

# A Novel Balanced Scorecard Design Based on Fuzzy Analytic Network Process and its Application

Cao Yuhong<sup>\*1</sup>, You Jianxin<sup>2</sup>

School of Economics and Management Tongji University, Shanghai, China

<sup>\*</sup>Corresponding author, e-mail: [angelcaoniuniu@sina.com](mailto:angelcaoniuniu@sina.com)<sup>1</sup>, [huwei3320@sina.com](mailto:huwei3320@sina.com)<sup>2</sup>

## Abstract

*In this paper, we propose a novel balanced scorecard design based on fuzzy analytic network process and then conduct performance evaluation through a case study. After analyzing the related works about balanced scorecard design and the algorithm of fuzzy analytic network process, we illustrate the improved balanced scorecard design. Firstly, the basic concepts for the balanced scorecards are introduced. Secondly, four perspectives of the balanced scorecards design are provided. Thirdly, the method to promote the performance of balanced scorecard design through the fuzzy analytic network process is demonstrated. In the proposed design, a fuzzy number is represented by the left and right formation of each degree of membership in fuzzy analytic network process. Furthermore, the degree possibility for a convex fuzzy number to be larger than a given convex fuzzy numbers can be represented by an effective scheme. Particularly, the basic structure in the fuzzy analytic network process model is organized hierarchically, and the local weights of the strategies, balanced scorecard perspectives and performance indicators can be obtained by matrix computing. Finally, a case study of college English classroom teaching quantitative evaluation is given to demonstrate the performance of the proposed balanced scorecard design. Experimental results show that the proposed balanced scorecard design is quite effective.*

**Keywords:** *balanced scorecard, fuzzy analytic network process, fuzzy number, case study, index weight*

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## 1. Introduction

The Balanced Scorecard is proposed in 1992 by professor Robert S. Kaplan and David P. Norton, and it has become one of the most expedient management methods on several research fields. At the highest conceptual level, balanced scorecard refers to a frame which can be used to help the organizations to transpose the strategy into operational objectives, in order to direct both the organization performance and behavior. A success factor in implementing the Balanced Scorecard is represented by the use of dedicated software tools [1].

The balanced scorecard refers to a performance measurement system which supplements traditional systems with the criteria that measure performance from three additional perspectives, including 1) customer perspective, 2) internal business perspective and 3) innovation and learning perspective [2-4]. Furthermore, Kaplan and Norton proposed a three layered structure for the four perspectives: 1) mission (to become the customers' most preferred supplier), 2) objectives (to provide the customers with new products) and 3) measures (percentage of turnover generated by new products). The balanced scorecard is designed to be a performance measurement system and a planning and control device. Therefore, some companies found that the measures on a balanced scorecard can be used as the cornerstone of a management system that communicates strategy, aligns individuals and teams to the strategy, establishes long term strategic targets, aligns initiatives, allocates long and short term resources and finally, provides feedback and learning about the strategy [1].

On the other hand, the analytic network process is a more general form of the analytic hierarchy process which is utilized in multi-criteria decision analysis. Analytic hierarchy process structures a decision problem into a hierarchy with a goal, decision criteria, and alternatives, while the analytic network process structures it as a network. Both then use a system of pairwise comparisons to measure the weights of the components of the structure, and then to rank the alternatives in the decision [5-8]. In this paper, we proposed a novel analytic network process and utilize it in the design of balanced scorecard.

The main innovations of this paper lie in the following aspects:

(1) A modified fuzzy analytic network process is proposed to make the balanced scorecard design.

(2) We choose balanced scorecard perspectives and the performance indicators based on the four perspectives, including 1) Customer perspective, 2) Internal business process perspective, 3) Learning and growth perspective, and 4) Financial perspective.

(3) The basic structure the fuzzy analytic network process model in a hierarchical form.

(4) The local weights of the strategies, balanced scorecard perspectives and performance indicators can be computed by pairwise comparison matrices effectively.

(5) The inner dependence matrix of each perspective is determined by the fuzzy scale according to the proposed four balanced scorecard perspectives.

