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Integrating hierarchical balanced scorecard with fuzzy linguistic for evaluating operating room performance in hospitals

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ABSTRACT

Health care organizations are operating in a complex environment. The competitive and dynamic health care sector has spurred hospitals into delivering greater flexibility and quality of services. An efficient performance evaluation system is essential for controlling, monitoring and improving service quality in health care organizations. The performance evaluation of operating room (OR) is a useful work for managers to control the operational process of OR team so as to promote the performance. This paper explores 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. The aim of this study was to build a performance evaluation system for OR and use a fuzzy linguistic to convert the subjective cognition of managers into an information entity and confirmation of improvement. This research results are able to help the organisation to evaluate and revise its strategy and generally to adopt modern management approaches in every day practise.

1. Introduction

Efficient and accurate performance measurement systems serve as a useful tool enabling managers to control, monitor and improve health care processes and performance. The health care industry currently faces considerable strategic challenges and strong pressure to become more responsive to customers' demands by simultaneously improving quality and efficiency (Chow, Ganulin, & Williamson, 1998; Lorden, Coustasse, & Singh, 2008). This situation imposed the traditional performance measurement and management control systems are insufficient guides for achieving multiple strategic objectives. As a consequence, organizations such as hospitals are required to improve their performance for multiple stakeholders and deliver an integrated care that means to work effectively, be innovative and organize efficiently (Lupi et al., 2011). In this way, hospitals increasingly adopt sophisticated and comprehensive management information systems, such as the balanced scorecard, to achieve their strategic goals (Fottler, Erickson, & Rivers, 2006; Yang & Tung, 2006).

Performance measurement is a multidimensional structure involving the various components which contribute differently to overall hospital performance. It is difficult and complex to make performance measurement. Since evaluators lack widely recognized performance measurement tools and well-defined criteria for making accurate measurements. Constructing and possessing available performance measurement tools not only increases evaluation efficiency but also saves costs. Traditional performance measurements generally use financial aspects to measure performance. The most significant limitation is that they emphasize the operational results, but not the internal process, which would result in ignoring forecasting function and lacking a long-term orientation.

BSC is a customer-based planning and control system that helps managers to translate strategy into an integrated set of financial and nonfinancial measures (Kaplan & Norton, 1996, 2001). Recent studies illustrated the adoption of BSC by a broad range of health care. Grigoroudis, Orfanoudaki, and Zopounidis (2012) presented BSC methodology for public health care organizations and generally adopted modern management approaches in every day practice. Huang and Chang (2004) use BSC to improve the

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performance of an emergency department. Kocakülâh and Austill (2007) discussed BSC generally from theoretical and technical views, and why BSC should be used by health care organizations. They argued that BSC is particularly applicable to hospitals, clinics, and other health care companies. Josey and Kim (2008) used BSC to improve performance and maintain competitive advantages. The results were impressive. Operational measures improved during the first year of the implementation, and they led to a significant increase in revenues and profit. Chang, Tung, Huang et al. (2008) implement BSC fully for the entire organization in hospital to enhance its competition. Verzola, Bentivegna, Carandina et al. (2009) implement and evaluate the use of BSC in two departments of the St. Anna University Hospital. Rabbani, Jafri, Abbas et al. (2010) applied a modified Delphi to design a BSC for a tertiary care hospital. Managers who are considering adopting a BSC for their organizations should research the topic thoroughly and, above all, know what they hope to achieve before they start the project. To be successful, especially in health care, the BSC will require the long term commitment characteristic of other major organizational changes (Voelker, Rakich, & French, 2001).

Hospital performance measurement requires more intangible assets include patient satisfaction, process innovation capability, etc. The non-financial information is crucial in hospital. But numerous non-financial indicators are difficult to quantify, yet they can significantly impact overall hospital performance measurement.

