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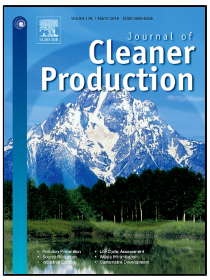

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Essential title page information

A hybrid Multiple Criteria Decision Making model of sustainability performance evaluation for Taiwanese Certified Public Accountant Firms

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Abstract:
Despite the increasing demand for sustainable development among Certified Public Accountant firms due to the more severe competitive environment, there is a dearth of research on a sustainability performance evaluation model for these firms' managerial decision-making. Therefore, by utilizing a multiple criteria decision-making model based on the Balanced Scorecard and combining Decision Making Trial and Evaluation Laboratory with Analytic Network Process and modified VlseKriterijumska Optimizacija I Kompromisno Resenje methods, this study sets up a model that can clarify the mutually influential relationships and comment weights of evaluation criteria, which have so far been ignored in prior studies on Certified Public Accountan firms' performances and the current situation of their sustainability performance. Based on interviews with partners of Taiwanese Certified Public Accountant firms, this paper finds that Client is the most important factor, followed by Internal processes, Learning and growth, and then Finance. The empirical result shows that client orientation rather than price-cutting may be a right strategy. In addition, more efforts are needed to improve Taiwanese Certified Public Accountant firms' sustainability performance. The results provide Certified Public Accountant firms' decision-makers with a managerial reference for building sustainability performance evaluation systems and for seeking out the priorities in sustainability performance strategies.

Keywords:
Sustainability performance
Certified Public Accountant firms
Multiple Criteria Decision Making
Decision Making Trial and Evaluation Laboratory
Analytic Network Process
VlseKriterijumska Optimizacija I Kompromisno Resenje

Abbreviations
CPA: Certified Public Accountant
MCDM: Multiple Criteria Decision Making
DEMATEL: Decision Making Trial and Evaluation Laboratory
ANP: Analytic Network Process
VIKOR: VlseKriterijumska Optimizacija I Kompromisno Resenje
BSC: Balanced Scorecard

Conflicts of Interest: None.

1. Introduction

After a number of accounting and auditing scandals such as those related to Enron in the early 2000s, Certified Public Accountant (CPA) firms, which offer auditing services by professional auditors to other organizations (Fernandez-Feijoo et al., 2016), are now exposed to intense pressure from more rigorous regulations and a growing number of global alliances (Chang et al., 2009a; Chang et al., 2011). For example, the Sarbanes-Oxley Act (SOX) in the U.S. requires that CPA firms cannot provide audit service to the same public company for more than 5 years in a row and cannot provide some types of non-audit services to their audit clients in order to improve auditor independence (Chang et al., 2009b). Additionally, there have been multiple mergers and acquisitions among CPA firms around the world. The so-called "Big Eight" CPA firms in the 1980s first dwindled to the "Big Five" and are now down to the "Big Four".

There has also been increasing competitive pressure among Taiwanese CPA firms. After the enactment of SOX, the Financial Supervisory Commission in Taiwan required that auditors should provide some mechanisms to increase the likelihood of high-level audit quality and appropriate professional conduct (Chen et al., 2008). In addition, the Fair Trade Commission in Taiwan determined that the audit fee standard was in violation of the Fair Trade Act, which enhanced audit-market competition through price-cutting strategies (Chang et al., 2009d). Therefore, how to obtain sustainable competitive advantage and improve corporate sustainability in this competitive environment is the primary decision-making issue for Taiwanese CPA firms' partners, the top management, and shareholders.

Corporate sustainability is defined as "meeting needs of the firm's direct and indirect stakeholders (such as shareholders, employees, clients, pressure groups, communities, etc.), without compromising its ability to meet future stakeholder needs as well" (Dyllick and Hockerts, 2002). Therefore, corporate sustainability performance depends on the extent of meeting the key stakeholders' needs (Searcy, 2012). According to the concept of triple bottom line (Elkington, 1997), the extent to which a firm considers economic, environmental, and social factors in its business is the key concern for evaluating corporate sustainability performance (Govindan et al., 2013; Peralta Álvarez et al., 2017). For CPA firms, the environmental factors are not the key concerns of their key stakeholders, because the professional services offered by CPA firms do not lead to harmful environmental impacts, such as pollution from manufacturing industries (Duff, 2011). Aside from shareholders' concern over financial performance, the literature has also looked at the economic and social demands of other key stakeholders of CPA firms (such as clients, employees, etc.) (Chen et al., 2008; Knechel et al., 2009). Unfortunately, previous studies focused more on evaluating productivity rather than sustainability performance of CPA firms (e.g. Cheng, 2000a.; Banker et al., 2002.; Banker et al., 2003; Chang et al., 2009a; Chang et al., 2009b; Chang et al., 2009c; Johnstone et al., 2004; Wang et al., 2014).

A good sustainability performance evaluation model should help CPA firms translate strategy into action and offer predictive measures concerning their future performance. In Taiwan, such a model can help the management of CPA firms to answer four important questions: (1) What is the influential network among the dimensions and criteria affecting the sustainability performance of CPA firms? (2) How can one identify the weights of these dimensions and criteria? (3) How can one measure the sustainability performance of CPA firms? (4) What is the actual level of CPA firms' sustainability performance?

Prior evaluation models of CPA firms' performance do not answer the above questions. First, according to the previous literature, there are mutual effects between many complicated dimensions and criteria of CPA firms' sustainability performance (Bell et al., 2008; Chen et al., 2008). However, earlier evaluation models of CPA firms' performance did not notice how these dimensions and criteria are interrelated. Second, the evaluation models of CPA firms' performance in prior studies did not rely on the application of a common weighting for the inputs and output to measure productivity and efficiency. In other words, these models did not provide a common set of weights that could present the preference structure of decision makers, which means that their evaluation results are not useful for making decisions based on multiple and complicated criteria (Opricovic and Tzeng, 2003).

Given the importance of evaluating CPA firms' sustainability performance and the deficiencies of prior CPA firms' performance evaluation models, this study establishes a hybrid Multiple Criteria Decision-Making (MCDM) model to solve these questions for Taiwanese CPA firms' decision-makers. MCDM techniques offer some significant advantages. For example, they can analyze qualitative evaluation criteria and make an optimal selection from many specified finite alternatives (Bozbura et al., 2007; Hwang and Yoon, 2012). One disadvantage of MCDM techniques is the high volume of calculations for finding pairwise comparison, and it is difficult to utilize them under a large number of criteria. These techniques need arbitrary ideal levels, but they are unable to match with the subjective features of the decision makers (Hu et al., 2016).

This paper first develops a hybrid model by using the Balanced Scorecard (BSC) as the assessment framework for Taiwanese CPA firms' sustainability performance. BSC incorporates key stakeholders' interests endogenously, which is the fundamental requirement of corporate sustainability (Kaplan, 2009). Accordingly, BSC has been strongly advocated to be an ideal corporate sustainability performance evaluation tool and management system (Figge et al., 2002; Dias-Sardinha and Reijnders, 2005; Searcy, 2012; Tsai et al., 2009). Second, this hybrid model uses the Decision Making Trial and Evaluation Laboratory (DEMATEL) method to explore the significance and relationship among the evaluation dimensions and criteria of Taiwanese CPA firms' sustainability performance, because it has the capacity to build a structural model involving causal relationships (Hsu et al., 2013; Su et al., 2016; George-Ufot et al., 2017). Third, we utilize the DEMATEL-based Analytic Network Process (DANP) method in this sustainability performance evaluation model, because DANP can obtain the common weights of criteria that are interdependent in the real world (Chen et al., 2015; Hu et al. 2015, 2016; Peng and Tzeng, 2017; Shen et al. 2017). Fourth, this hybrid model adopts the modified VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) approach, because the modified VIKOR can evaluate and identify the gaps in performance for future development (Opricovic and Tzeng, 2004; Chen et al., 2015; Peng and Tzeng, 2017). Finally, this study presents an empirical case based on data of Taiwanese CPA firms to demonstrate how this hybrid MCDM model can be applied to CPA firms' sustainability performance.

Compared to previous performance evaluation models of CPA firms, our hybrid MCDM model fills the gap in the CPA performance literature and provides more alternatives that are valuable for decision-makers of Taiwanese CPA firm. This MCDM model is able to simultaneously consider multiple sustainability performance criteria, thus assisting decision makers in evaluating the best case based on the characteristics of a limited number of alternative cases. This can be used in ranking and selection, as well as for building sustainability performance improvement strategies, such as solving the three major problems of this research. First, traditional statistical methods assume the criteria are independently, linearly, and hierarchically structured; however, in the real world, sustainability performance evaluation problems are often characterized by interdependent criteria and may even show feedback-like effects for avoiding "some statistics and economics that are unrealistic in reality" (Hu et al., 2017; Tzeng and Shen, 2017) such as assumptions, etc. Second, relatively good solutions according to the max-min concept of existing alternatives are replaced by "aspiration levels" to meet the needs of the real world, thus avoiding "picking the best apple among a barrel of rotten apples" (Liou and Tzeng 2012; Peng and Tzeng, 2013; Peng and Tzeng, 2017) (Simon received the Nobel Prize in Economics in 1978 and incorporated the basic concept of the "aspiration level" in his work; Simon, 1955, 1956, and 1959). Third, emphasis in the field has shifted from ranking when determining the most preferable approaches to sustainability performance improvement of existing methods by systematics, because "we need a systematic approach to problem-solving; instead of addressing the systems of the problem, we need to identify the sources of the problem" for avoiding "stop-gap piecemeal" (Liou and Tzeng, 2012; Peng and Tzeng, 2013).

