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Using hybrid method to evaluate the green performance in uncertainty

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Abstract Green performance measure is vital for enterprises in making continuous improvements to maintain sustainable competitive advantages. Evaluation of green performance, however, is a challenging task due to the dependence complexity of the aspects, criteria, and the linguistic vagueness of some qualitative information and quantitative data together. To deal with this issue, this study proposes a novel approach to evaluate the dependence aspects and criteria of firm's green performance. The rationale of the proposed approach, namely green network balanced scorecard, is using balanced scorecard to combine fuzzy set theory with analytical network process (ANP) and importance-performance analysis (IPA) methods, wherein fuzzy set theory accounts for the linguistic vagueness of qualitative criteria and ANP converts the relations among the dependence aspects and criteria into an intelligible structural modeling used IPA. For the empirical case study, four dependence aspects and 34 green performance criteria for PCB firms in Taiwan were evaluated. The managerial implications are discussed.

Keywords Analytic network process · Importance-performance analysis · Fuzzy set theory · Balanced scorecard · Green performance

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Introduction

Facing constantly fluctuating environments, original equipment manufacturing of printed circuit board (PCB) firms require maintaining environmental and managerial responses to changing environments and sustain competitive advantage in Taiwan. Such responses require PCB firms to indicate the green performance on overhauling operation process to achieve firm's goal of waste elimination and reduce the impact of environment to ensure corporate survival and sustainable development (Tseng 2008, 2009a, b; Tseng and Lin 2008). In addition, the firm's green performance evaluation is dependent on wider knowledge integration to achieve the goal due to the mandated environmental order from European Union such as Waste Electrical and Electronic Equipment (WEEE) and Restriction of Hazardous

Substances (ROHS) Directives. Hence, the performance evaluation is an on-going process that Requires continuous monitoring to maintain high level of internal process evaluation across a number of aspects in organization. The evaluation is important to help firm making environmental continuous improvement in the competitive and sustainable market.

Hence, the evaluation of green performance is an on-going process across a set of aspects and criteria. In terms of multi-aspects evaluation, the balanced scorecard (BSC) is well recognized in the literatures that performance measurement should incorporate both financial and non-financial measures; it captures not only a firm's current performance, but also the drivers of its future performance (Banker and Datar 1989; Dyson 2000). However, there are fewer studies of the development and implementation of the BSC in measuring the performance of green activities. Nevertheless, the BSC is a model for the analysis of performance measurement for all types of organization developed by Kaplan and Norton in 1992. The BSC is an important activity that helps organizations to make continuous improvements, due to a great emphasis on performance evaluation. However, BSC engenders multi-dimensional difficulties that involve numerous organizational functions and resource integration among various departments (Tseng et al. 2008; Tseng 2008). Traditionally, BSC categorized evaluation measures into four aspects: financial, customer, internal business process, and learning and growth aspect.

With regards to BSC, the firms can evaluate their management in terms of their effectiveness in creating value for customers, developing internal capabilities, and investing in the people and systems that are necessary to improve their future performance. In reality, there are dependence relations existed in the BSC aspects and criteria. Therefore, the traditional statistical approach is no longer suited to evaluate proposed network balanced scorecard (NBSC), due to the traditional approach assumed that the aspects are always independent. Moreover, the evaluation-related activities have inherent and highly uncertainty and imprecision, and difficult to assess accurately with qualitative information. This study proposes to utilize the analytical network process (ANP) technique to analyze the proposed NBSC. ANP developed by Saaty (1996) that this technique takes into account both the relations of feedback and dependence. In addition to these, merits of ANP provides a more generalized model in decision-making without making assumptions about the independence relations among the aspects and criteria.

In literatures, though, there are fewer studies of the development and implementation of the BSC in measuring the green performance of firm's activities. However, there are studies on other industries such as banking, textile, pharmaceutical etc. (Bremser and Barsky 2004; Cebeci 2009; Wu et al. 2009). The BSC conceptual framework has been widely accepted in the business community, the proper method of implementing the framework remains an issue. For instance, Leung et al. (2006) incorporating a wider set of non-financial attributes into the measurement system of a firm by using the analytic hierarchy process (AHP) and its variant, the analytic network process, to facilitate the implementation of the BSC. Yuan and Chiu (2009) used BSC design and proposed a three-level feature weights design to enhance case-based reasoning inference performance. BSC also minimizes the effect of subjective factors that has to be carefully dealt in performance evaluation process. Cebeci (2009) proposed decision support system integrated with strategic management by using BSC may be an alternative to some methods for ERP selection. There are even fewer studies dealing with the dependence relations of the BSC with measures in qualitative and quantitative approaches to carry out these activities and implement in a firm.

In addition, some of the qualitative criteria measured in linguistic expression are vague and uncertain in nature, and the quantitative data should be comparable to the qualitative information, which makes this evaluation more challenging. In view of qualitative and quantitative measures, the crisp values of criteria have varying values that cannot be compared. The crisp number must be converted to comparable form among all criteria (Karsak 2002; Tseng 2009a). In view of qualitative measures, the fuzzy set theory can address situations that lack well-defined boundaries of activity or observation sets (Zadeh 1965, 1975). In reality,

the human perceptions are uncertain and qualitatively descriptive, not easy to assign exact numerical values to precisely describe the preferences. Linguistic terms have been used for approximate reasoning within the framework of fuzzy set theory to handle the ambiguity of evaluating data and the vagueness of linguistic expression (Al-Najjar and Alsyouf 2003; Tseng and Lin 2008; Tseng et al. 2009c). A linguistic preference is a variable whose values (namely linguistic values) have the form of phrases or sentences in a natural language (Von Altrock 1996). Especially, linguistic preferences are used to evaluate the aspects or criteria whose values are not numbers but linguistic term. In practice, linguistic values can be represented by triangular fuzzy numbers (TFN). This study adopts fuzzy set theory to assess NBSC in the assessment of green performance measurement. This study addresses two important and related aspects in the implementation of NBSC: the handling of dependency among aspects and criteria—especially those of qualitative nature and transform the crisp values to compare with the other measures.

This study attempts to develop a green performance hierarchical framework that is sufficiently general in NBSC concept. To date, few studies have adopted such a rigorous methodology. This study presents a BSC multi-criteria hierarchical analytical framework that can be applied under various study settings (Tseng 2008; Tseng et al. 2009c). The firms' evaluation in this assessment method can help firms to measure the weighted aspects and criteria. Consequently, resolving problems in evaluating firm is fundamentally important to both researchers and practitioners. The unique point of this study was involved in qualitative and quantitative measures in linguistic preferences presented by triangular fuzzy numbers and defuzzified into a crisp value for analyses in dependence relations among aspects and criteria, and apply ANP to acquire the weights of aspects and criteria and thereafter uses importance-performance analysis (IPA) to draw and identify the relative importance of the aspects and criteria associated with green performance while at the same time indicating the degree of performance in quadrants (Martilla and James 1977).