Recently, many researchers have been developed and modified fuzzy linguistic approach in order to apply in diverse domains. Awasthi, Chauhan, and Giyal (2010) present a fuzzy multi-criteria approach for evaluating environment performance of suppliers. They used linguistic assessment to rate the criteria and the alternatives, and then combined through fuzzy TOPSIS to generate an overall performance score for each alternative. And the proposed approach can be practically applied in evaluating environmental performance of suppliers. Huang, Yeh, Lin, and Lee (2009) propose an effective and convenient performance evaluation model based a fuzzy AHP for implementing SPC in the Taiwanese LCD industry. The study demonstrates that the proposed model is an effective and convenient tool that can be used to analyze and improve the performance of an existing SPC system or to enhance success in implementing a new SPC system while working within constraints of time and costs. Fan, Bo, and Suo (2009) propose a fuzzy linguistic method for evaluating collaboration satisfaction of NPD team using mutual-evaluation information. The method is suitable to process linguistic information and could be embedded in decision support system to support managers/decision-makers in the process of NPD. Hu, Lee, and Yen (2010) use fuzzy linguistic approach to analyze out-patient service quality gaps in hospitals. They verify whether fuzzy linguistic is a better solution than the Likert scale and evaluate patients' feedback towards hospital service quality using fuzzy linguistic analysis.

In consideration of the significance of the non-financial information in hospital performance measurement. This research proposed an effective and efficient OR performance evaluating procedure by combining the BSC structure with a fuzzy linguistic to convert the subjective cognition of managers into an information entity. OR is one of the most critical and expensive resources in hospital. It is a crucial hospital resource, as 60–70% of all hospital admissions are caused by surgical interventions and it has been estimated that it accounts for more than 40% of the total expenses of a hospital (Denton, Viapiano, & Vogl 2007). Maynard and Bloor (1995) have shown that the utilization of OR largely affects the overturn of the surgical patients in hospital. Even a small problem in the process of OR will influence the quality of hospital management. So, as an important place of treatment for patients and scientific research, the process design and management plays an important role in hospital management (Van Tilburg, Leistikow, Rademaker, Bierings, & van Dijk, 2006). Inefficiencies in an OR can occur during and between cases and lead to multiple problems including delays in the delivery of patient care. Ultimately, delays are associated with dissatisfaction among patients as well as heath care providers. Many hospitals are affected by this problem and expend their resources to find opportunities to improve efficiency (Harders, Mark, Weight, & Sidhu, 2006).

The research based on the analysis of OR in hospital A which locates in Shanghai China. A study on the development of performance system for OR was done during July 2008 and December 2009. The study was divided into 4 phases. Phase 1 was literature review. We reviewed a great deal of literature at home and abroad to comprehend the application of BSC in process evaluation and the constitution of the process performance evaluation in hospital (Dexter, Epstein, & Marsh, 2001; Maresi, Thomas, & Alexander, 2008). The second phase was the drafting of performance evaluation system subsequently validated by specialists in OR and managers of hospital and researchers. Phase 3 was revising of BSC structure for the OR process performance. The fourth phase was using a fuzzy linguistic to convert the subjective cognition of managers into an information entity and confirmation of improvement.

2. Material and methods

The research based on the analysis of OR in hospital A which locates in Shanghai China. The hospital was built in 1920. Presently, it has more than 100 senior professional experts, 1800 staff members, 850 beds and 50 clinical and technical departments. It integrates medical treatment, prevention, education and research all together, and is on its highway of standardization and sustainable development (URL1).

This paper explores the use of BSC with fuzzy linguistic theory to evaluate OR performance. Based on the interaction financial, customers, internal business process and learning and growth perspective, the performance indicates system is developed for measuring the acceptable performance of OR. After that, fuzzy linguistic is proposed for measuring and improving the service. It aims to convert the subjective cognition of managers into an information entity and confirmation of improvement.

3. Theory

3.1. Balanced Scorecard

BSC was originally developed by Kaplan and Norton as a performance measurement tool for managers to obtain a quick, yet comprehensive view of how their businesses were operating (Kaplan & Norton, 1992). It added strategic non-financial performance measures to traditional financial metrics to give managers and executives a more 'balanced' view of organizational performance. It is used extensively in business and industry, government, and nonprofit organizations worldwide to align business activities to the vision and strategy of the organization, improve internal and external communications, and monitor organization performance against strategic goals (Kaplan & Norton, 1992).