2. Literature review

2.1. Performance evaluation of CPA firms

There is a growing realization that corporations must address the issue of sustainability (Searcy, 2012). Therefore, the pursuit of corporate sustainability performance should be the primary goal of CPA firms, but unfortunately, few studies have investigated CPA firms' sustainability performance. Although the main part of prior studies on CPA firms' performance focuses on the notion of productivity and efficiency (e.g. Cheng, 2000a.; Banker et al., 2002.; Banker et al., 2003; Chang et al., 2009a; Chang et al., 2009b; Chang et al., 2009c; Johnstone et al., 2004; Wang et al., 2014), they still can help us to find the appropriate criteria to evaluate CPA firms' sustainability performance. According to the triple bottom line concept, CPA firms' sustainability performance encompasses economic, environmental, and social aspects. Since environmental issues are not seen as particularly key for the operation of a professional service business like a CPA firm (Duff, 2011), how to meet the economic needs of shareholders and the non-economic needs of other stakeholders (such as employer and clients) is a core question for CPA firms' sustainability performance evaluation.

The economic factors that result in achieving financial goals are vital to sustainability performance measurement (Presley et al., 2007). As to the economic criteria of CPA firms' performance, Cheng et al. (2000b), Banker et al. (2003, 2005), and Chang et al. (2009a, 2011) measured the financial output of a CPA firm in terms of its net revenue generated from three sources: Accounting and Auditing, Tax Services, and Management Advisory Services. Except for net revenue, the revenue per employee of each CPA firm is also used to "measure labor productivity growth and decompose it into efficiency change, technical progress and capital deepening" (Kumar and Russell, 2002). Chen et al. (2008) defined CPA firms' financial performance as "total revenues minus total expenses plus partners' salaries, and then divided by the number of partners". Dopuch et al. (2003) used the realized fee/standard total fee plus expenses as the criteria to evaluate CPA firm performance. Cheng et al. (2000b) considered the labor cost, capital cost, and total cost as the financial inputs of CPA firm. Cheng et al. (2000a) adopted firm size, represented by a CPA firm's total operating revenues, when they evaluated the technical efficiencies of CPA firms in Taiwan.

The non-economic criteria used to evaluate the performance of CPA firms in prior literature are concentrated into the aspects of human resource quality, clients, and information system implementation. In terms of human resource quality, Banker et al. (2003, 2005) and Chang et al. (2009a, 2011) considered three human resources: number of partners, number of other professionals, and number of other employees. Chang et al. (2011) found human capital, which is estimated by a function of education level and work experience, to be a motivation for CPA firm performance. Cheng et al. (2000a) expected CPA firms with higher CPA-to-employee ratios to be more efficient, because practicing CPAs with high human resource quality can play an important role in the supervision of service provision. Therefore, the competition to attract talented accountants is fierce among accounting firms (Durocher et al., 2016). In terms of the client, Dopuch et al. (2003) evaluated the client-specific performance of audit teams in a public accounting firm, using client variables such as client assets, client complexity, client risk, effectiveness of a client's internal control, etc. Similarly, Knechel et al. (2009) regarded client's size, client's geographical distribution, client's organizational structure, and client's automaticity as client-specific characteristics. In terms of IT implementation, prior literature considered IT investment as a key driver of productivity improvement among CPA firms (Banker et al., 2002; Manson et al., 2001; Janvrin et al., 2008; Chang et al., 2011).

2.2. Balanced Scorecard and its extension in corporate sustainability

Balanced Scorecard, which was conceived by Kaplan and Norton (1992), provides a comprehensive framework for the evaluation of financial and non-financial performance measures from four different perspectives: Finance, Customer, Internal business process, and Learning and growth. Aside from being a performance evaluation framework, the balanced scorecard is a strategic management tool that can provide the drive forces of performance after a systematic analysis of the relevant factors required to meet the intended strategy (Kaplan and Norton, 1992, 1996, 2001; Ittner et al., 2003). The strategy map illustrates the picture of the causal relationships between some critical performance factors identified from the four perspectives mentioned above in accordance with the

value-added process (Chen and Tzeng, 2015). In order to evaluate the performance, the choice of appropriate indicators is emphasized on the best balance between the short- and long-term objectives, financial and non-financial measures, historic and forecast indicators, as well as external and internal performance measures (Bhagwat and Sharma, 2007; Xia et al., 2017).

Because BSC integrates the economic, environmental, and social needs of key stakeholders, both academics and practitioners consider that BSC is an appropriate tool to evaluate corporate sustainability performance (e.g. Figge et al., 2002; Dias-Sardinha and Reijnders, 2005; Tsai et al., 2009; Searcy, 2012; Zhao and Li, 2015). Furthermore, in line with the triple bottom line concept, some extended balanced scorecard designs have been developed, integrating the measurements of economic, social, and environmental factors, in order to evaluate corporate sustainability performance (e.g. Figge et al., 2002; Van der Woerd and van Den Brink, 2004; Van Marrewijk, 2004; Hansen and Schaltegger, 2012; Xia et al., 2017). Compared with those traditional and short-term oriented performance evaluation models, BSC can be an appropriate sustainability performance evaluation model for CPA firms, because BSC focuses more on the various stakeholders' interests, reflecting the need for corporation sustainability development (Zhao and Li, 2015) and the links between the main sources of value and corporate strategy (Kaplan and Norton, 1993).

2.3. A discussion about the prior literature

Although prior studies have greatly contributed to the performance evaluation of CPA firms and the application of BSC in sustainability issues, they paid more attention to evaluating the CPA firms' productivity by using the Data Envelopment Analysis (DEA) method, taking both outputs and inputs of CPA firms into account (e.g. Cheng, 2000a; Banker et al., 2002; Banker et al., 2003; Chang et al., 2009a; Chang et al., 2009b; Chang et al., 2009c; Johnstone et al., 2004; Wang et al., 2014), using MAUT (Multi-Attribute Utility Theory) for the ranking and selection of known alternatives (Ko and Fujita, 2016), and employing SAW (simple additive weighting) to calculate the weighted average of every alternative (Zhao et al., 2012).

There are four reasons why we need to undertake further research on the sustainability performance evaluation model for CPA firms. First, in prior studies, BSC for sustainability performance measures was mostly applied under an assumption that there was a one-way relationship between these dimensions and criteria. However, there are mutual effects between these four different BSC dimensions and their criteria of CPA firms' performance evaluation. For example, employee professional education and training are positively related to financial performance in CPA firms (Chen et al., 2008), which means there are mutual effects between the criteria of "Learning and growth" and the criteria of "Finance". A client's risk characteristics positively affect the allocation of quality and quantity of audit labor in CPA firms (Bell et al., 2008), implying there are mutual effects between the factor of "Customer" and the criteria of "Internal business process". Therefore, this paper uses the DEMATEL technique to identify the influential network among these criteria. The DEMATEL technique is "a comprehensive method for building and analyzing a structural model involving causal relationships" between complex perspectives and various assessment criteria (Hsu et al., 2013; Su et al., 2016; George-Ufot et al., 2017).

Second, as the main evaluation model of CPA firms' performance in prior studies, DEA cannot provide a common set of weights that present the preference structure of decision makers, because it creates a separate linear programming model for each decision-making unit (Charnes et al., 1978; Opricovic and Tzeng, 2003). The MAUT method and its qualitative criteria and assessments are even more complex than AHP, and thus it is less used in academic studies, because it has unrealistic assumptions in reality. For the SAW method, the presumption is that each attribute is independent, and accurate measurements will not be possible if some alternatives come with a qualitative or uncertain structure. Some studies tried to use AHP (Analytic Hierarchy Process) or ANP with BSC in order to solve this problem (Ravi et al., 2005; Chen et al., 2011). AHP and ANP are two extensively used MCDM approaches to rank alternatives by obtaining the relative weights of the criteria (Saaty, 1980, 1996). The ANP method can be used in a more flexible environment compared to AHP (Ravi et al., 2005;

Lam and Lai, 2015; Xu et al., 2015). Some papers have recommended a combination of ANP and DEMATEL to obtain the common weights of criteria that are interdependent in the real world (e.g. Chen et al., 2015; Hu et al. 2015, 2016; Peng and Tzeng, 2017; Shen et al. 2017). Therefore, this paper uses DANP to calculate the weights of evaluation dimensions and criteria of CPA sustainability performance.

Third, DEA can check the alternatives in a multiple objective sense without decision makers' preferences just at the engineering level. However, at the managerial level, decision makers' preference structure is the foundation of management decision-making. Therefore, the DEA results are not useful within MCDM (Opricovic and Tzeng, 2003). In such cases, making a comprehensive analysis and listing the important properties of no inferior and/or compromise solutions can help the decision making process. Therefore, this paper uses a compromised ranking method, called modified VIKOR, to solve this problem and improve the performance gaps. The modified VIKOR method finds the compromise solution that is closest to the ideal solution (Opricovic and Tzeng, 2004) and has been applied successfully to many practical decision-making (e.g. Valipour Parkouhi and Safaei Ghadikolaei, 2017; Vucijak et al., 2016; Xu et al., 2017; Peng and Tzeng, 2017; Shen et al. 2017).