The rest of the paper is organized as the following sections. Section 2 introduces the related works. Section 3 illustrates the proposed scheme for balanced scorecard design based on fuzzy analytic network process. In section 4, experiments are conducted to make performance evaluation with comparison to other existing methods. Finally, we conclude the whole paper in section 5.

## 2. Related Works

Balanced scorecard belongs to one of the most particular methods for performance measurement in several application fields. Balanced scorecard proposes a general framework which has been used more precisely by many researchers. Moreover, balanced scorecard as a general framework has been adapted by many practitioners to specific implementation areas. In the following parts, we will introduce the related works about the applications of balanced scorecard

Cattinelli et al. showed the potential of the proposed methods through illustrative results derived from the analysis of BSC data of 109 FME clinics in three countries. The authors were able to identify the performance drivers for specific groups of clinics and to distinguish between countries whose performances are likely to improve from those where a decline in performance might be expected [9].

Nasser et al. dealt with a case study that took place in a nutritional therapy company from January to November 2010. For analysis of the learning and growth perspective all 45 of the company's collaborators were considered and for client analysis 124 home-care clients were considered. The study sample consisted of 39 collaborators and 44 clients participating in the research [10].

Lin et al. explored the use of a management tool: balanced scorecard (BSC), which facilitates managers to meet multiple strategic goals, and fuzzy linguistic method for evaluating OR performance. BSC is a strategic planning and management system that is used extensively in business and industry, government and nonprofit organizations. First, a model is developed for measuring the acceptable performance of OR based on the interaction financial, customers, internal business process and learning and growth perspective. After that, BSC structure integrated with fuzzy linguistic is proposed for measuring and improving the service [11].

Mutale et al. applied the concept of balanced scorecard to describe the baseline status of three intervention districts in Zambia. To assess the baseline status of the participating districts, the authors used a modified balanced scorecard approach following the domains highlighted in the MOH 2011 Strategic Plan [12].

Hwa et al. set out to develop a BSC as part of a strategic planning initiative. Based on a needs assessment of the University of California, San Francisco, Division of Hospital Medicine, mission and vision statements were developed. The authors engaged representative faculty to develop strategic objectives and determine performance metrics across 4 BSC perspectives [13].

Jaksic et al. proposed an approach to integrate the Balanced Scorecard model and Analytic network process in the case of selected financial institutions in Serbia. The subject of analysis will be open-ended investment funds of property value growth. The reasons which led the authors in selecting these non-deposit financial institutions are first of all, their importance for the development of overall financial and real sector, as well as weak domestic portfolio management practices of these institutions, which resulted in the extremely high yield decline in the last four years [14].

Maurer et al. showed that the BSC can be used for the comprehensive control of a radiology department and thus provides a meaningful contribution in organizing the various diagnostic and treatment services, the management of complex clinical environment and can be of help with the tasks in research and teaching [15].

Javier et al. illustrated the design of a balanced scorecard for managing an emergency department in a tertiary care university teaching hospital; data derived by implementing the scorecard system are also presented. The project was carried out in the following phases: 1) selection of indicators of activity and quality of processes and outcomes for the scorecard, 2) validation of the indicators, 3) analysis of indicators from 2007 through 2009, and 4) conclusions regarding clinical performance in relation to the indicators that make up the scorecard [16].

Houck et al. introduced the concept of the balanced scorecard into the laboratory management environment. The balanced scorecard is a performance measurement matrix designed to capture financial and non-financial metrics that provide insight into the critical success factors for an organization, effectively aligning organization strategy to key performance objectives [17].

Wu et al. proposed a new hierarchical structure for the BSC with placing both finance and customer at the top, internal process at the next, and learning and growth at the bottom. Empirical examination has found the importance of the new BSC structure in assessing IT investments. Learning and growth plays the initial driver for reaching both customer and financial performance through the mediator of internal process. This can provide deep insight into effectively managing IT resources in the hospitals [18].

Next, some typical papers related to the fuzzy analytic network are illustrated as follows.