The success of BSC or a similar device will depend on the clear identification of non-financial and financial variables and their accurate and objective measurement and linking the performance to rewards and penalties. The aim of BSC is to direct, help manage and change in support of the long term strategy in order to manage performance. In general, a BSC system is considered to be a performance measurement system, a strategy evaluation system, and a communication tool, at the same time, defined by the following four distinct perspectives (Kaplan & Norton, 1996a). Kaplan and Norton (1996d) argued that the BSC program is a cause-and-effect

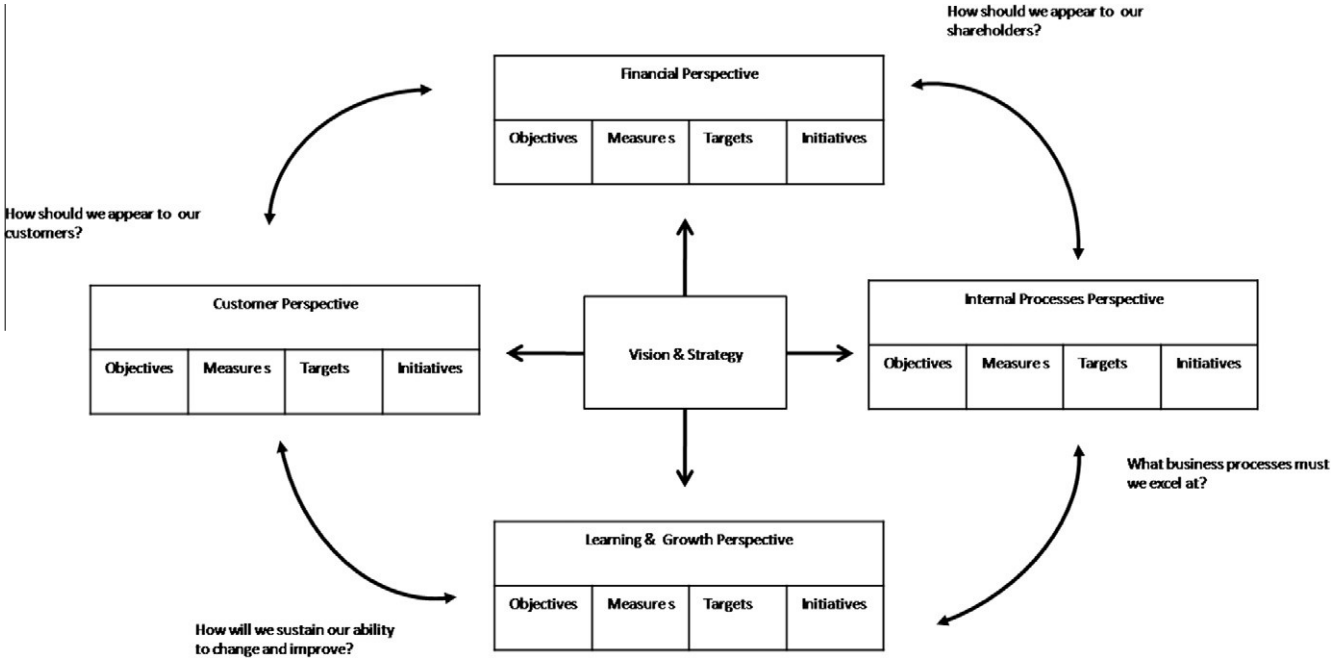

Fig. 1. The cause and effect of BSC adopted from Kaplan and Norton (1992).

relationship among different measurements in the selected perspective, as Fig. 1 shows.

- The learning and growth perspective includes employee training and corporate cultural attitudes related to both individual and corporate self-improvement. In the current climate of rapid technological change, it is becoming necessary for knowledge workers to be in a continuous learning mode. Metrics can be put into place to guide managers in focusing training funds where they can help the most. In any case, learning and growth constitute the essential foundation for success of any knowledge-worker organization.
- The internal processes perspective refers to internal business processes. Metrics based on this perspective allow the managers to know how well their business is running and whether its products and services conform to customer requirements. These metrics have to be carefully designed by those who know these processes most intimately; with unique missions these are not something that can be developed by outside consultants.
- The customer perspective emphasizes the satisfaction of the customers. Recent management philosophy has shown an increasing realization of the importance of customer focus and customer satisfaction in any business. These are leading indicators- if customers are not satisfied, they will eventually find other suppliers that will meet their needs. Poor performance from this perspective is thus a leading indicator of future decline, even if the current financial picture looks good. In developing metrics for satisfaction, customers should be analyzed in terms of kinds of customers and the kinds of processes for which a product or service to those customer group is provided.
- Timely and accurate funding data will always be a priority with managers doing everything necessary to provide it. In fact, often there is more than enough handling and processing of financial data. With the implementation of a corporate database, it is hoped that more of the processing can be centralized and automated. However, the point is that, the current emphasis on financial leads to the 'unbalanced' situation with regard to other perspectives. There is perhaps a need to include additional financial-related data, such as risk assessment and cost-benefit data, in this category.