Evaluations of NBSC on the IPA four quadrants then are combined into a matrix that allows a firm to identify key drivers of satisfaction, to formulate improvement priorities, and to find areas of possible overkill and areas of "acceptable" disadvantages. Tonge and Moore (2007) used IPA and gap analysis to evaluate the sensed quality of visitors to a Marine-Park to conduct more effective management with environmental protection. In practice, IPA is considered a simple but effective tool (Hansen and Bush 1999). It is very helpful in deciding how to best allocate scarce resources in order to maximize satisfaction (Eskildsen and Kristensen 2006; Daniels and Marion 2006; Shieh and Wu 2007). Hansen and Bush (1999) pointed out that IPA is a simple and effective technique that can assist practitioners in identifying improvement priorities for customer attributes and direct quality-based marketing strategies. Numerous practitioners and researchers have applied IPA to identify the critical performance factors in customer satisfaction survey data for products and services (Enright and Newton 2004; O'Neill and Palmer 2004; Zhang and Chow 2004).

The contribution is that this study is the first to combine the two concepts into a single study criteria framework to build a visual map and to evaluate NBSC successfully which few can systematically evaluate and which model contained complex dependence relations among aspects and criteria in uncertainty. Furthermore, the sector can apply this approach to evaluate and determine the aspects and criteria weights and to compose the visual map to reduce the management risks. In conclusion, this study contributes to, in particular, the literatures by: (1) proposing a green performance hierarchical framework that relates aspects and criteria in NBSC and (2) developing valid and reliable measures for the green performance based on expert's qualitative preferences together with quantitative data.

The study begins with a brief introduction of the green performance and study objectives. "Hierarchical structure" follows a discussion of the green performance hierarchical structure and related literatures. "Research method" presents the proposed method, especially; the aspects and criteria with dependence relations in linguistic preferences. "Results" presents the

empirical study result. A study framework suggests providing a context for applying the proposed methods. The measures are provided with measurement guidance. "Managerial implications" and "Concluding remarks" concludes with a summary of the study managerial implications of the study as well as concluding remarks for its further development and practical application.

Hierarchical structure

The proposed structure presents the evaluation aspects and criteria for this approach. The evaluation framework consists of four aspects with 34 criteria, which are determined from extensive literature review and expert suggestions. In this study, four primary dependence aspects of BSC are identified and to be evaluated: financial aspect; student aspect; internal operations aspect; and 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 emphasizes that the BSC is only a template and must be customized for the specific elements of an organization or industry. The BSC presented the knowledge, skills, and systems that the employees will need (learning and growth aspect) to innovate and build the right strategic capabilities and efficiencies (internal operations aspect) that deliver specific value to the high school student population (student aspect) which will eventually lead to higher shareholder value (financial aspect). This is even presented that there are dependence relations existed in evaluation process, in nature.

Financial aspect (AS1): financial objectives serve as the focus for the objectives and measures of the other criteria. Every measure should be part of interdependence relationships culminating in long-term, sustainable financial performance. The measures are sales, cost of sales, profitability, prosperity, growth, new green products/services, and industrial leadership. Customer aspect (AS2): financial success is closely linked to customer satisfaction. Satisfied customers mean repeat business, referrals and new green business, customer retention, customer acquisition, customer complain, customer profitability, and customer lead-time, and thereby 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 thus enable a firm to focus on maintaining and improving the performance of processes that deliver the established objectives that are keys to satisfying customers, which in turn satisfy shareholders. The criteria are service processing time, cost of service quality comparison, low cost green provider, reduce service cost, facilities utilization rate, and safety incident index. Learning and growth aspect (AS4): the ability, flexibility and motivation of staff support all of the financial results, customer satisfaction, and operational activities measured in the other quadrants of the NBSC. The AS4 criteria are innovation of green product measures, breakeven time, rate of new green products introduction per quarter, number of new green products with successful introduction to public, annual increase in number of new green products, employee capabilities, employee satisfaction survey, employee retention, employee productivity, salaries compared to the norm in the local industry, percentage of competency deployment matrix filled, number of promotions from within, and absenteeism rate (Fig. 1).

The NBSC shows how the firms' overall strategic green objectives are translated into the green performance measures that the firm has identified as critical success factors (criteria). The green performance drivers are translated into more tangible measures that allow the firm to quantify the performance measures. It should be noted to consider

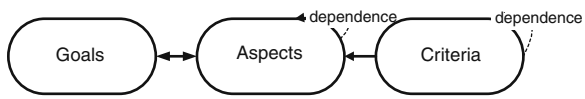

Fig. 1 The interdependence of goals, aspects and criteria

the collective evaluation results, thus the information of one aspect may be submerged by that of another aspect. Table 1 presents the evaluation aspects and criteria for firms' NBSC, narrated in details as follows.

Figure 2 presented the dependence relations of proposed framework. A two-way arrow among different levels of criteria may graphically represent the dependencies in an ANP model. If dependencies are present within the same level of analysis, a "looped arc" may be used to represent such interdependence. In order to solve the complexity relations, the following section proposed the hybrid methods (fuzzy set theory, analytical network process, and importance-performance analysis) for this approach.

Table 1 Evaluation aspects and criteria

Aspects	Criteria
Financial aspect (AS1)	Sales: annual growth in sales (C11) (last 3 years data)
	Cost of sales: extent that it remains flat or decreases each year (C12) (last 3 years data)
	Profitability: economic value added (EVA) or return on total capital employed (C13) (last 3 years data)
	Prosperity: cash flows (C14) (last 3 years data)
	Company growth versus industry growth (C15) (last 3 years data)
	Ratio of international sales to total sales (C16)
	New green product: gross profit/growth from green 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 in green products (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)	Shorten the service cycle processing time (C31)
	Cost of service quality comparison (Other firms) (C32)
	Low cost green 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 3 years data)
	Safety incident index (C36) (last 3 years data)
Learning and growth aspect (AS4)	Innovation of green products measures (C41) (last 3 years data)
	Breakeven time: the time from the beginning of green products development work till the green products been introduced (C42)
	Rate of new green products introduced per quarter (C43)
	Number of new green products with successful introduction to public (C44)
	Annual increase in number of new green products (C45)
	Employee capabilities in green efforts (C46)
	Employee satisfaction survey in green performance (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 3 years data)
	Number of promotions from within (C412) (last 3 years data)
	Absenteeism rate (C413) (last 3 years data)