Finally, few studies have used the MCDM method based on BSC to evaluate CPA firms' sustainability performance and to propose improvement priorities. Therefore, this paper develops a hybrid MCDM model by combining DEMATEL, ANP, and modified VIKOR based on BSC for examining CPA firms' sustainability performance.

3. Methodology: A hybrid MCDM model to evaluate Taiwanese CPA firms' sustainability performance

3.1. Data collection

Prior studies classified CPA firms into three categories: national, regional, and local CPA firms (Banker et al., 2003). The largest number of CPA firms is composed of local CPA firms in Taiwan, and so this study gets its data evidence from these local CPA firms. This paper involves a two-stage design, including expert pre-test questionnaire and final questionnaire. In the first step, the pre-test questionnaire was designed to find a limited number of criteria from a single perspective in order to ensure the validity of the pairwise comparison (Saaty, 1980). Fourteen domain experts were comprised of 10 partners of local CPA firms, 2 officials of the Financial Supervisory Commission in Taiwan, and 2 academicians that specialize in CPA auditing. These domain experts all have a deep understanding about Taiwanese CPA firms' sustainability theoretically or practically. They answered the pre-test questionnaire by face-to-face form to identify the important criteria from a criteria pool based on the prior literature. The pre-test questionnaire ranged from 0 to 10 with a high score representing higher importance. Therefore, the important criteria were selected according to the triangular fuzzy numbers (with a mean of 8 and above). The evaluation criteria for Taiwanese CPA firm's sustainability performance are shown in Table 1.

In the second step, the final questionnaire was designed to determine the influential weight of the DANP method and the satisfaction degree to evaluate Taiwanese CPA firms' sustainability performance by using the modified VIKOR method. The interviewees were 122 partners of Taiwanese CPA firms, composed of 60 partners in Taiwan's Taipei associations of accountants, 32 partners in Taiwan's Taichung associations of accountants, and 30 partners in Taiwan's Kaohsiung associations of accountants. Table 2 presents the detailed information of these partners.

There are two reasons why these partners of Taiwanese CPA firms were suitable for the final questionnaire. First, these partners all have a profound understanding about the interrelationships among those evaluation criteria affecting sustainability performance, because of their sufficient work experience in Taiwanese CPA firms. Second, as the top management of CPA firms, these partners are very familiar with the real situation about those evaluation criteria that are used to evaluate the sustainability performance of their CPA firms. These partners finished the questionnaire by face-to-face form to present the interactions between the CPA firms' sustainability performance dimensions and

criteria based on the four BSC dimensions. In addition, every partner gave his (or her) assessment of his (or her) CPA firm's sustainability performance based on the performance dimensions and criteria on a score of 0 to 10, with 0 showing much dissatisfaction (lowest score) and 10 being much satisfaction (highest score and aspiration level). By going through personal interviews and completing the questionnaire, 122 questionnaires were administered to obtain the assessment of their CPA firm's sustainability performance. Each final questionnaire took about 60-80 minutes.

Table 1
The evaluation criteria for Taiwanese CPA firm's sustainability performance

BSC Dimension	Criteria	Description
A CPA firm's learning and growth	a_1 Employee training	Employees' training and education to enhance their ability
	a_2 Employee professional ability	Staff professional knowledge and ability for providing auditing service
	a_3 Employee productivity	Service produced by each employee
B CPA firm's internal processes	b_1 Management efficiency enhancement	Provide professional services to clients in a timely and highly efficient manner
	b_2 Ability to keep existing clients	Services provided by the CPA firms are able to attract clients
	b_3 Resource allocation	Facility allocation level
	b_4 Information system	Level of information management
C Client	c_1 Client satisfaction	Client's satisfaction level to services provided by the CPA firms
	c_2 Service quality	Client's evaluation of the services provided by the CPA firms
	c_3 Firm image	CPA firm image construction and client's trust of such a brand
D Finance	d_1 Total service revenues	Service revenue income
	d_2 Revenue growth rate	Current period's total service revenue/Revenue in the same period last year
	d_3 Net profit ratio	Current period's net profit/Service revenue income

Source: Behn et al. (1997); Cheng et al. (2000b); Banker et al. (2002); Ellinger et al. (2002); Banker et al. (2003); Bell et al. (2008); Davis and Albright (2004); Banker et al. (2004, 2005); Papalexandris et al. (2005); Chen et al., (2006); Chen et al. (2008); Chang et al. (2011); Chen and Tzeng (2015); Durocher et al., (2016).

Table 2
Detailed information of interviewees

Category	Content	N	Percentage
Education level	Doctor's	2	1.6%
	Master's	60	49.3%
	College	58	47.5%
	High School and Below	2	1.6%
Sex	Male	62	50.8%
	Female	60	49.2%
Years of work experience in CPA firm	< 10 Years	19	15.6%
	10-15 years	21	17.2%
	15-20 years	40	32.8%
	> 20 years	42	34.4%

3.2. Building an influential network relation map based on DEMATEL

In the prior literature, CPA firms' performance evaluation models hypothetically considered that the evaluation dimensions and criteria are independent. However, there are mutual effects between these evaluation dimensions and criteria (Bell et al., 2008; Chen et al., 2008). This paper uses the DEMATEL technique to construct an influential network relation map (INRM) to show the relationships among these evaluation dimensions and criteria. The DEMATEL technique was developed for the purpose to explain specific societal problems based on a network relation diagram and a structural model. These basic concepts were used to create a series of new hybrid MCDM models to solve complex and dynamic real world problems (Peng and Tzeng, 2013; Hsu et al., 2013; Su et al., 2016; George-Ufot et al., 2017). The details of DEMATEL are shown in **Appendix A**.

3.3. Determining the weights by DANP

In the prior literature, CPA firms' performance evaluation models do not provide a common set of weights that could present the preference structure of decision makers (Charnes et al., 1978; Opricovic and Tzeng, 2003). This paper uses the DANP technique to obtain the influential weights. ANP combined with the DEMATEL can provide the DANP influential weights (also call "global weights"), thereby resolving the interdependence and making this technique more appropriate for real world application. Accordingly, this paper combines the advantages of ANP and DEMATEL to solve the problems of mutual dependence, feedback among criteria, and the comment set of weights (Chen et al., 2015; Hu et al. 2015). The details of DANP are shown in **Appendix B**.

3.4. Measuring the satisfaction performance by modified VIKOR

In the prior literature, the CPA firms' performance evaluation models did not provide the preference structure of decision makers, which is the foundation for solving the MCDM problem at the managerial level. The results obtained by prior CPA performance evaluation models were not useful within MCDM (Opricovic and Tzeng, 2003). Therefore, this paper uses the modified VIKOR technique to measure the sustainability performance of CPA firms. The VIKOR technique was first introduced by Opricovic (1998) and further developed by Opricovic and Tzeng (2007). The modified VIKOR uses the concept of aspiration levels, and the idea of aspiration levels were first proposed by the Nobel Prize Laureate H. A. Simon (1955, 1956, and 1959), replacing the classic selection or optimization decision based on Min-Max values by searching for the aspiration levels at each stage (Hu et al, 2017; Tzeng and Shen, 2017). The best one can be selected among the alternatives according to the concept of a compromise when dealing with the complex decision-making problems in the MCDM framework. The modified VIKOR is not only applied to rank and selecting the optimal alternative, but is also used for performance gap improvement. The details of the modified VIKOR are presented in **Appendix C**.

4. Empirical analysis of Taiwanese CPA firms' sustainability performance

Based on the questionnaire results from domain experts and partners of Taiwanese local CPA firms, this paper first discusses the relationship between Taiwanese CPA firms' sustainability performance evaluation dimensions and criteria by using the DEMATEL technique. Second, this paper utilizes the DANP method to determine the weights of these evaluation criteria. Third and finally, the modified VIKOR approach is adopted to evaluate the sustainability performance of CPA firms for continuous improvement. A diagram of the empirical analysis of Taiwanese local CPA firms' sustainability performance is illustrated in Figure 1.