BSC helps everyone in an organization understand and work towards a shared vision. A completed scorecard system aligns the organization's picture of the future, with business strategy, desired employee behavior and day-to-day operations. It is therefore a very important strategic management tool which helps an organization not only to measure performance, but also decide (manage) the strategies needed to be adopted (modified) so that the long-term goals are achieved (Sharma, 2009).

BSC gives us a valuable tool for enabling employees to understand the company's situation, a must if the company is to achieve the dynamism it needs to be competitive in the long run. It also provides us with useful documentation for continually developing those measures for control which most quickly will guide the company towards achieving its goals and its vision. Table 1 provides an overview of the process and also indicates the nature of the work and the time required for each step. As previously noted, the exact arrangement and thus also the time allotted must be adapted to the characteristics and situation of each company.

3.2. Fuzzy linguistic theory

Rephrase Zadeh (1975a) introduced the fuzzy set theory to enable uncertain and imprecise real world systems to be captured via linguistics variables. Fuzzy logic thus is a useful tool for dealing with decisions involving complex, ambiguous, and vague phenomena based on the meanings of the linguistic variables. Traditional quantitative methods are problematic when analysing complicated and ill-defined situations, the study by Zadeh (1975b, 1975c) point out the solution was the fuzzy linguistic method. Linguistics expression provides a useful approach for interpreting the semantics of vague based on the subjective judgments of evaluators. Linguistic variables are variables which do not bear numerical values but are words or sentences in a natural or artificial language. The concept of linguistic variables has been developed as a counterpart of the concept of a numerical variable.

Table 1
The step in the building process of balanced scorecard.

Step	Description	Procedure	Suggested time
1	Define the industry, describe its development and the role of the company	Interviews with as many people as possible. Should be done if possible by an outside party to obtain the most objective picture. Research on industry situation and trends	1–2 months
2	Establish/confirm the company's vision	Joint seminar attended by top management and opinion leaders	1–2 meetings of 1.5 days each
3	Establish the perspectives	Seminar attended by top management, the project group, and someone having previous experience with balanced scorecard projects	1–2 days
4	Break the vision down according to each perspective and formulate overall strategic goals	Joint seminar with the same group as in step 2	See below
5	Identify critical factors for success	At the seminar above	Total including step 4: 2–3 days
6	Develop measures, identify causes and effects and establish a balance	At the seminar above, if possible. However, a certain interval is often beneficial	Included above, otherwise 1–2 days
7	Establish the top level scorecard	Final determination by top management and the project group. Preferably, though, with the participation of someone having previous experience with balanced scorecard projects	1–2 days
8	Breakdown of the scorecard and measures by organizational unit	Suitable for a project divided up into appropriate organizational units under the leadership of the project group. Preferably all personnel involved should take part in the project work of each unit; a suitable form for the work would be a seminar. Progress reports and ongoing coordination with top management. Help from an experienced balanced scorecard architect is especially important in aligning success factors and measures	Total of 2 months and upward. For each local seminar, at least ½–1 day
9	Formulate goals	Proposals by each unit project leader. Final approval of goals by top management	No estimate
10	Develop an action plan	Prepared by each project group	No estimate
11	Implementing the scorecard	Ensured by ongoing monitoring under the overall responsibility of top management	No estimate