The aspects and criteria are with interdependent and self-feedback relationships

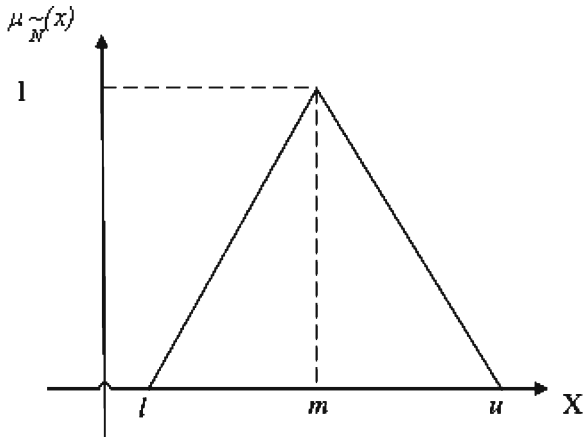

Fig. 2 A triangular fuzzy number $\tilde{N}$

Research method

To determine the green performance, the evaluation aspects and criteria are multiple and frequently structured into hierarchical structure. Hence, the first phase is to define the decision objective. After defining the decision objective, it is required to generate and establish evaluation aspects used BSC approach. As discussed in the previous section, four aspects of BSC are to be considered. Moreover, the criteria cluster has to dependence. Overall BSC evaluation can be obtained by (1) assigning weights to four aspects (AS1, AS2, AS3, and AS4) and their associated x_{ij} criteria (x_{ij}, $i = 1,2,3,4$; $j = 1,2,\ldots, x_j$) and (2) assessing the performance rating of each aspect and its associated criteria. This section is to introduce the fuzzy set theory, ANP technique, and IPA method and followed by the proposed analytical procedures.

Determining the quantitative data

The quantitative (crisp) numbers of criteria (last 3 years data, see Table 1) have varying value that cannot be compared. 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 follow in equation (Karsak 2002; Tseng 2009a).

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

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

Fuzzy set theory (qualitative data)

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

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

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

The criteria consist of four aspects and 34 measures, the criteria are determined from extensive literatures and expert team. The triangular fuzzy membership functions (Table 2) can accommodate the qualitative data while the evaluators process the evaluation in linguistic information. This proposed framework allows experts to identify options using linguistic expressions. The unique point of this study was involved in qualitative measures in linguistic terms presented by TFNs and defuzzified into a crisp value for analyze in ANP.

Furthermore, in achieving a favorable solution, the group decision-making is usually important to any organizations. 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 the problems in uncertainty, an effective fuzzy aggregation method is required. Any fuzzy aggregation method always needs to contain a defuzzification method because the results of human judgments with fuzzy linguistic variables are fuzzy numbers. The defuzzification refers to the selection of a specific crisp element based on the output fuzzy set, which convert fuzzy numbers into crisp may score. This study is applying the converting fuzzy data into crisp scores developed by Opricovic and Tzeng (2003), the main procedure of determining the left and right scores by fuzzy minimum and maximum, the total score is determined as a weighted average according to the membership functions.

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

$$\begin{cases} z_{L}x^{p}{}_{ij} = \left({}_{L}x^{k}{}_{ij} - \min {}_{L}x^{k}{}_{ij}\right) / \delta^{\max}_{\min} \\ z_{m}x^{p}{}_{ij} = \left({}_{m}x^{k}{}_{ij} - \min {}_{m}x^{k}{}_{ij}\right) / \delta^{\max}_{\min}; \\ \text{where} \quad \delta^{\max}_{\min} = \max {}_{R}x^{k}{}_{ij} - \min {}_{L}x^{k}{}_{ij} \\ z_{R}x^{k}{}_{ij} = \left({}_{R}x^{k}{}_{ij} - \min {}_{R}x^{k}{}_{ij}\right) / \delta^{\max}_{\min} \end{cases} \tag{4}$$

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

$$\begin{cases} zls^{p}_{ij} = z_{m}x^{k}_{ij} \Big/ \left(1 + {}_{m}x^{k}_{ij} - {}_{L}x^{k}_{ij}\right) \\ zrs^{p}_{ij} = z_{R}x^{k}_{ij} \Big/ \left(1 + {}_{R}x^{k}_{ij} - {}_{m}x^{k}_{ij}\right) \end{cases} \tag{5}$$

Compute total normalized crisp value

$$y^{k}_{ij} = \frac{\left[zls^{p}_{ij}\left(1 - zls^{p}_{ij}\right) + zrs^{k}_{ij}zrs^{k}_{ij}\right]}{\left[1 - zls^{p}_{ij} + zrs^{p}_{ij}\right]} \tag{6}$$

Compute crisp values:

$$w^{k}_{ij} = \min {}_{L}x^{k}_{ij} + y^{k}_{ij}\delta^{\max}_{\min} \tag{7}$$

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

$$\tilde{w} = \frac{1}{k}\left(\tilde{w}^{1}_{ij} + \tilde{w}^{2}_{ij} + \tilde{w}^{3}_{ij} + \ldots\ldots + \tilde{w}^{k}_{ij}\right) \tag{8}$$

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

This table is the linguistic scales and their corresponding TFNs defined by Wang et al. (2008)

ANP

The ANP is a generalization of the analytical hierarchical process (Saaty 1996). While the AHP represents a framework with a unidirectional hierarchical AHP relationship, the ANP allows for complex interrelationships among decision levels and criteria. The ANP feedback approach replaces hierarchies with networks in which the relationships between levels are not easily represented as higher or lower, dominant or subordinate. Hence, given the problems encountered in reality, a dependent and feedback relationship is

usually generated among the evaluation criteria and such dependent relations usually becomes more complex with the change in scope and depth of the decision-making problems.

ANP uses supermatrix to deal with the relations of feedback and dependence 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 be 0 and an unweighted supermatrix M will be obtained. If the matrix does not conform to the principle of column stochastic, the decision maker can provide the weights to adjust it into a supermatrix that conforms to the principle of column stochastic, and it will become a weighted supermatrix M. Then get the limited weighted supermatrix M* based on Eq. 9 and allow for gradual convergence of the interdependence relationship to obtain the accurate relative weights among the criteria: The following descriptions are the equations applied in this study.

$$M^* = \lim_{k\to\infty} M^k \tag{9}$$

In testing for the consistency of judgment matrix, the matrix result to be acceptable, consistency index (C.I.) and consistency ratio (C.R.) values should be less than 0.1, the C.I. of a judgment matrix can be obtained as follows:

$$\text{C.I.} = \frac{\lambda_{\max} - n}{n-1} \tag{10}$$

When $\lambda_{\max} = 0$, complete consistency exists within judgment procedures. When $\lambda_{\max} = n$, the C.R. of C.I. to the mean random consistency index R.I. is expressed as C.R. The equation as follows

$$\text{C.R.} = \frac{\text{C.I.}}{\text{R.I.}} \tag{11}$$

Moreover, the ANP is the mathematical theory that can deal with all kinds of dependence systematically. The ANP has been successfully applied in many fields (Shang et al. 2004; Yurdakul 2004). Messey (2008) studies on multi-objective resource allocation of shared resources by group decision-making can combine analytic and qualitative modeling, the subsequent phases of the qualitative and the analytic solution of a multi-objective cooperative resource allocation problem can be 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 et al. 2008): (1) both tangibles and intangibles, individual values, and shared values can be included in the decision process; (2) the discussion in a group can be focused on objectives rather than on alternatives; (3) the discussion can be structured so that every factor relevant to the decision is considered; and (4) in a structured analysis, the discussion continues until relevant information from each individual member in the group is considered and a consensus is achieved.