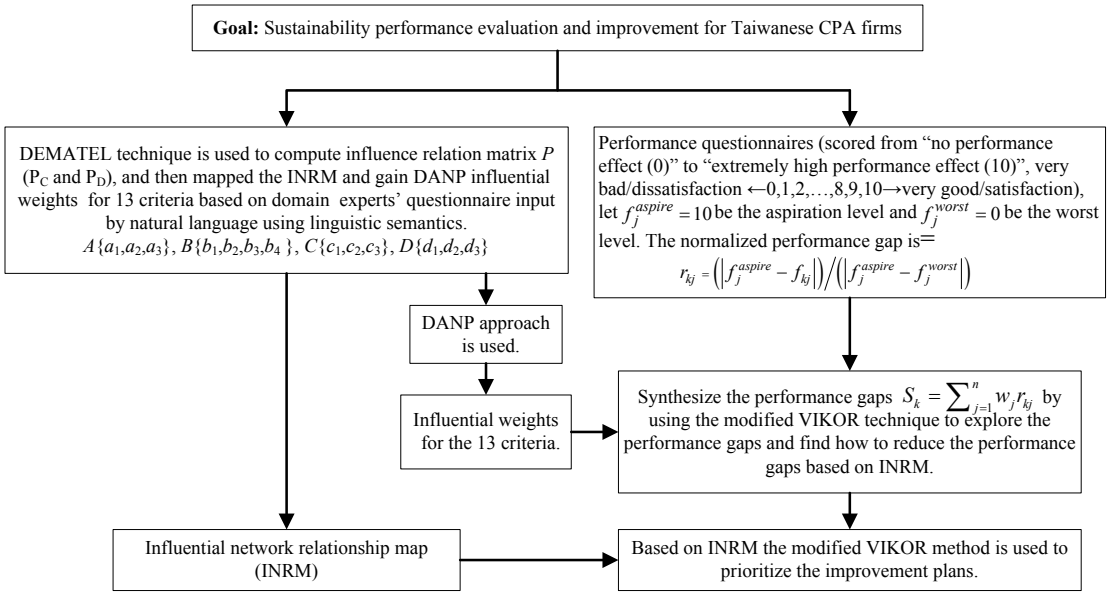

Fig. 1. Diagram of the process for the empirical analysis of Taiwanese CPA firms' sustainability performance

4.1. Empirical results

4.1.1. The DEMATEL for analyzing the relationships between dimensions and criteria

According to the methodology described above, a 13×13 average initial direct-influence matrix ***F***, including 13 criteria, can be derived based on the data collected by interviews from Taiwanese CPA firms' partners. The normalization matrix shown in Table 3 can be obtained by applying Eqs. (A.2) and (A.3) in DEMATEL's step 2.

Table 3

Normalization matrix Y

Criteria	a_1	a_2	a_3	b_1	b_2	b_3	b_4	c_1	c_2	c_3	d_1	d_2	d_3
a_1	0	0.103	0.085	0.088	0.078	0.075	0.064	0.067	0.065	0.078	0.069	0.077	0.085
a_2	0.106	0	0.084	0.086	0.084	0.078	0.065	0.069	0.068	0.085	0.064	0.069	0.066
a_3	0.089	0.084	0	0.097	0.088	0.087	0.079	0.077	0.069	0.081	0.069	0.077	0.063
b_1	0.085	0.086	0.097	0	0.085	0.092	0.077	0.081	0.067	0.084	0.067	0.073	0.067
b_2	0.080	0.087	0.094	0.083	0	0.087	0.075	0.077	0.069	0.095	0.075	0.080	0.072
b_3	0.080	0.082	0.087	0.091	0.088	0	0.087	0.092	0.081	0.084	0.076	0.081	0.072
b_4	0.069	0.069	0.078	0.080	0.072	0.089	0	0.073	0.068	0.068	0.061	0.067	0.060
c_1	0.069	0.069	0.079	0.080	0.070	0.091	0.071	0	0.082	0.069	0.059	0.064	0.061
c_2	0.068	0.075	0.072	0.070	0.067	0.080	0.071	0.082	0	0.071	0.061	0.062	0.062
c_3	0.079	0.086	0.091	0.084	0.102	0.086	0.067	0.072	0.069	0	0.064	0.066	0.063
d_1	0.069	0.071	0.077	0.072	0.083	0.083	0.063	0.060	0.058	0.067	0	0.087	0.080
d_2	0.079	0.074	0.078	0.070	0.084	0.082	0.069	0.060	0.058	0.066	0.089	0	0.091
d_3	0.084	0.069	0.070	0.063	0.070	0.070	0.063	0.055	0.056	0.063	0.081	0.083	0

As shown in Table 4, the total influence-relation matrix of the criteria can be derived through Step 3 of DEMATEL on the basis of the normalization impact matrix described above.

Table 4
Total influence-relation matrix of criteria

Criteria	a_1	a_2	a_3	b_1	b_2	b_3	b_4	c_1	c_2	c_3	d_1	d_2	d_3
a_1	0.808	0.901	0.914	0.895	0.892	0.908	0.785	0.798	0.752	0.846	0.775	0.823	0.794
a_2	0.897	0.801	0.906	0.887	0.891	0.904	0.780	0.793	0.749	0.846	0.765	0.809	0.772
a_3	0.909	0.905	0.857	0.923	0.922	0.939	0.816	0.826	0.773	0.868	0.792	0.841	0.792
b_1	0.908	0.908	0.947	0.837	0.921	0.945	0.817	0.830	0.772	0.872	0.792	0.839	0.797
b_2	0.914	0.920	0.955	0.924	0.853	0.951	0.824	0.836	0.783	0.892	0.809	0.855	0.811
b_3	0.931	0.933	0.967	0.947	0.951	0.890	0.850	0.864	0.809	0.899	0.824	0.872	0.826
b_4	0.806	0.806	0.840	0.822	0.821	0.852	0.666	0.744	0.699	0.774	0.710	0.753	0.713
c_1	0.814	0.814	0.849	0.830	0.827	0.862	0.740	0.683	0.718	0.783	0.715	0.758	0.721
c_2	0.793	0.798	0.821	0.801	0.804	0.831	0.721	0.740	0.624	0.765	0.699	0.737	0.704
c_3	0.880	0.885	0.917	0.891	0.911	0.915	0.786	0.800	0.754	0.773	0.769	0.811	0.773
d_1	0.819	0.820	0.851	0.827	0.843	0.860	0.737	0.743	0.700	0.786	0.664	0.782	0.742
d_2	0.851	0.846	0.877	0.849	0.867	0.882	0.762	0.764	0.720	0.807	0.766	0.724	0.772
d_3	0.797	0.784	0.810	0.784	0.796	0.812	0.705	0.706	0.668	0.748	0.708	0.746	0.638

The total influence matrix P_d for each dimension/criterion is derived, as shown in Table 5. Results of Table 5 show that four dimensions/criteria, namely CPA firm's learning and growth (A), CPA firm's internal processes (B), Client (C), and Finance (D), are mutually influential.

Table 5
The sum of effects on dimensions

Dimensions	*A*	*B*	*C*	*D*
CPA firm's learning and growth (*A*)	0.878	0.601	0.806	0.796
CPA firm's internal processes (*B*)	0.903	0.867	0.814	0.800
Client (*C*)	0.841	1.102	0.738	0.743
Finance (*D*)	0.621	0.608	0.738	0.727

As shown in Table 6, the sum of the influence of each dimension and criterion can be derived by applying Eqs. (A.5) and (A.6) in DEMATEL's step 3. INRM in Figure 2 illustrates the influential network-relationship from BSC's four perspectives and their subsystem. The criteria with positive values of $d_i - r_i$ have great influence on other criteria. The criteria with negative values of $d_i - r_i$ are greatly influenced by the other criteria. A significantly positive value of $d_i - r_i$ represents that this criterion affects other criteria much more than those other criteria affect it, which means it should be a priority for improvement. Therefore, according to the value of influence given $d_i - r_i$, Finance (D) is influenced by CPA firm's learning and growth (A), CPA firm's internal processes (B), and Client (C), because the $d_i - r_i$ value of Finance (D) is negative and a minimum (-0.372). In turn, CPA firm's learning and growth (A) is influenced by CPA firm's internal processes (B) and Client (C), whereas CPA firm's internal processes (B) are influenced by Client (C). Thus, to improve the Finance (D) dimension of CPA firms' sustainability performance, the improvements to CPA firm's learning and growth (A), CPA firm's internal processes (B), and Client (C) should be emphasized. In turn, to improve the CPA firm's learning and growth (A) dimension of CPA firms' sustainability performance, the improvements to CPA firm's internal processes (B) and Client (C) should be emphasized. Finally, Client (C) with a maximum value of $d_i - r_i$ (0.328) has the most influence on the other dimensions. Similarly, it also can be illustrated in Figure 2 that the priority of influence of the four dimensions/criteria of Taiwanese CPA firms' sustainability performance from BSC's four perspectives is in the order of Client (C), CPA firm's internal processes (B), CPA firm's learning and growth (A), and Finance (D).