Yu et al. proposed a two-stage fuzzy logarithmic preference programming with multi-criteria decision-making, in order to derive the priorities of comparison matrices in the analytic hierarchy process (AHP) and the analytic network process (ANP). The Fuzzy Preference Programming (FPP) proposed by Mikhailov and Singh is suitable for deriving weights in interval or fuzzy comparison matrices, especially those displaying inconsistencies. However, the weakness of the FPP is that it obtains priorities of comparison matrices by additive constraints, and generates different priorities by processing upper and lower triangular judgments [19].

Isalou et al. developed an integrated fuzzy logic and analytic network process to locate a suitable location for landfilling municipal solid wastes generated in Kahak Town, Qom, Iran. In this paper, the authors findings revealed that integration of fuzzy logic and ANP can give better idea compared with other models like AHP, fuzzy logic, and ANP (individually). Therefore, this model can be applied in site selection for landfill of other similar places<sup>[20]</sup>.

Moalagh et al. proposed a practical framework for assessing a firm's ERP post-implementation success utilising current models through a fuzzy analytic network process. The construct of ERP success is broken down into three main parts, including managerial success, organisational success, and individual success. Using this framework, the firm's ERP system success can be determined and the required improvement projects can be proposed to promote the success level [21].

Pang et al. developed a supplier evaluation approach based on the analytic network process (ANP) and fuzzy synthetic evaluation under a fuzzy environment. The importance weights of various criteria are considered as linguistic variables. These linguistic ratings can be expressed in triangular fuzzy numbers by using the fuzzy extent analysis. Fuzzy synthetic evaluation is used to select a supplier alternative and the Fuzzy ANP (FANP) method is applied to calculate the importance of the criteria weights [22].

Kiris et al. proposed a fuzzy analytic network process to determine the weights of the criteria and the scores of the inventory items were determined with simple additive weighting by using linguistic terms. Applying fuzzy ANP to a multi-criteria inventory classification problem is the novelty of this study in the related literature. In addition, the application area of the problem which is the management of the engineering vehicles' items in a construction firm is different from the other studies [23].

### 3. The Proposed Scheme

Before illustrating the proposed scheme of balanced scorecard design based on fuzzy analytic network process, basic concepts of balanced scorecard are described in advanced. As is shown in Figure 1, we choose an example of a business problem to introduce the main ideas of balanced scorecard design.