Importance-performance analysis

An IPA is to draw implications for managing green performance aspects and criteria. It identifies the relative importance of the aspects and criteria associated with a service or product while at the same time indicating the degree of performance (Martilla and James 1977). The results are plotted graphically on a two-dimensional grid, in which the importance of the criteria is displayed on the vertical axis while the satisfaction level is displayed on the horizontal axis. Yavas and Shemwell (2001) integrated relative importance as a weighted index to replace the vertical-axis importance and employed relative performance to compare and calculate the difference between organization performance and the competition's performance regarding each quality characteristic. The resulting four quadrants are labeled as: Concentrate here, Keep up the good work, Low priority, and Possible overkill (Fig. 3).

1. In the "Concentrate here" quadrant, the criteria are perceived to be very important, but the performance levels are seen by the experts as below average. This implies that improvement efforts should be concentrated here.
2. Criteria situated in the "Keep up the good work" quadrant are perceived to be very

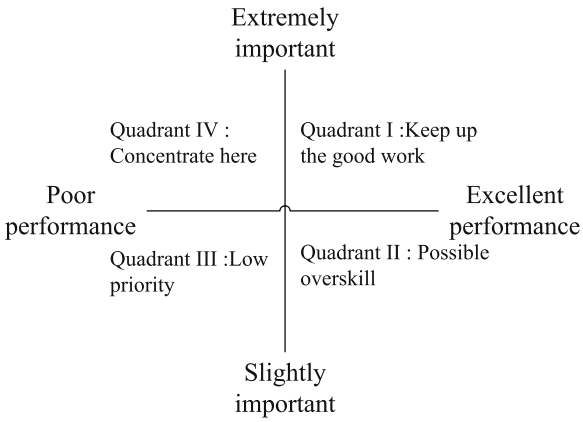

Fig. 3 Importance-performance analysis evaluation grid

important to the experts and the firm performs highly in these activities.

3. In the "Low priority" quadrant, the attributes are performed lowly by the firm but they are of low importance to the customers. Limited resources should be expended on these criteria as experts do not care too much about them in evaluating the green performance.
4. The "Possible overkill" quadrant contains low importance criteria with relatively high performance. The evaluators are satisfied with the firm's green performance; however, present efforts on the criteria are over-utilized and managers should consider resources allocated elsewhere.

Using simple visual analysis, the IPA evaluation grid reveals strengths and weaknesses of the aspects and criteria under consideration and so draws managerial implications for resource allocation. The firm's current competitive positions are identified, and further improvement strategies are discussed.

Proposed approach

1. Identifying decision goal—gathering the relevant information from the literature review and expert's opinions. It is necessary to consult a group of experts to confirm reliable information of the criteria influences and directions and moreover develop the evaluation of BSC aspects and criteria and survey instrument (pairwise comparison in linguistic preferences). It is important to establish a set of aspects and criteria for evaluation with qualitative and quantitative information. However, the aspects and criteria have the nature of complicated relations within the cluster of aspects and criteria. To deal with the problem of dependence, the ANP is appropriate to be applied.
2. The crisp value number must be normalized to achieve criteria values that are comparable among all criteria using Eq. 1. In addition, interpret the linguistic preferences into fuzzy linguistic scale, shown in Table 2, and uses linguistic preferences to convert TFNs into crisp value, the fuzzy assessments using the definition in Eqs. 2 and 3 and applies the Eqs. 4–8 are defuzzified and aggregated as a crisp value ($\tilde{w}$).
3. Analyze the proposed method in decision goal and the crisp values are to compose the unweighted supermatrix. The result can obtain the normalized unweighted supermatrix from the multiplied result and raises to limiting powers to calculate the overall priority weights, using Eq. 9.
4. Using visual analysis IPA evaluation grid to draw the four quadrants for the proposed aspects and criteria, the evaluation grid reveals strengths and weaknesses of the aspects and criteria of green performance.

Results

This section aims to operationalize evaluation methodology of the aspects and criteria, which is relatively important to the PCB sector. There are reasons, first, the case firms continue to improve green manufacturing processes and face challenge to how they manage the green performance in the competitive market. Second, case firms have to sustain reform of the green performance in the sector in order to deal with market competition and customer green requirements. The expert perceptions are obtained from the industrial and academic expert group with extensive experience consulting in this study.

Study problem

Under the prosperous and booming electronic consumption products and network market, Taiwan plant are built for I.C. substrates and entering I.C. packing field meeting the customer demand in related product in 1998. Now, PCB manufacturing sector needs the most advanced equipment in the entire production line and the most convenient services to at the disposal stage. The sector is with different types of PCB such as a single-side, double-side, multi-layer, ceramic, Teflon, aluminum substrate, flexible PCB, or for other special processes.

There are five largest PCB firms in Taiwan, and ranked as largest firms worldwide. To offer the best service for electronic manufacturer, the firms are continuing to develop new green generation technology, enhance environmental competitiveness, and fully satisfy the green market and customer demands. The firms insisting on the principle of "ISO 14000", have and continue to spend a lot of effort on improving production processes, developing in green performance and set the fully green quality system to meet customer environmental requirements. Due to electronic product replacement, rapid and new technologies are explored; the capability of developing of and researches in new green technology are global competition resources, which can meet green product demands from customer and explore new green product in market. When facing intense global competition, this study is not only devoted to satisfy the green market and customer demands. The green performance is relatively important for the sector to sustain in such competitive market. Therefore, the drawing of strategic map (using IPA) is to act as a strategic decision to develop a total approach solution.

The results

This study follows the four proposed steps to analyze the data from the experts. The data analysis and the results are addressed in this section.

1. The study objectives are to explore the relative importance of aspects and criteria that influence the green performance and to evaluate the competitiveness of the largest PCB firms in the world. It is necessary to consult a group of experts to confirm reliable information of the criteria influences and directions. To carry out the study objective, survey data are collected and four BSC aspects, namely financial, customer, internal business, and learning and growth aspects, are defined. Table 3 presents the sample of pair-comparison in linguistic preferences.
2. The crisp value number must be normalized to achieve criteria values that are comparable among all criteria using Eq. 1. In addition, interpret the linguistic preferences into fuzzy linguistic scale, shown in Table 2, and uses linguistic preferences to convert TFNs into crisp value, the fuzzy assessments using the definition in Eqs. 2 and 3 and applies the Eqs. 4–8 are defuzzified and aggregated as a crisp value ($\tilde{w}$). Table 4 presents the pairwise comparison of four aspects after defuzzification and uses Matlab 6.5 to decompose the matrix into Eigen vector (E vector). Using Eqs. 10 and 11, the CR should be less than 0.1. It indicates that the consistency level of the pairwise comparison matrix is acceptable. When CR is greater than 0.1, it indicates that the results of the decision process are not consistent, suggesting that the decision maker needs to perform the pairwise comparison again.