Table 6
The sum of influences and ranking of each dimension and criterion

Dimension and criterion (i)	Row sum (d_i)	Column sum (r_i)	$d_i + r_i$	$d_i - r_i$	Ranking
CPA firm's learning and growth (A)	**3.081**	**3.243**	**6.324**	**-0.163**	
a_1 Employee training	2.623	2.615	5.238	0.008	1
a_2 Employee professional ability	2.605	2.607	5.213	-0.002	2
a_3 Employee productivity	2.672	2.677	5.349	-0.005	3
CPA firm's internal processes (B)	**3.384**	**3.178**	**6.562**	**0.207**	
b_1 Management efficiency enhancement	3.519	3.530	7.049	-0.011	4
b_2 Ability to keep existing clients	3.552	3.546	7.099	0.006	1
b_3 Resource allocation	3.638	3.637	7.275	0.001	3
b_4 Information system	3.161	3.156	6.317	0.005	2
Client (C)	**3.424**	**3.096**	**6.520**	**0.328**	
c_1 Client satisfaction	2.185	2.224	4.409	-0.040	3
c_2 Service quality	2.130	2.096	4.226	0.034	1
c_3 Firm image	2.327	2.321	4.648	0.006	2
Finance (D)	**2.694**	**3.066**	**5.760**	**-0.372**	
d_1 Total service revenues	2.188	2.139	4.327	0.049	1
d_2 Revenue growth rate	2.262	2.252	4.514	0.011	2
d_3 Net profit ratio	2.092	2.152	4.214	-0.060	3

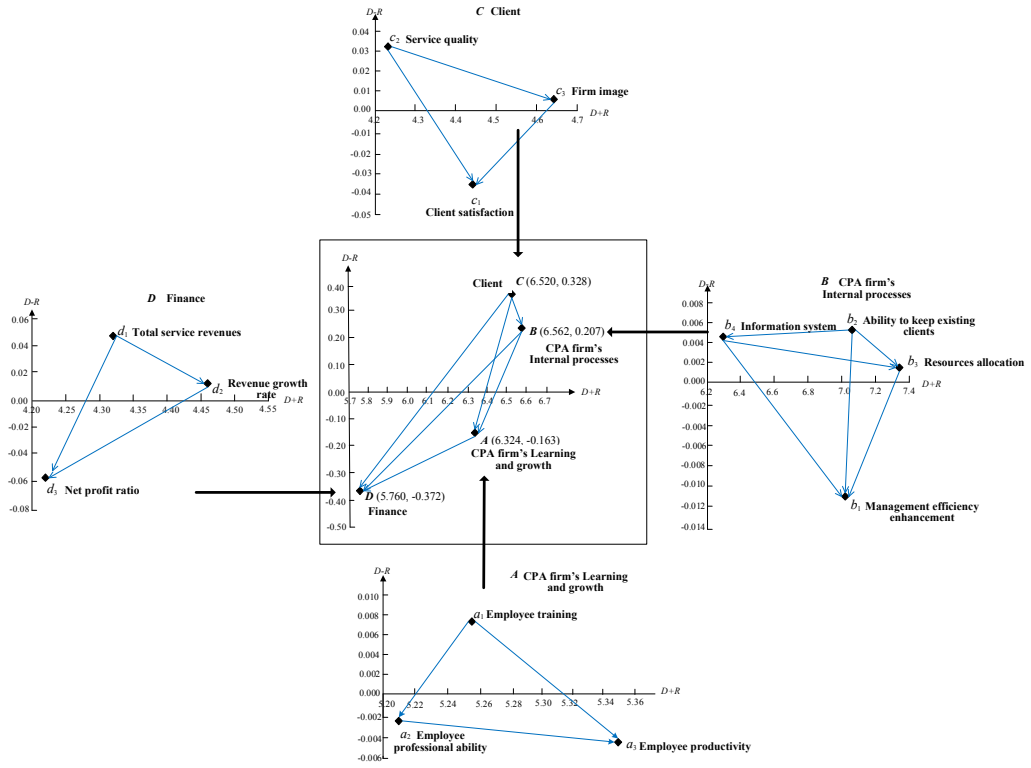

Fig. 2. The map of influential network relations of each dimension and criterion

As shown in Table 6 and Figure 2, the analysis of each criterion shows that in the CPA firm's learning and growth (A) dimension, Employee training (a_1) is the most important criterion ($d_i - r_i$ =0.008), whereas Employee productivity (a_3) is the least influential criterion ($d_i - r_i$ =-0.005). In most industries, employee training is voluntary, but it is mandatory in the auditing industry. According to the regulations of Taiwan Certified Public Accountant, to enhance auditing service quality, auditors and their assistants should attend professional training under the requirement of minimum academic

hours. In the auditing industry, auditors provide professional auditing services that require knowledge improvement and mandatory training. Thus, employee training is the most important criterion in this dimension.

In the CPA firm's internal processes (B) dimension, Ability to keep existing clients (b_2) is the most important criterion ($d_i - r_i$ =0.006), whereas Management efficiency enhancement (b_1) is the least influential criterion ($d_i - r_i$=-0.011). Auditing, as an industry, also faces the pressure of surviving and seeking profit. Under current environmental conditions, retaining customers is critical for CPA firms' revenues and development. Thus, the ability to keep existing clients (b_2) is the most important criterion to the CPA firm's internal processes (B) dimension.

In the Client (C) dimension, Service quality (c_2) is the most important criterion ($d_i - r_i$ =0.034), whereas Client satisfaction (c_1) is the least influential criterion ($d_i - r_i$ =-0.040). DeAngelo (1981b) indicated CPA firms charge differently for services of different qualities in an auditing market with fierce competition. A higher audit fee indicates higher audit quality. Generally, a company pays higher audit fees for higher quality auditors (Francis, 2004). From the viewpoint of audit demand, the reason behind this is that companies with high agency costs are willing to pay higher audit fees to reduce agency costs. High-quality service helps enhance revenues, and so service quality is the most important criterion to the Client (C) dimension. In the Finance (D) dimension, Total service revenues (d_1) represent the most important criterion with a more influential effect ($d_i - r_i$ =0.049), whereas Net profit ratio (d_3) is the least influential criterion ($d_i - r_i$ =-0.060). The reason is the same as described above.

4.1.2. Using DANP for calculating weights of the criteria

As shown in Table 7, the influential weights of DANP for each criterion can be obtained by utilizing a combination of DEMATEL and ANP methods. The DEMATEL Total influence-relation matrix is used to construct the weighted supermatrix by applying Eqs (B.4) and (B.5) in DANP's step 2. The weighted supermatrix for each criterion can be obtained by applying Eqs. (B.2) and (B.8). Consequently, the limit supermatrix is used to obtain the global weights of the elements, which are applied to the modified VIKOR approach to evaluate the performance of each criterion.

Table 7

Influential weights of DANP for each criterion obtained by $lim_{h\to\infty}(W^{\propto})^h$

Criterion	a_1	a_2	a_3	b_1	b_2	b_3	b_4	c_1	c_2	c_3	d_1	d_2	d_3
	0.081	0.081	0.083	0.081	0.082	0.085	0.072	0.073	0.068	0.077	0.071	0.075	0.071

4.1.3. Measuring the performance of each dimension and criterion

The modified VIKOR method is an applicable technique to evaluate the overall performance gap of CPA firms' sustainability performance. Based on the data from 122 partners' assessment of their CPA firms' sustainability performance in Taiwan, each criterion score and the total average gap ($S_k = \sum_{j=1}^{n} w_j r_{kj}$) are obtained by using the DANP global weights multiplied by the gap (r_{kj}). As shown in Table 8, the average performance value is calculated based on the criteria performance value ($f_{kj} \mid j = 1,2,...,n$) and their relative gaps ($r_{kj} = (\left|f_j^{aspire} - f_{kj}\right|)/(\left|f_j^{aspire} - f_j^{worst}\right| j = 1,2,...,n$) of all criteria. With the help of these sustainability performance values, the decision-makers of CPA firms are able to find solutions for the problems of each dimension and criterion. The results indicate that Client (C) exhibits the highest performance value (6.824), and that a CPA firm's learning and growth (A) exhibit the lowest value (6.392). From the viewpoint of criteria, Client satisfaction (c_1) obtains the highest performance value of 7.24 and the lowest gap value of 0.276. The Information system (b_4) ends up with the lowest performance value (6.265) and the largest gap value (0.374). The overall average sustainability performance value of Taiwanese CPA firms is 6.577, which means there is about a 34.2% gap from the expected aspiration level (=10).

Table 8
Sustainability Performance Evaluation of Taiwanese CPA firms

Dimension and Criteria	Local Weight	Global Weight (*by DANP*)	Level of Performance	Relative Gaps
CPA learning and growth (*A*)	**0.244**		**6.392**	**0.361**
Employee training (a_1)	0.330	0.081	6.434	0.357
Employee professional ability(a_2)	0.329	0.081	6.331	0.367
Employee productivity (a_3)	0.341	0.083	6.412	0.359
CPA firm's internal processes (*B*)	**0.319**		**6.426**	**0.357**
Management efficiency enhancement (b_1)	0.255	0.081	6.360	0.364
Ability to keep existing clients (b_2)	0.257	0.082	6.471	0.353
Resource allocation (b_3)	0.262	0.085	6.610	0.339
Information system (b_4)	0.227	0.072	6.265	0.374
Client (*C*)	**0.219**		**6.824**	**0.318**
Client satisfaction (c_1)	0.334	0.073	7.243	0.276
Service quality (c_2)	0.314	0.068	6.669	0.333
Firm image (c_3)	0.352	0.077	6.599	0.344
Finance (*D*)	**0.217**		**6.748**	**0.325**
Total service revenues (d_1)	0.327	0.071	6.478	0.352
Revenue growth rate (d_2)	0.345	0.075	7.132	0.287
Net profit ratio (d_3)	0.328	0.071	6.632	0.337
Total Performance			**6.577**	
Total Gap (S_k)				**0.342**

5. Management implications and discussion

This paper presents some management implications for the decision-makers of Taiwanese CPA firms in order to seize key sustainability performance. As shown in Figure 2, INRM indicates the order of priority for improving key factors in Taiwanese CPA firms' sustainability performance as follows: Client (C), CPA firm's internal processes (B), CPA firm's learning and growth (A), and Finance (D). The result of this paper supports the Client Orientation strategy from the new perspective of sustainability development, thus providing new evidence for the strategy of CPA firms. The value of a CPA firm equals the present value of all clients' future quasi-rent (DeAngelo, 1981b; Gong et al., 2015). Since auditors have to retain customers to realize future quasi-rent, Client (C), including especially client satisfaction, service quality, and firm image, should be the focus of Taiwanese CPA firms' sustainability performance management. Taiwanese CPA firms can invest more in their brand reputation and industry specialization and supply more differentiated audit services that competitors cannot easily replicate (Chen et al., 2006; Greenwood et al., 2005; Martínez-Ferrero and García-Sánchez, 2016). However, it is important to note that maintaining auditor independence should not be ignored when an auditor delivers higher-quality services for clients' satisfaction, although the clients are very important to any CPA firm. Moreover, this finding implies that low price competition is not a good strategy. Market segmentation exists in the auditing industry due to government regulation or the size of clients served (Ghosh and Lustgarten, 2006; Simons and Zein, 2016). Although prior studies indicated there exists 'low balling' on initial audit engagements (DeAngelo, 1981a; Chan, 1999; Stanley et al., 2015; Hua et al., 2016;), obtaining short-term financial performance through financial instruments such as 'low balling' is not an effective way to improve sustainable performance.