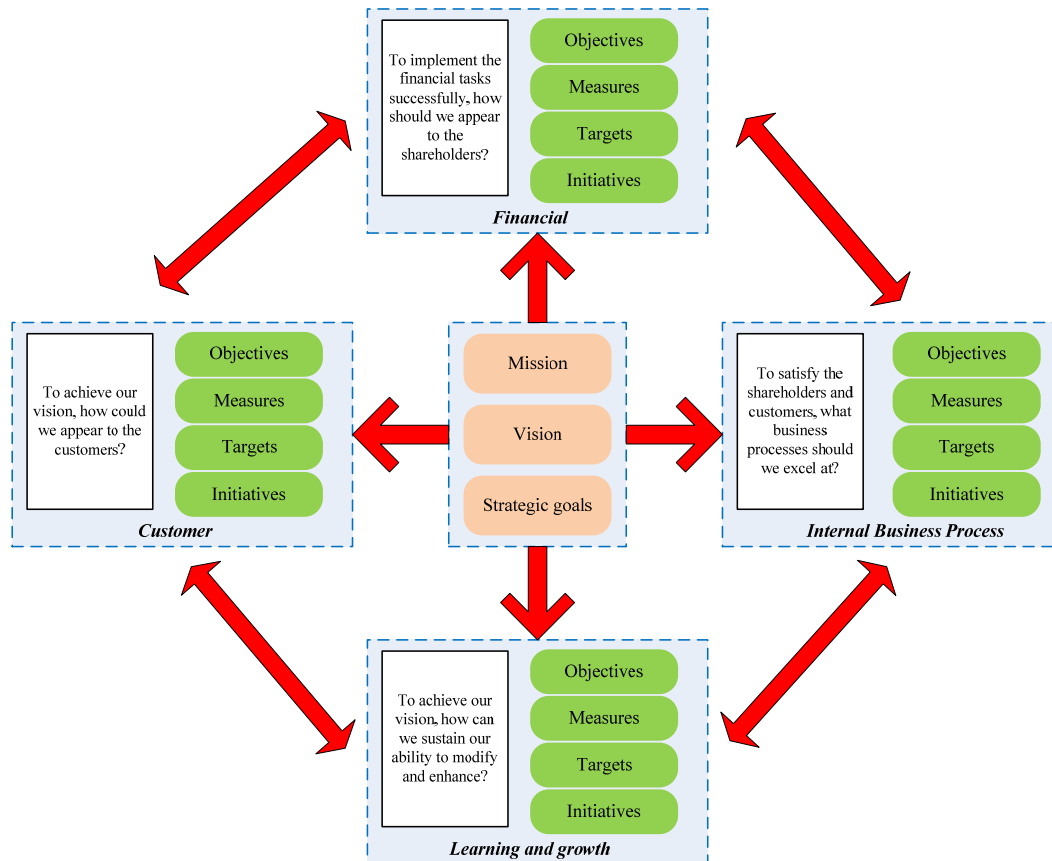


Figure 1. Basic Concepts for the Balanced Scorecards

In Figure 1, we present how the business profitability is evaluated from many aspects which can be measured throughout financial and non-financial indicators, and then they are classified in the following classes: 1) Financial perspective, 2) Client perspective, 3) Internal perspective, 4) Development, 5) Learning perspective. Particularly, the frame of balanced scorecard is based on four processes which bind the short term activities to long term objectives.

As is shown in Figure 1, there are four perspectives in the design of balanced scorecards as follows.

(1) Customer perspective.

As the companies can create value through customers, making it clear that how these companies view performance is regarded as an important problem of performance measurement.

(2) Internal business process perspective.

The internal business process perspective could executive to identify the key internal processes in which the organization must overbear.

(3) Leaning and growth perspective.

The leaning and growth perspective in the balanced scorecard can distinguish the infrastructure which the organization should be constructed to create a long-term growth and improvement.

(4) Financial perspective.

In the design of balanced scorecard, financial performance can indicate if the strategy, implementation, and execution of a company can contribute to bottom line improvement.

In the following section, we will demonstrate how to enhance the performance of balanced scorecard design through the fuzzy analytic network process.

Firstly, supposing  $X = \{x_1, x_2, \dots, x_n\}$  be a set of object, and  $U = \{u_1, u_2, \dots, u_m\}$  be a set of goal. Afterwards,  $m$  extended analyzing values for each object could calculated, which can be represented as follows:

$$M_{gi}^1, M_{gi}^2, \dots, M_{gi}^m, i \in \{1, 2, \dots, n\} \tag{1}$$

Where each  $M_{gi}^j$  is belonged to triangular fuzzy number, and the value of fuzzy synthetic extent which is related to the  $i^{th}$  object is defined as follows:

$$S_i = \sum_{j=1}^k M_{gi}^j \otimes \left[ \sum_{i=1}^n \sum_{j=1}^k M_{gi}^j \right]^{-1} \tag{2}$$

In order to achieve the results of  $\sum_{j=1}^k M_{gi}^j$ , the fuzzy addition operation of the  $k$  extent analysis values for a given matrix should be executed as follows.

$$\sum_{j=1}^k M_{gi}^j = \left\{ \sum_{j=1}^k l_j, \sum_{j=1}^k k_j, \sum_{j=1}^k u_j \right\} \tag{3}$$

The degree of possibility of  $M_2 = (l_2, k_2, u_2) \geq M_1 = (l_1, k_1, u_1)$  can be computed as follows.

$$P(M_2 \geq M_1) = \begin{cases} 1, & \text{if } k_2 \geq k_1 \text{ is satisfied} \\ 0, & \text{if } l_1 \geq u_2 \text{ is satisfied} \\ \frac{l_1 - u_2}{k_2 - u_2 - k_1 + l_1}, & \text{otherwise} \end{cases} \tag{4}$$

Particularly, a fuzzy number can be represented by the left and right formation of each degree of membership, which is shown in Figure 2.