Table 5 is presented the notification of submatrix for supermatrix composition. To compose the supermatrix, analyses in decision goal and the crisp values are to compose the unweighted supermatrix, shown in Table 6.

3. The result can obtain the normalized unweighted supermatrix from the multiplied result and raises to limiting powers to calculate the overall priority weights, using Eq. 9. The unweighted supermatrix contains the weights derived from the pairwise comparisons of the aspects and criteria. In an unweighted supermatrix, its columns may not be column stochastic. To obtain a stochastic matrix (i.e., each column sums to one), multiply the blocks of the unweighted supermatrix by the cor-

Table 3 An illustration of financial pairwise comparison with other aspects

Aspect	Extreme unimportance	Demonstrated unimportance	Strong unimportance	Moderate unimportance	Equal importance	Moderate importance	Strong importance	Demonstrated importance	Extreme importance	Aspect
Financial							v			Customer
			v							Internal business
							v			Learning and growth

Table 4 An illustration of aspect matrix (Firm 1)

Goal	AS1	AS2	AS3	AS4	E-vector	Weights
AS1	1.00	0.14	0.14	1.52	0.719	0.563
AS2	6.95	1.00	0.17	1.46	0.219	0.172
AS3	0.77	6.00	1.00	0.16	0.253	0.198
AS4	0.66	0.69	6.32	1.00	0.085	0.067

$\lambda max = 8.245$, C.I. = 0.084, C.R. = 0.075

responding cluster weight. The supermatrix must satisfy the principle of column stochastic, which means every column should add up to 1. Based on the rule of ANP (Saaty 1996), the decision makers believe that if the column-stochastic is not conformed, then the matrix weights of the column are 0.5 and the remaining matrix weights would add up to 0.5. The columns in Table 6 have to multiple 0.5 in order to satisfy the principles.

Table 7 presents the converged supermatrix of firm 1, the result showed that the weights are (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, and C413) = (0.0321, 0.1257, 0.1358, 0.1487, 0.0985, 0.1721, 0.1487, 0.1600, 0.1709, 0.1970, 0.1196, 0.1201, 0.1560, 0.0832, 0.0682, 0.0770, 0.0986, 0.0806, 0.1001, 0.0989, 0.1732, 0.1505, 0.1174, 0.1397, 0.1716, 0.1078, 0.0566, 0.0432, 0.0410, 0.0426, 0.0471, 0.0309, 0.0444, 0.0382, 0.0360, 0.0351, 0.0369, 0.0401, and 0.0294). Hence, the most considered top five criteria of firm 1 are company growth versus industry growth (C15-0.1970), shorten the service cycle processing time (C31-0.1732), service output per hour/facilities utilization (C35-0.1716), sales: annual growth in sales (C11-0.1721), and prosperity: cash flows (C14-0.1709). The numerical numbers of firms 1–5 were repeated the proposed analytical process.

Table 5 Submatrix notation for supermatrix composition

	Goal	Aspects	Criteria
Goal	A		
Aspects	B	C	
Criteria		D	E

Table 6 An illustration of column stochastic supermatrix (Firm 1)

	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	1.000	0.000	0.000	0.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
AS1	0.563	0.269	0.119	0.366	0.121	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AS2	0.172	0.167	0.336	0.092	0.257	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AS3	0.198	0.461	0.347	0.086	0.298	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AS4	0.067	0.104	0.199	0.456	0.324	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	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	0.141	0.000	0.000	0.000	0.015	0.141	0.095	0.128	0.152	0.118	0.070	0.205	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	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	0.078	0.000	0.000	0.000	0.113	0.098	0.157	0.107	0.173	0.118	0.224	0.156	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	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	0.241	0.000	0.000	0.000	0.154	0.146	0.185	0.095	0.158	0.182	0.180	0.058	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	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	0.135	0.000	0.000	0.000	0.091	0.223	0.098	0.078	0.121	0.072	0.107	0.176	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	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	0.164	0.000	0.000	0.000	0.123	0.078	0.182	0.153	0.095	0.140	0.154	0.085	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	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	0.049	0.000	0.000	0.000	0.111	0.185	0.175	0.149	0.109	0.056	0.093	0.105	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	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	0.062	0.000	0.000	0.000	0.178	0.099	0.055	0.185	0.102	0.132	0.116	0.101	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	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	0.130	0.000	0.000	0.000	0.215	0.030	0.053	0.105	0.090	0.182	0.057	0.114	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	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	0.090	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.154	0.240	0.172	0.144	0.229	0.216	0.152	0.000	0.000	0.000	0.000	0.000	0.000	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	0.102	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.228	0.052	0.153	0.052	0.112	0.109	0.154	0.000	0.000	0.000	0.000	0.000	0.000	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	0.096	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.105	0.183	0.183	0.197	0.180	0.085	0.182	0.000	0.000	0.000	0.000	0.000	0.000	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	0.153	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.213	0.130	0.171	0.253	0.105	0.204	0.110	0.000	0.000	0.000	0.000	0.000	0.000	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	0.129	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.101	0.109	0.184	0.103	0.101	0.153	0.195	0.000	0.000	0.000	0.000	0.000	0.000	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	0.215	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.104	0.201	0.095	0.124	0.052	0.103	0.135	0.000	0.000	0.000	0.000	0.000	0.000	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	0.215	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.095	0.085	0.042	0.127	0.221	0.130	0.072	0.000	0.000	0.000	0.000	0.000	0.000	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	0.213	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.121	0.203	0.217	0.237	0.158	0.240	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	0.156	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.229	0.168	0.190	0.211	0.179	0.179	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	0.126	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.199	0.073	0.226	0.111	0.195	0.052	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	0.173	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.105	0.196	0.161	0.146	0.118	0.215	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	0.211	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.245	0.204	0.099	0.183	0.183	0.185	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	0.121	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.101	0.156	0.107	0.112	0.167	0.128	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	0.121	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.098	0.103	0.050	0.135	0.114	0.091	0.083	0.047	0.118	0.152	0.050	0.081	0.135
C42	0.000	0.000	0.000	0.000	0.094	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.108	0.120	0.049	0.049	0.046	0.085	0.045	0.089	0.045	0.046	0.103	0.047	0.095