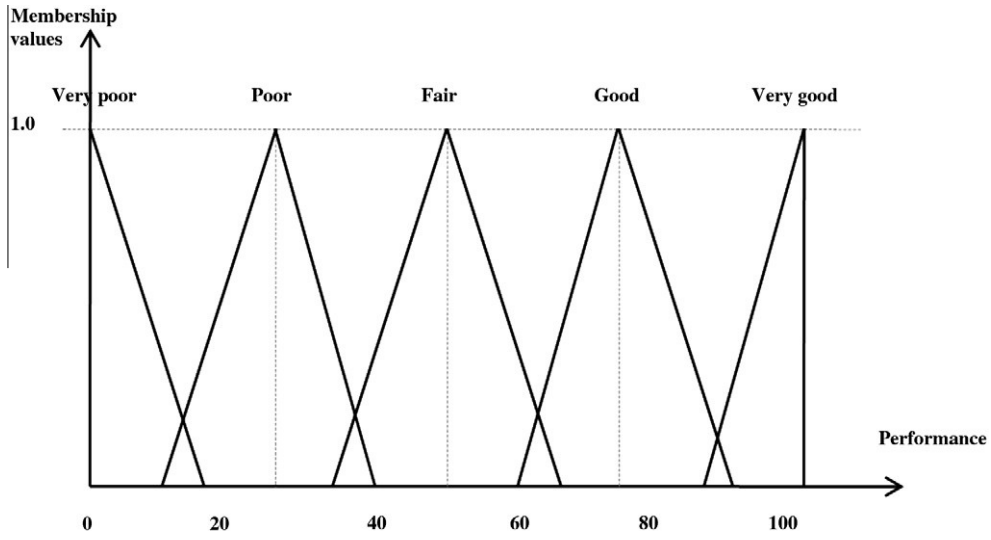

Fig. 2. Fuzzy linguistic values of performance.

Fuzzy theory constructs a conceptual framework for a systematic treatment of fuzziness in linguistic variables that are represented in words or sentences. These linguistic variables are interpreted as fuzzy sets characterised by membership functions. A fuzzy set is a mapping of a set of real numbers () onto membership values () that lie in the range [0,1]. Membership function can capture the human quantitative meaning of such variables so they can be processed as data. To capture the true human meaning of words or sentences, constructing their membership functions is important for the success of fuzzy applications.

The objective of a fuzzy linguistic is to solve complicated, subjective and undefined situations. The fuzzy linguistic variables are adopted to be triangular fuzzy numbers which are classified to symmetry. Linguistic variables are triangular fuzzy numbers, no matter whether they are symmetric, and have similar estimated results. It is of no difference whether using symmetric or asymmetric triangular fuzzy number in research (Wu, Tsai, Shih, & Fu, 2010).

The linguistic scale given in Fig. 2 is used for the evaluation since people use usually linguistic terms to define their logical judgments (Olcer & Odabasi, 2005). Fig. 2 shows triangular fuzzy numbers for the intangible linguistic scale where linguistic terms are defined as very poor (VP), poor (P), fair (F), good (G), very good (VG). The corresponding fuzzy numbers of the five linguistic scale are (0,0,15), (10,25,40), (35,50,65), (60,75,90), (85,100,100).

To weight the importance of each criterion, it is adopted with a five-scale fuzzy linguistic: absolutely unimportant (AU), unimportant (U), moderately important (MI), important (I), and very important (VI) (Fig. 3), where the corresponding fuzzy numbers are (0,0,0.15), (0.1,0.25,0.4), (0.35,0.5,0.65), (0.6,0.75,0.9), (0.85,1,1), respectively.

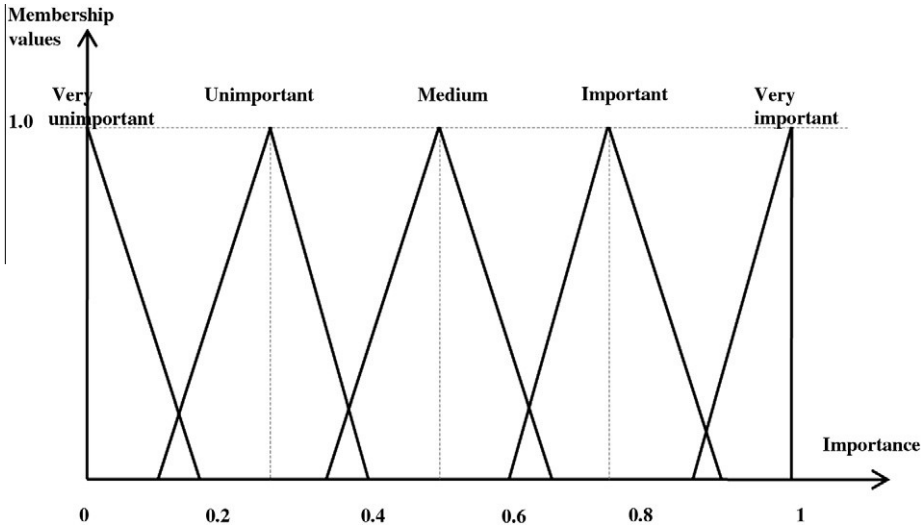

Fig. 3. Fuzzy linguistic values of importance.

Table 2
The BSC indicators system of OR.

