119 | 0.079 | 0.120 | 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 |
| C32 | 0.000 | 0.000 | 0.000 | 0.078 | 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 | 0.115 | 0.084 | 0.095 | 0.105 | 0.090 | 0.090 | 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 |
| C33 | 0.000 | 0.000 | 0.000 | 0.063 | 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 | 0.099 | 0.037 | 0.113 | 0.056 | 0.098 | 0.026 | 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 |
| C34 | 0.000 | 0.000 | 0.000 | 0.087 | 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 | 0.053 | 0.098 | 0.081 | 0.073 | 0.059 | 0.108 | 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 |
| C35 | 0.000 | 0.000 | 0.000 | 0.106 | 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 | 0.123 | 0.102 | 0.050 | 0.092 | 0.091 | 0.093 | 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 |
| C36 | 0.000 | 0.000 | 0.000 | 0.061 | 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 | 0.051 | 0.078 | 0.054 | 0.056 | 0.083 | 0.064 | 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 |
| C41 | 0.000 | 0.000 | 0.000 | 0.000 | 0.061 | 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 | 0.049 | 0.052 | 0.025 | 0.068 | 0.057 | 0.046 | 0.042 | 0.023 | 0.059 | 0.076 | 0.025 | 0.041 | 0.068 |
| C42 | 0.000 | 0.000 | 0.000 | 0.000 | 0.047 | 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 | 0.054 | 0.060 | 0.024 | 0.024 | 0.023 | 0.043 | 0.023 | 0.045 | 0.022 | 0.023 | 0.052 | 0.024 | 0.048 |
| C43 | 0.000 | 0.000 | 0.000 | 0.000 | 0.034 | 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 | 0.078 | 0.049 | 0.036 | 0.043 | 0.019 | 0.044 | 0.030 | 0.021 | 0.054 | 0.052 | 0.041 | 0.054 | 0.059 |
| C44 | 0.000 | 0.000 | 0.000 | 0.000 | 0.049 | 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 | 0.026 | 0.024 | 0.024 | 0.046 | 0.052 | 0.025 | 0.026 | 0.027 | 0.047 | 0.027 | 0.027 | 0.048 | 0.024 |
| C45 | 0.000 | 0.000 | 0.000 | 0.000 | 0.055 | 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 | 0.026 | 0.048 | 0.043 | 0.038 | 0.023 | 0.023 | 0.043 | 0.050 | 0.038 | 0.022 | 0.048 | 0.043 | 0.022 |
| C46 | 0.000 | 0.000 | 0.000 | 0.000 | 0.028 | 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 | 0.041 | 0.021 | 0.061 | 0.021 | 0.039 | 0.018 | 0.020 | 0.020 | 0.023 | 0.048 | 0.021 | 0.052 | 0.023 |
| C47 | 0.000 | 0.000 | 0.000 | 0.000 | 0.049 | 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 | 0.038 | 0.027 | 0.029 | 0.050 | 0.027 | 0.059 | 0.041 | 0.037 | 0.030 | 0.059 | 0.029 | 0.028 | 0.029 |
| C48 | 0.000 | 0.000 | 0.000 | 0.000 | 0.038 | 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 | 0.026 | 0.040 | 0.026 | 0.028 | 0.034 | 0.052 | 0.041 | 0.093 | 0.023 | 0.020 | 0.024 | 0.043 | 0.019 |
| C49 | 0.000 | 0.000 | 0.000 | 0.000 | 0.031 | 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 | 0.019 | 0.038 | 0.054 | 0.054 | 0.054 | 0.025 | 0.030 | 0.023 | 0.059 | 0.020 | 0.054 | 0.022 | 0.052 |
| C410 | 0.000 | 0.000 | 0.000 | 0.000 | 0.028 | 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 | 0.024 | 0.048 | 0.050 | 0.025 | 0.041 | 0.048 | 0.024 | 0.067 | 0.027 | 0.048 | 0.041 | 0.054 | 0.024 |
| C411 | 0.000 | 0.000 | 0.000 | 0.000 | 0.032 | 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 | 0.023 | 0.045 | 0.042 | 0.023 | 0.048 | 0.041 | 0.054 | 0.024 | 0.052 | 0.039 | 0.046 | 0.023 | 0.059 |
| C412 | 0.000 | 0.000 | 0.000 | 0.000 | 0.039 | 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 | 0.040 | 0.026 | 0.041 | 0.039 | 0.026 | 0.054 | 0.043 | 0.026 | 0.023 | 0.041 | 0.043 | 0.048 | 0.054 |
| C413 | 0.000 | 0.000 | 0.000 | 0.000 | 0.012 | 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 | 0.059 | 0.025 | 0.048 | 0.043 | 0.059 | 0.025 | 0.088 | 0.048 | 0.043 | 0.028 | 0.052 | 0.024 | 0.021 |