C43	0.000	0.000	0.000	0.000	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	0.000	0.000	0.156	0.097	0.072	0.085	0.039	0.087	0.059	0.041	0.107	0.103	0.082	0.107	0.118
C44	0.000	0.000	0.000	0.000	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	0.000	0.000	0.051	0.049	0.049	0.091	0.103	0.050	0.052	0.053	0.094	0.054	0.054	0.095	0.049
C45	0.000	0.000	0.000	0.000	0.109	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.052	0.095	0.085	0.076	0.045	0.046	0.085	0.099	0.076	0.043	0.095	0.086	0.044
C46	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	0.081	0.042	0.121	0.041	0.077	0.036	0.039	0.040	0.047	0.095	0.041	0.103	0.046
C47	0.000	0.000	0.000	0.000	0.097	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.075	0.054	0.057	0.099	0.055	0.118	0.081	0.073	0.059	0.118	0.059	0.056	0.057
C48	0.000	0.000	0.000	0.000	0.075	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.052	0.079	0.052	0.056	0.068	0.103	0.081	0.186	0.046	0.039	0.048	0.085	0.037
C49	0.000	0.000	0.000	0.000	0.062	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.038	0.075	0.108	0.107	0.107	0.049	0.059	0.045	0.118	0.040	0.107	0.044	0.103
C410	0.000	0.000	0.000	0.000	0.056	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.047	0.095	0.099	0.051	0.081	0.096	0.048	0.133	0.055	0.095	0.081	0.107	0.048
C411	0.000	0.000	0.000	0.000	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	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.045	0.089	0.083	0.047	0.095	0.081	0.107	0.047	0.103	0.078	0.091	0.046	0.118
C412	0.000	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	0.000	0.000	0.000	0.000	0.000	0.079	0.052	0.081	0.078	0.051	0.107	0.085	0.051	0.047	0.081	0.085	0.095	0.107
C413	0.000	0.000	0.000	0.000	0.023	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.117	0.051	0.095	0.085	0.118	0.050	0.176	0.095	0.085	0.056	0.103	0.049	0.042

Table 8 presented the completed picture of the weights for aspects and criteria.

4. Using visual analysis IPA evaluation grid to draw the four quadrants for the proposed aspects and criteria, the evaluation grid reveals strengths and weaknesses of the aspects and criteria of green performance.

Table 8 presents the top five PCB firms in Taiwan, and also ranked as largest firms on worldwide (firms 1–5). The industrial professionals and academicians evaluated the column of PCB industry that is the weights after converged of supermatrix. The top-five weighted aspects and criteria of industrial sector are internal business aspect (AS3-2.6870), learning and growth aspect (AS4-2.6850), profitability: economic value added (EVA) or return on total capital employed (C13-2.6740), innovation of green products measures (C41-2.569), and breakeven time: the time from the beginning of green products development work until the green products has been introduced (C42-2.56). The top-five weighted average aspects and criteria are financial aspect (AS1-0.8694), customer aspect (AS2-0.8051), internal business aspect (AS3-0.9332), new green product: gross profit/growth from green products (C17-0.7825), and industry leadership: market share (C18-0.7430).

The IPA evaluation is displayed in Fig. 4. It composed by the industrial average as *x*-axis and expert's perception on PCB sector as *y*-axis. There were 13 criteria (goal, C13, C42, C22, C24, C411, C21, and C32) loaded in the "Concentrate here" quadrant. Three of the eight criteria were related to the customer aspect and the study goal is located in the quadrant, means the goal should be concentrated. In addition, 12 criteria were located in the "Low priority" quadrant which are C44, C410, C14, C25, C23, C27, C48, C413, C46, C49, C16, and C33. Although the ten criteria preformed below the average level, they were considered not very important to green performance. As the respondents were putting less attention to these criteria, the firm may not need to invest much to improve its performance in the areas. Ten criteria were identified in the "Possible overkill" quadrant. They are AS1, C17, C26, C412, C15, C47, C35, C31, C36, and C18. Finally, the remaining eight criteria were in the "Keep up the good

Table 7 An illustration of converged supermatrix (Firm 1)

	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	1.000	0.000	0.000	0.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
AS1	0.563	0.269	0.119	0.366	0.121	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AS2	0.172	0.167	0.336	0.092	0.257	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AS3	0.198	0.461	0.347	0.086	0.298	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AS4	0.067	0.104	0.199	0.456	0.324	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	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	0.141	0.000	0.000	0.000	0.015	0.141	0.095	0.128	0.152	0.118	0.070	0.205	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	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	0.078	0.000	0.000	0.000	0.113	0.098	0.157	0.107	0.173	0.118	0.224	0.156	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	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	0.241	0.000	0.000	0.000	0.154	0.146	0.185	0.095	0.158	0.182	0.180	0.058	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	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	0.135	0.000	0.000	0.000	0.091	0.223	0.098	0.078	0.121	0.072	0.107	0.176	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	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	0.164	0.000	0.000	0.000	0.123	0.078	0.182	0.153	0.095	0.140	0.154	0.085	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	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	0.049	0.000	0.000	0.000	0.111	0.185	0.175	0.149	0.109	0.056	0.093	0.105	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	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	0.062	0.000	0.000	0.000	0.178	0.099	0.055	0.185	0.102	0.132	0.116	0.101	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	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	0.130	0.000	0.000	0.000	0.215	0.030	0.053	0.105	0.090	0.182	0.057	0.114	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	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	0.090	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.154	0.240	0.172	0.144	0.229	0.216	0.152	0.000	0.000	0.000	0.000	0.000	0.000	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	0.102	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.228	0.052	0.153	0.052	0.112	0.109	0.154	0.000	0.000	0.000	0.000	0.000	0.000	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	0.096	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.105	0.183	0.183	0.197	0.180	0.085	0.182	0.000	0.000	0.000	0.000	0.000	0.000	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	0.153	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.213	0.130	0.171	0.253	0.105	0.204	0.110	0.000	0.000	0.000	0.000	0.000	0.000	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	0.129	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.101	0.109	0.184	0.103	0.101	0.153	0.195	0.000	0.000	0.000	0.000	0.000	0.000	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	0.215	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.104	0.201	0.095	0.124	0.052	0.103	0.135	0.000	0.000	0.000	0.000	0.000	0.000	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	0.215	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.095	0.085	0.042	0.127	0.221	0.130	0.072	0.000	0.000	0.000	0.000	0.000	0.000	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	0.213	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.121	0.203	0.217	0.237	0.158	0.240	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	0.156	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.229	0.168	0.190	0.211	0.179	0.179	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	0.126	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.199	0.073	0.226	0.111	0.195	0.052	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	0.173	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.105	0.196	0.161	0.146	0.118	0.215	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	0.211	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.245	0.204	0.099	0.183	0.183	0.185	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	0.121	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.101	0.156	0.107	0.112	0.167	0.128	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	0.121	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.098	0.103	0.050	0.135	0.114	0.091	0.083	0.047	0.118	0.152	0.050	0.081	0.135
C42	0.000	0.000	0.000	0.000	0.094	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.108	0.120	0.049	0.049	0.046	0.085	0.045	0.089	0.045	0.046	0.103	0.047	0.095
C43	0.000	0.000	0.000	0.000	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	0.000	0.000	0.000	0.156	0.097	0.072	0.085	0.039	0.087	0.059	0.041	0.107	0.103	0.082	0.107	0.118
C44	0.000	0.000	0.000	0.000	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	0.000	0.000	0.000	0.051	0.049	0.049	0.091	0.103	0.050	0.052	0.053	0.094	0.054	0.054	0.095	0.049
C45	0.000	0.000	0.000	0.000	0.109	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.052	0.095	0.085	0.076	0.045	0.046	0.085	0.099	0.076	0.043	0.095	0.086	0.044
C46	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	0.000	0.081	0.042	0.121	0.041	0.077	0.036	0.039	0.040	0.047	0.095	0.041	0.103	0.046
C47	0.000	0.000	0.000	0.000	0.097	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.075	0.054	0.057	0.099	0.055	0.118	0.081	0.073	0.059	0.118	0.059	0.056	0.057
C48	0.000	0.000	0.000	0.000	0.075	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.052	0.079	0.052	0.056	0.068	0.103	0.081	0.186	0.046	0.039	0.048	0.085	0.037
C49	0.000	0.000	0.000	0.000	0.062	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.038	0.075	0.108	0.107	0.107	0.049	0.059	0.045	0.118	0.040	0.107	0.044	0.103
C410	0.000	0.000	0.000	0.000	0.056	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.047	0.095	0.099	0.051	0.081	0.096	0.048	0.133	0.055	0.095	0.081	0.107	0.048
C411	0.000	0.000	0.000	0.000	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	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.045	0.089	0.083	0.047	0.095	0.081	0.107	0.047	0.103	0.078	0.091	0.046	0.118
C412	0.000	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	0.000	0.000	0.000	0.000	0.000	0.000	0.079	0.052	0.081	0.078	0.051	0.107	0.085	0.051	0.047	0.081	0.085	0.095	0.107
C413	0.000	0.000	0.000	0.000	0.023	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.117	0.051	0.095	0.085	0.118	0.050	0.176	0.095	0.085	0.056	0.103	0.049	0.042