The average value of Taiwanese CPA firms' sustainability performance as shown in Table 8 is 6.577 (the aspiration level is 10). Moreover, the average gap for improvement is 0.342 (the maximum gap value is 1). This means that the current average sustainability performance of CPA firms has a 34.2% gap in distance from the ideal performance level, which indicates there is relatively large promotion space for CPA firms in Taiwan.

Among the four BSC dimensions, CPA firm's learning and growth provide the largest gap (0.361) as shown in Table 8, denoting the largest in Taiwanese CPA firms' sustainability performance. The

dimension of "learning and growth" has three criteria: employee training, employee professional ability, and employee productivity. Auditing professional services are so complicated that auditors are required to improve their auditing technical ability and continually acquire tacit managerial knowledge through advanced training, work experience, and professional ability (Chang et al., 2011). Therefore, auditors with a high education level, continuing professional training, and more experience have greater auditing professional productivity, which can produce high quality services for clients in turn. According to the Certified Public Accountant Act in Taiwan amended on 20 April 2016, only a person who has passed the CPA examination and then acquired a CPA certificate can conduct audit services. CPAs must pursue continuing professional education for minimum course hours; for example, the minimum academic hours of CPA continuing professional education in Taiwan shall not be less than forty hours within one year. Although accountants in Taiwan have strict requirements for professional qualifications and continuing professional education as mentioned above, it seems that higher requirements should still be emphasized even more, because of the low assessment of the "CPA firm's learning and growth" dimensions. For example, the requirements of continuing professional education in China, which include no less than 180 hours per three years and no less than 40 hours per year, are stricter than those in Taiwan.

Among the 13 criteria as indicated in Table 8, "information system" has the largest gap value, which means this aspect needs more work on it in order to improve CPA firms' sustainability performance in Taiwan. Information system is one of the most important drivers of sustainability performance among CPA firms. With the application of a better information system, the routine auditing tasks of CPA firms can be automated, and the efficiency of work collaboration and communication within audit teams can be improved (Chang et al., 2011). Furthermore, CPA firms often provide some professional service to help clients integrate their own information systems or some other relative systems about office automation and automated warehousing (Banker et al., 2002). Consequently, the information system itself, the experience with information systems, and the related services of CPA firms can help promote overall sustainability performance.

6. Conclusion

Faced with a constant changing competition environment, Taiwanese CPA firms need to utilize an appropriate sustainability performance evaluation model to enhance their competitive advantage. Therefore, this study builds a hybrid MCDM model combining DEMATEL with ANP and modified VIKOR based on BSC, so as to evaluate the sustainability performance of Taiwanese CPA firms.

First, using the DEMATEL method, this hybrid MCDM model can indicate the directions for improvement of CPA firms' sustainability performance, rather than just rank the performance. This sustainability performance evaluation model helps CPA firms' decision-makers to understand the most important factors of their firms' sustainability performance through INRM, which can provide an overall picture of the influential network among these complicated factors. Based on data from interviews with partners of Taiwanese CPA firms, the priority of influence of the four dimensions of CPA firms' sustainability performance from the BSC perspectives is: Client (C), CPA firm's internal processes (B), CPA firm's learning and growth (A), and Finance (D). Specifically, this finding implies that Client Orientation may be a right strategy choice for local CPA firms in Taiwan.

Second, based on the DANP method, this hybrid MCDM model solves the problem of the interdependent relationships among the criteria of Taiwanese CPA firms' sustainability performance. Therefore, this model provides the influential weights for these CPA firms' sustainability performance evaluation in the real world.

Third, we have applied a modified VIKOR method to alter the traditional "max-min" as an ideal point and the negative ideal point into the aspiration level and the worst value, respectively. The relatively good solution from existing alternatives based on "max-min" as a benchmark was replaced by the aspiration level and worst value in order to avoid "choosing the best among inferior options/alternatives". They were used not only in ranking and selection, but also in performance gap improvement among the criteria and their dimensions and even for the overall performance gap. Thus,

this new model provides more accurate information about the gap between the current sustainability performance of CPA firms and the target level. This information can help CPA firms' decision makers understand their sustainability performance situation over the range from the target level to the tolerable level for all dimensions and criteria.

Based on the data from the interviews with local CPA firms' partners in Taiwan, the empirical result shows a relatively large promotion space for these firms' sustainability performance. Specifically, learning and growth represent the largest gap in Taiwanese CPA firms' sustainability performance from BSC's four perspectives, which means more work needs to be done in constant education and training in order to improve employees' professional abilities. When the professional knowledge and competency of CPA firms' employees can be enhanced, the service quality provided by these employees will be improved, thus increasing client satisfaction levels. In turn, improvements in financial performance can also be expected.

This paper offers several contributions to the CPA performance literature. First, the topic of this paper focuses on the sustainability performance of CPA firms, which has rarely been studied in the prior literature. Second, this paper establishes a hybrid MCDM model combining DEMATEL with ANP and VIKOR based on BSC to evaluate the sustainability performance of CPA firms. This model is able to illustrate the influential network among the criteria of Taiwanese CPA firms' sustainability performance, which was ignored by traditional models that presumed the dimensions and criteria of CPA firms' sustainability performance are independent and hierarchical in structure. Furthermore, this model presents the key factors and their weights of CPA firms' sustainability performance, which were not provided by models in prior CPA performance studies.

This paper is of course subject to several limitations. First, the criteria system of this paper will change with the understanding of the concept of CPA firms' sustainability performance, and so these criteria could be adjusted and developed. For example, other criteria related to economic, environmental, and social factors should be considered in a future study. Second, the determination of influential weights and the satisfaction degrees of these criteria by the partners of Taiwanese CPA firms are dependent on their subjective and personal opinions, despite their deep understanding of the real situation at their CPA firms. Third, in the case study herein, this paper investigates only Taiwanese CPA firms' sustainability performance. Although CPA firms around the world are facing severe competition and increasing demand for sustainable development, the hybrid model and some results of this paper have some limitations about their generality and validity due to the special data of Taiwanese CPA firms. Therefore, further applications of this model and comparative studies can be conducted based on the data of CPA firms from other countries. Fourth, the modified VIKOR integrates each criterion into each dimension, and the overall value was calculated using an additive model; however, the product selection of multi-attribute preference values differs from traditional multi-attribute utility (value-function aggregation in multi-attribute) due to the use of an additive model. Real-world situations require "non-additive" models (super-additive models), and fuzzy integrals are "non-additive" models. Thus, practical problems could be better solved by integrating each criterion and each dimension with all the others. Irrespective of this, the present study still used the additive type in integrating each criterion into each dimension, and the "fuzzy integral" was used to solve the "non-additive type" problem, which integrates each criterion into each dimension. This is better suitable for use on practical problems. Finally, other methodologies can be employed to identify other possible criteria, such as longitudinal studies.

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Appendix A: Building an INRM by DEMATEL

DEMATEL technique comprises three steps follow:

Step 1. Calculate the direct influence-relation average matrix F based on scores. Assume that there are P number of CPA firms' partner experts and n number of criteria, are asked to propose that the pairwise comparisons between any two criteria and an integer score from 0 to 4, expressing the range

from "absolutely no influence (0)" to "very high influence (4)", and showing the influence degree that each criterion *i* affects each criterion *j*. Each domain expert questionnaire forms an n×n non-negative matrix $\boldsymbol{X}^p = [x_{ij}^p]_{n\times n},\ p = 1,2,...,P,$ where $\boldsymbol{X}^1,...,\boldsymbol{X}^p,...,\boldsymbol{X}^P$ are the response matrices by the *P* number of domain experts, and the elements of $\boldsymbol{X}^p$ are denoted by x_{ij}^p from domain expert *p*. Thus, an n×n average matrix *F* of all domain experts given can be built by Eq. (A.1):

$$\boldsymbol{F} = \begin{bmatrix} f_{11} & \cdots & f_{1j} & \cdots & f_{1n} \\ \vdots & & \vdots & & \vdots \\ f_{i1} & \cdots & f_{ij} & \cdots & f_{in} \\ \vdots & & \vdots & & \vdots \\ f_{n1} & \cdots & f_{nj} & \cdots & f_{nn} \end{bmatrix} \tag{A.1}$$

The average scores of the *P* domain experts are $f_{ij} = \frac{1}{P}\sum_{f=1}^{P} x_{ij}^p$. The average matrix is "initial direct relation matrix *F*", represents the degree of influence of one criterion on another criterion, and the degree of influence from other criteria.