Goal	Perspectives	Criterion
Operating room performance measurement	Learning and growth perspective	Capabilities to apply information systems
		Number of seminars on the topic and research results
		Number of papers published
		Staff training and knowledge management
		Staff satisfaction
		Internal communication
		Employ and retain competent people
		Teamwork
	Internal processes perspective	Process continuous improvement capability
		Process standardization capability
		Response of discovering mistakes
		Time of correcting mistakes
		Regulation management capability
		Internal and external communication
		Efficient production, distribution and logistics
		Effective information systems
		Ability of coordination
	Customer perspective	Waiting time
		Operation time
		Postoperative recovery time
		Postoperative infection rate
		Patient satisfaction about the operation team
		Patient complaint
		Ability of providing service to patient in time
		Ability of response to patients' inquiries
		Sufficient and accurate information
	Financial perspective	Return per employee
		Margins
		Capital turnover
		Low-cost administration
		Production and distribution at lowest possible cost
		Customer-focused purchasing processes at lowest possible cost

Let P_{ij}^m be the performance value evaluated by expert m for perspective i and criterion j, and the membership function of triangular fuzzy number $P_{ij}^m \in T$. Let W_{ij}^m be the weight of importance evaluated by respondent m for perspective i and criterion j, and the membership function of triangular fuzzy number $W_{ij}^m \in S$

$$P_{ij}^m = \left(\mathrm{LP}_{ij}^m, \mathrm{MP}_{ij}^m, \mathrm{UP}_{ij}^m\right),\ P_{ij}^m \in T, \quad \text{where } 0 \leqslant \mathrm{LP}_{ij}^m \leqslant \mathrm{MP}_{ij}^m \leqslant \mathrm{UP}_{ij}^m \leqslant 100 \tag{1}$$

$$W_{ij}^m = \left(\mathrm{LW}_{ij}^m, \mathrm{MW}_{ij}^m, \mathrm{UW}_{ij}^m\right),\ W_{ij}^m \in S, \quad \text{where } 0 \leqslant \mathrm{LW}_{ij}^m \leqslant \mathrm{MW}_{ij}^m \leqslant \mathrm{UW}_{ij}^m \leqslant 1 \tag{2}$$

Table 3
Experts weights.

Experts	A	B	C	D	E	F	G
Weight	0.15	0.18	0.09	0.12	0.16	0.19	0.11

The Eqs. (3) and (4) are used to aggregate the expert opinions of performance value and importance

$$P_{ij} = P_{ij}^1 * W_{e1} + P_{ij}^2 * W_{e2} + \cdots + P_{ij}^m * W_{em} \tag{3}$$

$$W_{ij} = W_{ij}^1 * W_{e1} + W_{ij}^2 * W_{e2} + \cdots + W_{ij}^m * W_{m2} \tag{4}$$

Table 4
The performance values.

Criterion		Expert						
		A	B	C	D	E	F	G
1	Capabilities to apply information systems	G	GV	F	G	G	F	G
2	Number of seminars on the topic and research results	G	G	G	VG	G	G	VG
3	Number of papers published	F	G	F	G	G	F	G
4	Staff training and knowledge management	F	F	F	F	F	F	F
5	Staff satisfaction	G	F	G	G	G	F	F
6	Internal communication	F	P	F	F	F	P	F
7	Employ and retain competent people	G	F	G	G	G	G	G
8	Teamwork	F	F	G	G	F	F	F
9	Process continuous improvement capability	P	P	P	F	P	P	P
10	Process standardization capability	P	F	F	F	P	P	P
11	Response of discovering mistakes	F	F	G	F	F	F	F
12	Time of correcting mistakes	F	F	F	P	P	F	F
13	Regulation management capability	G	VG	G	G	G	VG	VG
14	Internal and external communication	G	F	G	F	F	G	G
15	Efficient production, distribution and logistics	G	VG	VG	G	G	G	G
16	Effective information systems	G	G	G	G	G	G	G
17	Ability of coordination	F	F	F	F	F	F	F
18	Waiting time	P	P	F	F	P	P	P
19	Operation time	VG	G	G	G	VG	VG	VG
20	Postoperative recovery time	G	G	G	G	G	G	G
21	Postoperative infection rate	G	F	G	G	G	G	F
22	Patient satisfaction about the operation team	G	G	VG	G	G	G	F
23	Patient complaint	F	F	G	F	F	F	F
24	Ability of providing service to patient in time	G	G	G	F	G	G	F
25	Ability of response to patients' inquiries	G	F	F	F	G	G	F
26	Sufficient and accurate information	F	F	G	F	G	G	G
27	Return per employee	G	G	G	G	F	G	G
28	Margins	F	G	G	F	G	G	G
29	Capital turnover	F	F	F	G	F	G	F
30	Low-cost administration	G	G	G	G	G	G	G
31	Production and distribution at lowest possible cost	G	G	G	G	G	F	G
32	Customer-focused purchasing processes at lowest possible cost	F	P	F	P	F	F	F