work" quadrant, of which internal business aspect (AS3) received the highest importance, and learning and growth aspect (AS4) are most satisfactory by the expert group, indicating that the firm had performed particularly well in this area. The ANP analysis result showed that the "internal business aspect" is the most satisfactory and important aspect. In addition, the "cost of sales" is the most satisfactory criteria and the "profitability" is the most important criteria.

Managerial implications

Managing and controlling green performance using BSC provides a number of important insights for the management. It reveals the importance and application of BSC four aspects in green performance (financial, customer, internal business process, and learning and growth aspect). The green performance derived from the BSC aspects is critical to their firms' financial and non-financial goals. Specifically, the development and usage of green concepts of customer aspects that motivated the internal business and learning and growth aspects to direct their business activities and processes in a coordinated manner to attain firms' goals. This is particularly crucial for those firms that focus on the BSC and satisfy their customers' needs to improve firm's green performance. The key managerial implications of this study emphasize some issues.

First, as the result, there is a need to coordinate firm's activities with various related departments. The improvement plan of case firms might derive from "Concentrate here" and "Keep up the good work" quadrant. The quadrants indicated the internal business aspect received highest importance and learning and growth aspect gives most satisfactory result. The importance of learning and growth aspect provided support from past learning experience, the experience are indicated two critical points (1) the innovation of green products measures and (2) the breakeven time from the beginning of green products development work until the green products has been introduced. This result provided the reference to decision-makers to focus on (1) green product innovation and (2) green product development.

Table 8 Expert evaluation of importance and satisfaction of PCB firms' green performance

	Industrial evaluation	Firm 1	Firm 2	Firm 3	Firm 4	Firm 5	Average
Goal	1.9850	0.3210	0.2971	0.2985	0.3315	0.2988	0.3094
AS1	0.8690	1.2570	0.6510	0.7572	0.8274	0.8546	0.8694
AS2	1.5890	1.3580	0.9610	0.9627	0.7439	0.0000	0.8051
AS3	2.6870	1.4870	0.9040	0.7616	1.0278	0.4856	0.9332
AS4	2.6850	0.9850	0.8180	0.7193	0.7323	0.0000	0.6509
C11	1.8590	1.7205	0.1250	0.0970	0.1060	0.8754	0.5848
C12	1.4600	1.4870	0.7250	0.0837	0.0914	1.3250	0.7424
C13	2.6740	1.6001	0.1260	0.1468	0.1604	0.1870	0.4441
C14	0.8950	1.7093	0.1860	0.0972	0.1062	0.1709	0.4539
C15	0.5540	1.9695	0.1200	0.1105	0.1207	0.9560	0.6553
C16	0.3560	1.1958	0.0580	0.0676	0.0739	0.2145	0.3220
C17	0.8910	1.2009	1.0670	0.0671	0.0733	1.5042	0.7825
C18	0.1580	1.5601	0.7500	0.0874	0.0955	1.2221	0.7430
C21	1.2120	0.8317	0.1270	0.1271	0.0982	0.8145	0.3997
C22	1.7560	0.6824	0.1130	0.1130	0.0873	0.5561	0.3104
C23	0.7850	0.7701	0.1220	0.1224	0.0946	0.7652	0.3748
C24	1.7500	0.9864	0.1560	0.1563	0.1208	0.8540	0.4547
C25	1.0500	0.8061	0.1280	0.1279	0.0989	0.7456	0.3813
C26	0.8600	1.0012	1.0590	0.1591	0.1229	0.9542	0.6593
C27	0.5600	0.9894	0.1570	0.1570	0.1213	0.8756	0.4600
C31	0.1700	1.7316	0.1820	0.1533	0.2069	0.5682	0.5684
C32	1.2250	1.5049	0.1580	0.1332	0.1798	0.1759	0.4304
C33	0.2790	1.1743	0.1230	0.1040	0.1403	0.1856	0.3455
C34	1.5260	1.3966	0.1470	0.1237	0.1669	1.1120	0.5892
C35	0.3590	1.7159	0.1820	0.1519	0.2050	0.5522	0.5614
C36	0.2150	1.0784	0.0890	0.9550	0.1289	0.5246	0.5552
C41	2.5690	0.5661	0.1680	0.7810	0.7952	0.4562	0.5533
C42	2.5600	0.4318	0.1520	0.5950	0.6060	0.3586	0.4287
C43	1.8560	0.4103	0.8840	0.5660	0.5160	0.4445	0.5642
C44	1.1112	0.4264	0.0690	0.5880	0.5990	0.3951	0.4155
C45	1.2730	0.4713	0.0740	0.6500	0.6620	0.8597	0.5434
C46	0.2563	0.3092	0.0710	0.4260	0.4340	1.0256	0.4532
C47	0.5890	0.4435	0.1205	0.6120	0.6230	1.2050	0.6008
C48	0.5510	0.3821	0.1520	0.5270	0.5260	0.5124	0.4199
C49	0.3670	0.3602	0.1792	0.4970	0.5060	0.2356	0.3556
C410	1.1456	0.3511	0.1555	0.4840	0.4930	0.4580	0.3883
C411	1.5830	0.3691	0.1625	0.5090	0.5180	0.3691	0.3855
C412	0.5680	0.4007	0.1235	0.5520	0.5620	1.3250	0.5926
C413	0.5620	0.2945	0.2540	0.4050	0.4130	0.1524	0.3038
Mean	1.1641	0.9676	0.3102	0.3598	0.3465	0.6301	0.5228