to studying how to model a BSC for a performance measurement and how to implement a BSC successfully, very few studies have systematically evaluated and modeled the linguistically vague criteria of a BSC. The proposed BSC framework adds precision to an otherwise subjective decision-making process. This approach can be extended to real-world applications by considering additional criteria and the comparable of quantitative and qualitative values.

The present study has proposed a novel approach, the FNBSC, which can be useful for weighting aspects and criteria and identifying key aspect or criteria in a complex hierarchical system. The firm analyzed in our case study has shown that the proposed FNBSC approach can successfully weight aspects and criteria. The results from the case study have shown that the internal business aspect is the most influential aspect for internal business.

To the authors' knowledge, this study is to apply the fuzzy set theory with ANP method to implement a BSC performance evaluation, where the fuzzy set theory method accounts for the vagueness of the language used to express the qualitative criteria and the ANP converts the

**Table 7.** Converged supermatrix

| | | Goal | AS1 | AS2 | AS3 | AS4 | C11 | C12 | C13 | C14 | C15 | C16 | C17 | C18 | C21 | C22 | C23 | C24 | C25 | C26 | C27 | C31 | C32 | C33 | C34 | C35 | C36 | C41 | C42 | C43 | C44 | C45 | C46 | C47 | C48 | C49 | C410 | C411 | C412 | C413 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | Goal | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 | 0.0592 |
| 2 | AS1 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 | 0.0602 |
| 3 | AS2 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 | 0.0598 |
| 1 | AS3 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 | 0.0632 |
| 14 | AS4 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 | 0.0472 |
| 15 | C11 | 0.0463 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 | 0.4630 |
| 6 | C12 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 | 0.0575 |
| 4 | C13 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 | 0.0596 |
| 11 | C14 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 | 0.0490 |
| 7 | C15 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 | 0.0514 |
| 8 | C16 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 | 0.0507 |
| 13 | C17 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 | 0.0480 |
| 16 | C18 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 | 0.0413 |
| 20 | C21 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 | 0.0330 |
| 24 | C22 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 | 0.0227 |
| 22 | C23 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 | 0.0288 |
| 21 | C24 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 | 0.0318 |
| 23 | C25 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 | 0.0238 |
| 25 | C26 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 | 0.0207 |
| 26 | C27 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 | 0.0197 |
| 10 | C31 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 | 0.0494 |
| 9 | C32 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 | 0.0499 |
| 18 | C33 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 | 0.0375 |
| 17 | C34 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 | 0.0398 |
| 12 | C35 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 | 0.0484 |
| 19 | C36 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 | 0.0336 |
| 27 | C41 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 |
| 35 | C42 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 |
| 28 | C43 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 | 0.0141 |
| 39 | C44 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 |
| 36 | C45 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 | 0.0110 |
| 37 | C46 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 | 0.0109 |
| 34 | C47 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 | 0.0113 |
| 38 | C48 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 | 0.0108 |
| 32 | C49 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 |
| 30 | C410 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 | 0.0124 |
| 31 | C411 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 | 0.0123 |
| 33 | C412 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 | 0.0120 |
| 29 | C413 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 | 0.0135 |

dependence relationship among the aspects and criteria. It is worthwhile to perform more case studies improve this proposed FNBSC approach.

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