Table 5
Weight of importance.

Criterion		Expert						
		A	B	C	D	E	F	G
1	Capabilities to apply information systems	I	VI	I	I	VI	VI	VI
2	Number of seminars on the topic and research results	I	I	I	I	I	I	I
3	Number of papers published	I	VI	I	I	I	I	I
4	Staff training and knowledge management	VI	VI	VI	I	I	I	I
5	Staff satisfaction	I	I	I	I	I	I	I
6	Internal communication	I	VI	I	I	VI	I	I
7	Employ and retain competent people	M	I	I	I	I	M	I
8	Teamwork	I	I	I	I	I	I	I
9	Process continuous improvement capability	I	I	I	VI	I	I	I
10	Process standardization capability	VI	VI	VI	I	VI	I	VI
11	Response of discovering mistakes	I	I	I	VI	I	I	I
12	Time of correcting mistakes	M	I	M	I	I	I	M
13	Regulation management capability	I	I	VI	I	M	I	I
14	Internal and external communication	I	VI	VI	I	I	VI	I
15	Efficient production, distribution and logistics	M	I	I	I	M	I	I
16	Effective information systems	VI	VI	VI	VI	VI	VI	I
17	Ability of coordination	I	I	I	I	I	I	I
18	Waiting time	M	M	I	I	M	I	I
19	Operation time	M	M	I	M	I	M	I
20	Postoperative recovery time	I	I	I	M	I	I	I
21	Postoperative infection rate	I	I	VI	I	I	VI	I
22	Patient satisfaction about the operation team	I	I	I	I	I	I	I
23	Patient complaint	VI	VI	I	I	VI	I	I
24	Ability of providing service to patient in time	M	I	M	I	M	M	M
25	Ability of response to patients' inquiries	I	I	I	M	I	I	I
26	Sufficient and accurate information	I	I	VI	I	I	I	I
27	Return per employee	I	VI	VI	VI	I	VI	I
28	Margins	M	I	M	I	I	I	I
29	Capital turnover	I	I	I	VI	I	I	I
30	Low-cost administration	I	I	I	I	I	I	I
31	Production and distribution at lowest possible cost	I	M	I	I	I	I	I
32	Customer-focused purchasing processes at lowest possible cost	VI	I	I	I	I	I	I

Table 6
Performance score of each criteria.

	Criterion	Performance score
1	Capabilities to apply information systems	62.8648
2	Number of seminars on the topic and research results	59.7
3	Number of papers published	50.5005
4	Staff training and knowledge management	41.7
5	Staff satisfaction	47.25
6	Internal communication	33.3335
7	Employ and retain competent people	46.8825
8	Teamwork	41.4375
9	Process continuous improvement capability	21.672
10	Process standardization capability	30.858
11	Response of discovering mistakes	40.4415
12	Time of correcting mistakes	28.4875
13	Regulation management capability	61.5888
14	Internal and external communication	53.467
15	Efficient production, distribution and logistics	54.069
16	Effective information systems	69.6
17	Ability of coordination	37.5
18	Waiting time	18.98188
19	Operation time	51.448
20	Postoperative recovery time	54
21	Postoperative infection rate	54.6065
22	Patient satisfaction about the operation team	55.5375
23	Patient complaint	44.308
24	Ability of providing service to patient in time	39.81875
25	Ability of response to patients' inquiries	45
26	Sufficient and accurate information	48.96
27	Return per employee	61.486
28	Margins	47.0925
29	Capital turnover	44.6985
30	Low-cost administration	56.25
31	Production and distribution at lowest possible cost	49.52625
32	Customer-focused purchasing processes at lowest possible cost	33.15
	Performance score of OR	46.44

where P_{ij}, W_{ij}, W_{em} and m are performance value of expert opinion for perspective i and criterion j, importance evaluated by expert for perspective i and criterion j, expert weight and number of expert in performance evaluation group, respectively.