Second, the hierarchical structure contains of a set of criteria that can lay as the foundation for effective measures in green performance. The green performance act as opportunities in turbulent and competitive green markets. To emphasize on green performance is preeminent over other issues due to the evaluation that enables PCB firms to maintain long-term competitive advantage. Moreover, through the establishment of green routinely develops that encourage the green concepts creating better business process, allows a firm to offer new green products, and to improve their business process.

Third, this analytical result allows the development of new green knowledge in firms through identifying the IPA quadrants (Concentrate here quadrant, Low priority quadrant, Possible overkill quadrant, and Keep up the good work quadrant).

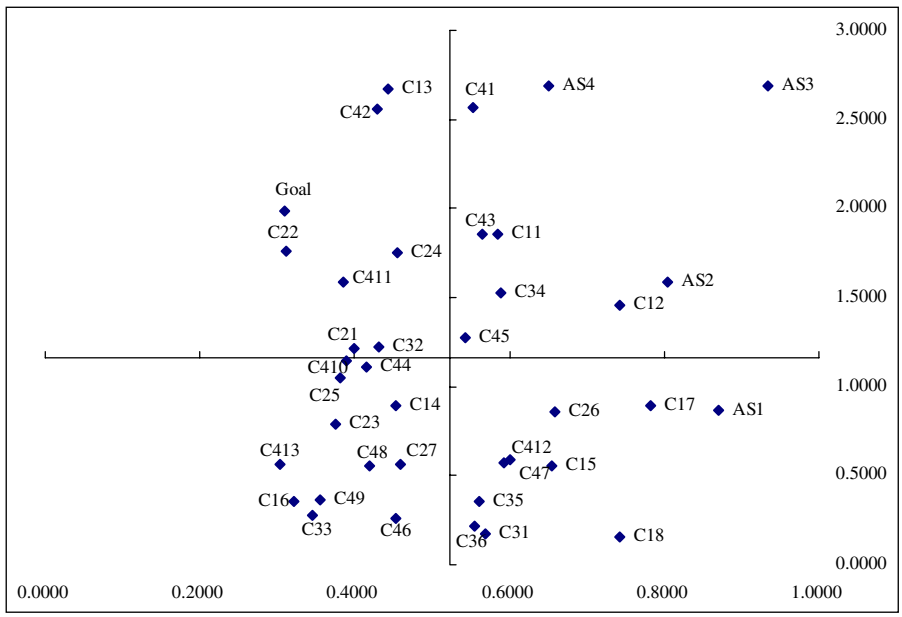

Fig. 4 IPA evaluation grid map (average vs. industrial)

These four quadrants constitute a single firm's evaluation. That is to say, the aspects and criteria are either to be concentrated or improved, but they are continually with dependence relations in interacting. Moreover, not only the firm's aspects and criteria are determined in quadrants, but also the industrial sector perceptions on BSC aspects and criteria are determined.

Fourth, with the aim of evaluated each case firm in green performance, sustainability of case firms should be awarded. The top-five weighted aspects and criteria are financial aspect, customer aspect, internal business aspect, new green product: gross profit/growth from green products, and industry leadership: market share. This implied that the management should be awarded with a total solution approach, which are analyzing the effects of business internal process, to be in contact with customers about green products, the industry leadership all around the industrial sector will encourage all firms to be conscious on green products and more challenges in green market.

Fifth, the results also indicate that possible over kills quadrant is a necessity but not a sufficient condition for the maintaining of competitive advantage. The important managerial implications are that financial aspect may help firms to direct their efforts to attain a competitive advantage and can help firms in a first stage, but the competitive environment obliges firms to attain more on green development to respond to corporate social responsibility than comprehensive financial details.

Sixth, this hybrid approach based on industry experts' evaluation; the result showed that internal business aspect is the most satisfaction and importance aspects to competitiveness. The other important role of keeping up the good work are followed by customer aspect (AS2), learning and growth aspect (AS4), sales (C11), cost of sales (C12), reduce service costs (C34), innovation of green products measures (C41), rate of new green products introduction per quarter (C43), and annual increase in number of new green products (C45).

Finally, this hierarchical BSC aspects and criteria are externally or internally generated that could be converted to result into strategic improvement plan, or may help to reduce the management costs. In any case, failure in the identification, measures, and evaluation of the worth of green performance leads to the decisions that may not attain competitive advantage in the long term. In addition, this study emphasizes the network relations among the aspects and criteria as an important organizational interacting rule for evaluation. In practice, customer aspect should

be always with all the relevant knowledge to internal business process and therefore this study proposed study framework as network balanced scorecard. Green performance evaluation is critical to PCB firms due to the environmental directives (WEEE and ROHS). The measures support a plan that can give the management easier assessment to the result. Consequently, the firms should aim to become success in the sustainable business.

Concluding remarks

The proposed model incorporates hierarchical aspects and criteria structure, fuzzy set theory, ANP, and IPA, and comprise an effective weighting of firms from subjective. This method is also useful for evaluating final decision making of the firms. This proposed approach can easily and effectively accommodate that aspects and criteria are not independent. This result is involving the dependence relations and uncertainty. In particular, the IPA draws the strategic map from the evaluation of industry and firm's experts. The PCB manufacturing is gaining an increasingly large portion of world electronic market, which has to satisfy the environmental directives (ROHS and WEEE). This analysis is consistent not only with the case firms along, but also with the industry sector. These observations point to case firm is industrial focus. This analysis reveals the potential aspects and criteria for its success in the competitive global market.

From the experiences of the world market, useful lessons and managerial implications may be drawn from this study for performing a higher level of green performance in the four aspects as well as developing a green customer-oriented business plans. The study has also raised two future studies. First, uncovering the potential criteria behind the evaluation discrepancy between the industry and firm experts remained an interesting area of future research. Second, it will be worthwhile to study the perception gap between industry and firm experts. The effective and appropriate analysis for industry and firm experts acquired by applying the proposed approach thus enables business managers to achieve a competitive advantage.

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