Step 2. Normalize the initial direct-influence relation average matrix *Y*. The normalized initial direct influence relation matrix *Y* can be obtained by normalizing the average matrix *F*. The matrix *Y* can be derived from Eqs. (A.2) and (A.3), and all principal diagonal criteria value are equal to zero:

$$\boldsymbol{Y} = s \cdot F \tag{A.2}$$

$$s = \min\left\{\frac{1}{\max_{1\le i\le n}\sum_{j=1}^{n} f_{ij}}, \frac{1}{\max_{1\le j\le n}\sum_{i=1}^{n} f_{ij}}\right\} \tag{A.3}$$

Step 3: Construct the total influence-relation matrix P. A continuous decrease of the indirect effects of problems moves with the powers of the matrix *Y*, e.g. $\boldsymbol{Y}^2, \boldsymbol{Y}^3, \ldots, \boldsymbol{Y}^\infty$, and $\lim_{k\to\infty} \boldsymbol{Y}^k = [0]_{n\times n}$, for $\lim_{k\to\infty}(\boldsymbol{I} + \boldsymbol{Y} + \boldsymbol{Y}^2 + \ldots + \boldsymbol{Y}^k) = (\boldsymbol{I} - \boldsymbol{Y})^{-1}$, where $\boldsymbol{I}$ is a $n \times n$ unit matrix. The total influence- relation matrix P is a $n \times n$ matrix, and is defined by $\boldsymbol{P} = \left[t_{ij}\right]_{n\times n}, i, j = 1,2,\ldots,n$ as shown in Eq. (A.4).

$$\begin{aligned} \boldsymbol{P} &= \boldsymbol{Y} + \boldsymbol{Y}^2 + ... + \boldsymbol{Y}^k \\ &= \boldsymbol{Y}(\boldsymbol{I} + \boldsymbol{Y}^2 + ... + \boldsymbol{Y}^{k-1}) \\ &= \boldsymbol{Y}(\boldsymbol{I} + \boldsymbol{Y}^2 + ... + \boldsymbol{Y}^{k-1})(\boldsymbol{I} - \boldsymbol{Y})(\boldsymbol{I} - \boldsymbol{Y})^{-1} \\ &= \boldsymbol{Y}(\boldsymbol{I} - \boldsymbol{Y})^{-1}, when \lim_{k\to\infty} \boldsymbol{Y}^k = [0]_{n\times n} \end{aligned} \tag{A.4}$$

The total influence relation matrix *P* of INRM can be derived from Eqs. (A.4), (A.5) and (A.6) are used to generate the sum of each column and row forms in the matrix *P*, respectively.

$$\boldsymbol{d} = (d_i)_{n\times 1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} = (d_1,...,d_i,...,d_n)' \tag{A.5}$$

$$\boldsymbol{r} = (r_j)_{n\times 1} = (r_j)'_{1\times n} = \left[\sum_{i=1}^{n} t_{ij}\right]'_{1\times n} = (r_1,...,r_j,...,r_n)' \tag{A.6}$$

Where d_i is the sum of a row in the total influence relation matrix *P*, and represents the total influence (direct and indirect) of criterion/dimension i on the all other criteria/ dimensions $\left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1}$. Likewise, r_j is the column sum in the total influence relation matrix *P*, and represents the total influence (direct and indirect) of criterion/ dimension j received from the all other criteria/ dimensions $\left[\sum_{i=1}^{n} t_{ij}\right]'_{1\times n}$. Thus, when $i = j$, $d_i - r_i$ offers an index of the strength of the total influences given and received, that is $d_i + r_i$ indicating the important degree of the criterion/dimension i plays in the system. In addition, $d_i - r_i$ provides an index of the degree of the cause of total influence. If $d_i - r_i$ is positive, then criterion/ dimension i is a net influencer, and if $d_i - r_i$ is negative, then criterion/ dimension *i* is a net influenced.

Appendix B: Determining the weights by DANP

The details of DANP include the following steps:

Step 1. Construct the total influence relation matrix $\boldsymbol{P}_C$. The DEMATEL is used to derive total influence relation matrix $\boldsymbol{P}_C$ from each dimension (or dimension), with different degrees of influence relation for the criteria, is shown in Eq. (B.1):

$$\boldsymbol{P}_C = \begin{array}{c} \\ D_1 \\ \\ \\ D_i \\ \\ \\ D_n \\ \\ \end{array} \begin{array}{c} \begin{array}{cccccc} D_1 & & \cdots & D_i & & \cdots \quad D_n \\ c_{11}\ldots c_{1m_1} & & \cdots & c_{i1}\ldots c_{im_i} & & \cdots \quad c_{n1}\ldots c_{nm_n} \end{array} \\ \begin{array}{c} c_{11} \\ c_{12} \\ \vdots \\ c_{1m_1} \\ c_{i1} \\ c_{i2} \\ \vdots \\ c_{imi} \\ c_{n1} \\ c_{n2} \\ \vdots \\ c_{nm_n} \end{array} \begin{bmatrix} \boldsymbol{P}_C^{11} & \cdots & \boldsymbol{P}_C^{1j} & \cdots & \boldsymbol{P}_C^{1n} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{P}_C^{i1} & \cdots & \boldsymbol{P}_C^{ij} & \cdots & \boldsymbol{P}_C^{in} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{P}_C^{n1} & \cdots & \boldsymbol{P}_C^{nj} & \cdots & \boldsymbol{P}_C^{nn} \end{bmatrix} \end{array} \tag{B.1}$$

Where D_n is the nth cluster; c_{nm} is the mth criterion in the nth dimension; and $\boldsymbol{P}_C^{ij}$ is a submatrix of the influence relation by the criteria from a comparison of the ith dimension and the jth dimension. In addition, if the ith dimension has no influence on the jth dimension, then submatrix $\boldsymbol{P}_C^{ij} = [0]$, shows independence (no influence relation) in each criterion on other criterion.

Step 2. Form an un-weighted supermatrix $\boldsymbol{W}$. Normalize the total influence relation matrix $\boldsymbol{P}_C$ as shown in Eq. (B.2):

$$\boldsymbol{P}_C^{\alpha} = \begin{array}{c} \\ \boldsymbol{D}_1 \\ \\ \\ \boldsymbol{D}_i \\ \\ \\ \boldsymbol{D}_n \\ \\ \end{array} \begin{array}{c} \begin{array}{cccccc} \boldsymbol{D}_1 & & \cdots & \boldsymbol{D}_j & & \cdots \quad \boldsymbol{D}_n \\ c_{11}\ldots c_{1m_1} & & \cdots & c_{j1}\ldots c_{jm_j} & & \cdots \quad c_{n1}\ldots c_{nm_n} \end{array} \\ \begin{array}{c} c_{11} \\ c_{12} \\ \vdots \\ c_{1m_1} \\ c_{i1} \\ c_{i2} \\ \vdots \\ c_{im_i} \\ c_{n1} \\ c_{n2} \\ \vdots \\ c_{nm_n} \end{array} \begin{bmatrix} \boldsymbol{P}_C^{\alpha 11} & \cdots & \boldsymbol{P}_C^{\alpha 1j} & \cdots & \boldsymbol{P}_C^{\alpha 1n} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{P}_C^{\alpha i1} & \cdots & \boldsymbol{P}_C^{\alpha ij} & \cdots & \boldsymbol{P}_C^{\alpha in} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{P}_C^{\alpha n1} & \cdots & \boldsymbol{P}_C^{\alpha nj} & \cdots & \boldsymbol{P}_C^{\alpha nn} \end{bmatrix} \end{array} \tag{B.2}$$

Where $\boldsymbol{P}_C^{\alpha}$ represents the normalizing total influence relation matrix, and $\boldsymbol{P}_c^{\alpha 12}$ can be derived from Eqs. (B.3) and (B.4); and $\boldsymbol{P}_c^{\alpha nn}$ can be similarly obtained.

$$P_i^{12} = \sum_{j=1}^{m_2} P_{ij}^{12}, \quad i = 1, 2, \cdots, m_1 \tag{B.3}$$

$$\boldsymbol{P}_c^{\alpha 12} = \begin{bmatrix} p_{11}^{12}/p_1^{12} & \cdots & p_{1j}^{12}/p_1^{12} & \cdots & p_{1m_2}^{12}/p_1^{12} \\ \vdots & & \vdots & & \vdots \\ p_{i1}^{12}/p_i^{12} & \cdots & p_{ij}^{12}/p_i^{12} & \cdots & p_{im_2}^{12}/p_i^{12} \\ \vdots & & \vdots & & \vdots \\ p_{m_1 1}^{12}/p_{m_1}^{12} & \cdots & p_{m_1 j}^{12}/p_{m_1}^{12} & \cdots & p_{m_1 m_2}^{12}/p_{m_1}^{12} \end{bmatrix} = \begin{bmatrix} p_{11}^{\alpha 12} & \cdots & p_{1j}^{\alpha 12} & \cdots & p_{1m_2}^{\alpha 12} \\ \vdots & & \vdots & & \vdots \\ p_{i1}^{\alpha 12} & \cdots & p_{ij}^{\alpha 12} & \cdots & p_{im_2}^{\alpha 12} \\ \vdots & & \vdots & & \vdots \\ p_{m_1 1}^{\alpha 12} & \cdots & p_{m_1 j}^{\alpha 12} & \cdots & p_{m_1 m_2}^{\alpha 12} \end{bmatrix} \tag{B.4}$$