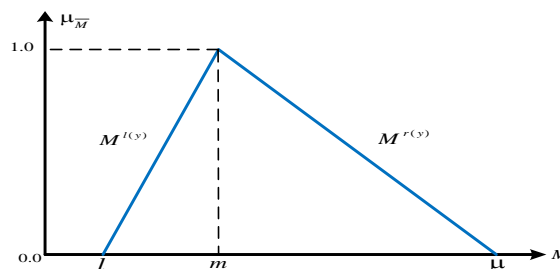


Figure 2. Illustration of a Triangular Fuzzy Number

The degree possibility for a convex fuzzy number to be larger than  $k$  convex fuzzy numbers  $M_i, (i \in \{1, k\})$  can be represented as follows:

$$\begin{aligned}
 P(M \geq M_1, M_2, \dots, M_k) &= P(M \geq M_1) \cap \\
 &\quad (M \geq M_2) \cap \dots \cap (M \geq M_k) \\
 &= \min P(M \geq M_i), i \in \{1, 2, \dots, k\}
 \end{aligned}
 \tag{5}$$

The linguistic variables' membership functions can be determined by the process which is shown in Figure 3.

Based on the above formal description, the balanced scorecard can be designed by the fuzzy analytic network process as the following steps.

- (1) Constructing a performance evaluation team which is made up of experts and determination of business vision.
- (2) Choosing the strategies to be pursued in order to obtain the business vision.
- (3) Selecting balanced scorecard perspectives and the performance indicators based on these perspectives.
- (4) Organizing the basic structure the fuzzy analytic network process model hierarchically.
- (5) Calculating the local weights of the strategies, balanced scorecard perspectives and performance indicators through pairwise comparison matrices.
- (6) Determine the fuzzy scale, the inner dependence matrix of each perspective according to other balanced scorecard perspectives.
- (7) Computing the global weights for the performance indicators.
- (8) Measuring the performance indicators.
- (9) Determining the business performance for a specific period of time by using the global weights calculated in the seventh step.

#### 4. Case study

In this section, we will give a case study of college English classroom teaching quantitative evaluation to demonstrate the performance of the proposed balanced scorecard design. Firstly, a hierarchy structure of the index system for college English classroom teaching quality evaluation is given in Table 1. The proposed hierarchy structure of the index system is made up of two main sections: 1) Evaluation of teachers and 2) Evaluation of students. Based on the above Hierarchy structure of the index system, twenty one indexes for quality evaluation are presented.

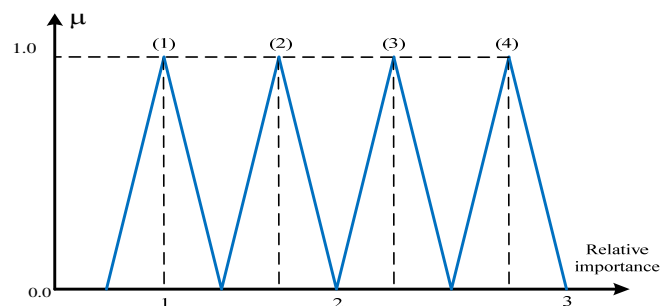


Figure 3. Membership Functions of the Linguistic Variables to Represent the Relative Importance

In this section, we make performance evaluation for the proposed approach by the case of college English classroom teaching quality evaluation. Furthermore, 17 indexes are used in this experiment, therefore, we should test the contribution rate for each index. 20 classes are arranged to make our performance evaluation, and we test the weight of each index for each class. The results are shown in Table 2.

Based on the results of Table 2, the contribution rate for each index is calculated by averaging the index weight (shown in Figure 4), which illustrates the contribution degree for each index in the case of college English classroom teaching quality evaluation.