This study adopts BSC with fuzzy linguistic to evaluate OR performance. Since the output of the fuzzy system is a fuzzy set, the defuzzification procedure is used to convert the fuzzy result into a numerical value to represent the performance of OR. Mean-of-maximum (MOM) defuzzification and centre-of-area (COA) defuzzification are popular methods that convert a fuzzy set to non-fuzzy value. Braae and Rutherford (1978), Runkler and Glesner (1993) compared these two defuzzification methods and concluded that COA yields better results than MOM. The COA is a simple and practical method of calculating BNP value (Wu et al., 2010). Eqs. (5) and (6) show the BNP values of fuzzy performance and fuzzy weight, respectively

$$\mathrm{BNP}_i^p = \frac{[(\mathrm{UP}_i - \mathrm{LP}_i) + (\mathrm{MP}_i - \mathrm{LP}_i)]}{3} + \mathrm{LP}_i \quad \forall i \tag{5}$$

$$\mathrm{BNP}_i^w = \frac{[(\mathrm{UW}_i - \mathrm{LW}_i) + (\mathrm{MW}_i - \mathrm{LW}_i)]}{3} + \mathrm{LW}_i \quad \forall i \tag{6}$$

Finally, the PS is calculated with BNP_i^w and BNP_i^p. PS is the performance score of OR

$$\mathrm{PS} = \frac{\Sigma \mathrm{BNP}_i^w * \mathrm{BNP}_i^p}{n} \tag{7}$$

where n is the number of criterion.

4. Results

4.1. Indicators system of OR

Following the review of literatures and multidisciplinary experts (hospital managers, clinical staff and academic), and according to the four perspectives of BSC e.g. financial perspective, internal processes perspective, learning and growth perspective and customer perspective, we got the performance indicators system for OR. Thirty-two indicators were finally selected and organized by expert panel into the four BSC, depicted in Table 2.

4.2. Performance score of OR

The experts include hospital managers, clinical staff and academic. A, B and C are managers of hospital; D and E are clinical staff; F and G are academic. The weight of each expert shows in Table 3.

The fuzzy numbers of the five linguistic scales for the performance values are VP, P, F, G, and VG. The weight of importance of five-scale fuzzy linguistic are AU, U, MI, I, and VI. The experts according to their own understanding to give the performance values and the weight of importance. Based on the experts opinions, the performance values of each criteria and the weight of importance are shown in Tables 4 and 5.

According to the Eqs. (3)–(6), we can get the performance score of each criteria (Table 6). And finally, the performance score of OR is 46.44.

5. Conclusion and discussion

Balanced scorecard is a tool for translating strategy into action via various sets of performance measurement indicators. Numerous studies and literatures have devised procedures for evaluating performance measurements. However, few such studies use fuzzy linguistic to convert the subjective cognition into an information entity which is still problematic for health care management. Thus, this study used BSC theory to build a performance indicators system depending on expert consensus opinions from experts working in hospital and academics. Furthermore, this study also proposed fuzzy linguistic integrating with BSC to evaluate OR performance. An important advantage of the fuzzy linguistic method is that the performance indicators can be clearly identified and expressed quantitatively.

Hospital performance evaluation is a very difficult and complex work, it requires more non-financial information. For this aim, a new performance evaluation method has been developed in this paper. Compared with the traditional performance evaluation, the proposed hierarchical balanced scorecard with Fuzzy linguistic has the following advantages:

- The performance indicators system and performance values are proposed by hospital managers, clinical staff and academic with a comprehensive view and overcomes the decision makers' subjective consciousness.
- The hierarchical BSC performance evaluation system can establish a communication system that bridges the gap between goals established by high-level managers and the staff whose performances is ultimately responsible for achieving organizational goals.
- The performance indicators values and the weight of importance are evaluated in a fuzzy linguistic rather than in precise numerical values. This enables the experts to express their judgments more realistically and makes the assessment easier to be carried out.

- The proposed method can be used by public sectors for self-assessment which evaluation data is unavailable or unreliable, as it does not force precision.

For the future study, following topics can be handled: (i) the performance value and weight of importance can be obtained through involving more participants from different expertise knowledge; (ii) to generalize the results to different hospitals and other public sectors.

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