Table 1. The Index System used in our this Experiment

Objects of evaluation	Index of evaluation	
Evaluation of teachers	Teaching aims C1:Combination of language knowledge and language application	
	Teaching approaches C2:Emphasis on application C3:Proper choice of teaching media C4:Adaptation to students' present level	
	Teaching design C5:The optimal design which can realize the teaching aims C6:Proper allocation of time C7:Students focus on learning tasks at hand	
	Learning attitude C8:Students have curiosity for and interest in study exploration C9:Students' active participation in listening, speaking, reading, writing and translation	
Evaluation of students	Participation in English learning C10:Students' eagerness to finish task-based activities C11:Students' practice of language knowledge based on daily communication C12:Proper choice of learning methods	
	Learning Methods C13:Practice and application C14:Students' progress and improvement C15:Satisfaction with learning atmosphere	
	Learning Effect	C16:Satisfaction with learning results C17:Satisfaction with learning methods

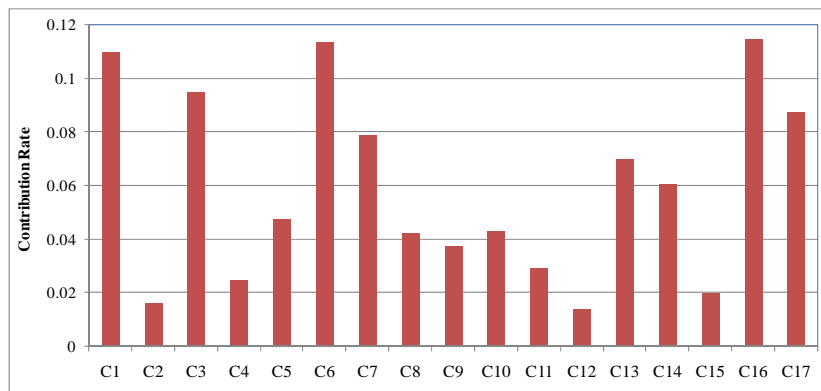


Figure 4. Contribution Rate for Each Index

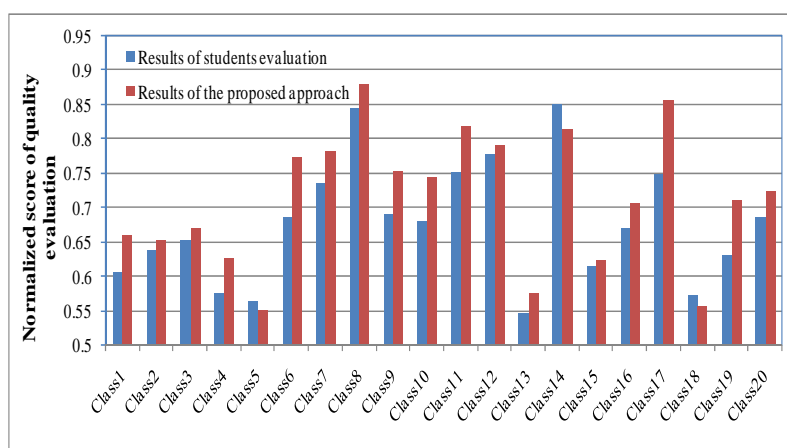


Figure 5. The Normalized Score of Quality Evaluation for Different Classes

Table 2. Index Weight for Each Class

	Evaluation of teachers							Evaluation of students									
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17
Class 1	0.07	0.08	0.04	0.05	0.08	0.02	0.10	0.07	0.08	0.02	0.05	0.09	0.04	0.07	0.01	0.09	0.04
Class 2	0.11	0.04	0.06	0.08	0.04	0.03	0.05	0.00	0.07	0.04	0.11	0.04	0.03	0.08	0.03	0.07	0.11
Class 3	0.07	0.07	0.04	0.10	0.01	0.03	0.10	0.03	0.04	0.10	0.07	0.01	0.03	0.07	0.05	0.10	0.09
Class 4	0.09	0.02	0.08	0.02	0.01	0.02	0.06	0.09	0.11	0.07	0.04	0.09	0.05	0.06	0.08	0.02	0.10
Class 5	0.05	0.07	0.08	0.10	0.00	0.09	0.03	0.05	0.02	0.09	0.08	0.06	0.05	0.10	0.05	0.07	0.01
Class 6	0.06	0.05	0.07	0.04	0.00	0.10	0.09	0.11	0.04	0.07	0.12	0.05	0.00	0.04	0.07	0.05	0.02
Class 7	0.01	0.08	0.00	0.10	0.11	0.11	0.09	0.08	0.01	0.01	0.05	0.01	0.06	0.03	0.09	0.10	0.07
Class 8	0.11	0.04	0.06	0.07	0.07	0.08	0.06	0.09	0.06	0.10	0.10	0.03	0.06	0.01	0.02	0.01	0.03
Class 9	0.07	0.09	0.04	0.06	0.08	0.06	0.03	0.06	0.08	0.07	0.01	0.08	0.07	0.07	0.06	0.05	0.02
Class 10	0.03	0.04	0.01	0.06	0.12	0.01	0.12	0.08	0.11	0.08	0.05	0.02	0.10	0.03	0.09	0.00	0.04
Class 11	0.07	0.07	0.07	0.03	0.05	0.05	0.08	0.08	0.05	0.06	0.07	0.05	0.05	0.05	0.05	0.06	0.06
Class 12	0.04	0.03	0.09	0.07	0.05	0.03	0.09	0.08	0.09	0.03	0.02	0.09	0.03	0.09	0.02	0.06	0.09
Class 13	0.04	0.10	0.04	0.04	0.10	0.06	0.07	0.07	0.11	0.11	0.02	0.02	0.04	0.08	0.05	0.03	0.04
Class 14	0.07	0.10	0.05	0.01	0.06	0.04	0.08	0.10	0.10	0.05	0.03	0.08	0.06	0.03	0.04	0.09	0.02
Class 15	0.12	0.05	0.11	0.10	0.02	0.05	0.05	0.09	0.02	0.04	0.02	0.01	0.06	0.05	0.05	0.06	0.10
Class 16	0.08	0.04	0.02	0.06	0.00	0.07	0.03	0.10	0.06	0.10	0.10	0.02	0.06	0.01	0.10	0.08	0.06
Class 17	0.06	0.01	0.07	0.06	0.06	0.09	0.10	0.10	0.03	0.11	0.04	0.06	0.08	0.06	0.01	0.04	0.02
Class 18	0.09	0.10	0.04	0.09	0.08	0.06	0.00	0.04	0.09	0.10	0.02	0.02	0.09	0.07	0.03	0.03	0.04
Class 19	0.12	0.07	0.04	0.00	0.07	0.07	0.05	0.06	0.10	0.08	0.07	0.03	0.10	0.08	0.01	0.01	0.05
Class 20	0.04	0.11	0.13	0.00	0.01	0.11	0.02	0.05	0.02	0.04	0.01	0.12	0.05	0.03	0.06	0.12	0.09

For each class, we compare the normalized score of quality evaluation between the results of students' evaluation and results of the proposed approach. As is show in Fig.5, we can know that the performance of the proposed design is very close to the evaluation of students. Therefore, the conclusions can be drawn that the proposed balanced scorecard design is quite effective for the quality education reform oriented college English classroom teaching quantitative evaluation.

From the above experimental results, it can be seen that the performance of the proposed design is very effective. The main reasons lie in the following aspects:

(1) The design of the proposed balanced scorecard is based on four processes which bind the short term activities to long term objectives, including: 1. Financial perspective, 2. Client perspective, 3. Internal perspective, 4. Development, 5. Learning perspective.

(2) In the proposed balanced scorecard design, financial performance can express if the strategy, implementation, and execution of a company can contribute to bottom line improvement.

(3) In this paper, a fuzzy number can be represented by the left and right formation of each degree of membership in the proposed fuzzy analytic network process.

(4) The degree possibility for a convex fuzzy number to be larger than a given convex fuzzy numbers can be represented by an effective scheme.

(5) The basic structure in the fuzzy analytic network process model is organized in the hierarchical mode, and the local weights of the strategies, balanced scorecard perspectives and performance indicators can be obtained by pairwise comparison matrices.

## 5. Conclusion

We illustrate a novel balanced scorecard design based on fuzzy analytic network process in this paper. The main innovations of this paper lie in that 1) a fuzzy number is



represented by the left and right formation of each degree of membership in fuzzy analytic network process. 2) The degree possibility for a convex fuzzy number to be larger than a given convex fuzzy numbers can be represented by an effective scheme. 3) The basic structure in the fuzzy analytic network process model is organized hierarchically, and the local weights of the strategies, balanced scorecard perspectives and performance indicators can be obtained by matrix computing.

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