Based on the pairwise comparisons within the criteria, and the basic concept of ANP, the un-weighted supermatrix W can be constructed by transposing the normalized influence-relation matrix $\boldsymbol{P}_C^{\alpha}$ by dimensions (or cluster), i.e. $\boldsymbol{W} = (\boldsymbol{P}_C^{\alpha})'$, as shown in Eq. (B.5).

$$\boldsymbol{W}=(\boldsymbol{P}_C^{\alpha})'=\begin{array}{c} \\ D_1\ c_{11},c_{12},\cdots,c_{1m_1} \\ \vdots \\ D_j\ c_{j1},c_{j2},\cdots,c_{jm_j} \\ \vdots \\ D_n\ c_{n1},c_{n2},\cdots,c_{nm_n} \end{array}\begin{array}{c} \begin{array}{cccccc} D_1 & & D_i & & D_n \\ c_{11}\cdots c_{1m_1} & \cdots & c_{i1}\cdots c_{im_i} & \cdots & c_{n1}\cdots c_{nm_n} \end{array} \\ \begin{bmatrix} \boldsymbol{W}^{11} & \cdots & \boldsymbol{W}^{i1} & \cdots & \boldsymbol{W}^{n1} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{W}^{1j} & \cdots & \boldsymbol{W}^{ij} & \cdots & \boldsymbol{W}^{nj} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{W}^{1n} & \cdots & \boldsymbol{W}^{in} & \cdots & \boldsymbol{W}^{nn} \end{bmatrix} \end{array} \tag{B.5}$$

Step 3. Derived the weighted supermatrix $\boldsymbol{W}^{\alpha}$. The total influence-relation matrix $\boldsymbol{P}_D$ of dimensions is obtained according to the DEMATEL method, as given by Eq. (B.6):

$$\boldsymbol{P}_D=\begin{bmatrix} p_D^{11} & \cdots & p_D^{1j} & \cdots & p_D^{1n} \\ \vdots & & \vdots & & \vdots \\ p_D^{i1} & \cdots & p_D^{ij} & \cdots & p_D^{in} \\ \vdots & & \vdots & & \vdots \\ p_D^{n1} & \cdots & p_D^{nj} & \cdots & p_D^{nn} \end{bmatrix} \tag{B.6}$$

The normalized total influence-relation matrix $\boldsymbol{P}_D^{\alpha}$ of dimensions can be derived from the total influence-relation matrix $\boldsymbol{P}_D$ divided by $\sum_{j=1}^{n} p^{ij}=p^{i}, i=1,2,\cdots,n.$, as shown in Eq. (B.7).

$$\boldsymbol{P}_D^{\alpha}=\begin{bmatrix} p_D^{11}/p_1 & \cdots & p_D^{1j}/p_1 & \cdots & p_D^{1n}/p_1 \\ \vdots & & \vdots & & \vdots \\ p_D^{i1}/p_i & \cdots & p_D^{ij}/p_i & \cdots & p_D^{in}/p_i \\ \vdots & & \vdots & & \vdots \\ p_D^{n1}/p_n & \cdots & p_D^{nj}/p_n & \cdots & p_D^{nm}/p_n \end{bmatrix}=\begin{bmatrix} p_D^{\alpha 11} & \cdots & p_D^{\alpha 1j} & \cdots & p_D^{\alpha 1n} \\ \vdots & & \vdots & & \vdots \\ p_D^{\alpha i1} & \cdots & p_D^{\alpha ij} & \cdots & p_D^{\alpha in} \\ \vdots & & \vdots & & \vdots \\ p_D^{\alpha n1} & \cdots & p_D^{\alpha nj} & \cdots & p_D^{\alpha nn} \end{bmatrix} \tag{B.7}$$

The normalized $\boldsymbol{P}_D^{\alpha}$ and the un-weighted supermatrix $\boldsymbol{W}$ (shown as Eq. (B.5)), and the weighted supermatrix $\boldsymbol{W}^{\alpha}$ (normalized supermatrix) can be easily obtained by Eq. (B.8).

$$\boldsymbol{W}^{\alpha}=\boldsymbol{P}_D^{\alpha}\times\boldsymbol{W}=\begin{bmatrix} p_D^{\alpha 11}\times\boldsymbol{W}^{11} & \cdots & p_D^{\alpha i1}\times\boldsymbol{W}^{i1} & \cdots & p_D^{\alpha n1}\times\boldsymbol{W}^{n1} \\ \vdots & & \vdots & & \vdots \\ p_D^{\alpha 1j}\times\boldsymbol{W}^{1j} & \cdots & p_D^{\alpha ij}\times\boldsymbol{W}^{ij} & \cdots & p_D^{\alpha nj}\times\boldsymbol{W}^{nj} \\ \vdots & & \vdots & & \vdots \\ p_D^{\alpha 1n}\times\boldsymbol{W}^{1n} & \cdots & p_D^{\alpha in}\times\boldsymbol{W}^{in} & \cdots & p_D^{\alpha nn}\times\boldsymbol{W}^{nn} \end{bmatrix} \tag{B.8}$$

Step 4. Calculate the limit supermatrix $\boldsymbol{W}^{\alpha}$. Limit the weighted supermatrix by raising it to the kth power, until the supermatrix has converged and become a stable supermatrix. The global priority vectors are derived, which are known as the DANP influential weights, such as $\lim_{h\to\infty}(\boldsymbol{W}^{\alpha})^{h}$, where h represents any number of power.

Appendix C: Measuring the satisfaction performance by modified VIKOR

The modified VIKOR method steps are described as follows:

Step 1. Determine the positive-ideal solution and negative-ideal solution and replace aspiration levels and worst value to adapt the current world situation. The aspiration level of *j* criterion is defined as f_j^{aspire} and the worst value f_j^{worst} for all criteria, which can be derived from the traditional form to the modified form.

(1) Export the positive-ideal solution and negative-ideal solution from traditional approach are as follows.

Positive-ideal solution: $\boldsymbol{f}^{*}=(f_1^{*},...,f_j^{*},...,f_n^{*})$, where $f_j^{*}=\max_k\{f_{kj}\,|\,k=1,2,...,m\}$;

Negative-ideal solution: $\boldsymbol{f}^{-}=(f_1^{-},...,f_j^{-},...,f_n^{-})$, where $f_j^{-}=\min_k\{f_{kj}\,|\,k=1,2,...,m\}$.

(2) The modified method for replacement by "aspiration level" and "worst value", that is:

Aspiration level: $\boldsymbol{f}^{aspire}=(f_1^{aspire},...,f_j^{aspire},...,f_n^{aspire})$, where f_j^{aspire} is an aspiration level (or call "best value");

Worst values: $\boldsymbol{f}^{worst}=(f_1^{worst},...,f_j^{worst},...,f_n^{worst})$, where f_j^{worst} is a worst value.

In this research, the satisfaction performance scores from 0 to 10 (very dissatisfaction ←0,1,2,...,9,10→very high satisfaction) are used natural language in the linguistic/semantic questionnaire, therefore, "aspiration level" takes the highest score of 10 and "worst value" takes the lowest value of 0. Hence, $f_j^{aspire}=10$ is defined as "aspiration level" and $f_j^{worst}=0$ as "worst value", it can avoid choosing the best among inferior choices/options/alternatives. In other words, this method can be avoided "picking the best apple from a barrel of rotten apples".

Step 2. Calculate the mean regret group utility S_k gap and the maximal gap Q_k to prioritize improvement. These values can be exported using Eqs. (C.1) and (C.2), respectively:

$$S_k=\sum_{j=1}^{n}w_j r_{kj}=\sum_{j=1}^{n}w_j\left(|f_j^{aspire}-f_{kj}|\right)/\left(|f_j^{aspire}-f_j^{worst}|\right) \tag{C.1}$$

$$Q_k=\max_j\{(|f_j^{aspire}-f_{kj}|)/(|f_j^{aspire}-f_j^{worst}|)\,|\,j=1,2,...,n\} \tag{C.2}$$

Where S_k is defined as the normalized ratio of distance to "aspiration level", and implies the synthesized gap of the criteria, and Q_k is defined as the normalized ratio of distance to "worst value", which implies the maximum gap in j criteria, and should be a priority improvement. The w_j represents the influential weights of the criteria and derived from DANP, and the r_{kj} represents the normalized gap of the distance to "aspiration level".

Step 3. Obtain the comprehensive performance criteria and rank the results. The values can be calculated by using Eq. (C.3):

$$R_k=v(S_k-S^{*})/(S^{-}-S^{*})+(1-v)(Q_k-Q^{*})/(Q^{-}-Q^{*}) \tag{C.3}$$

Where $S^{*}=\min_k S_k$, $S^{-}=\max_k S_k$, $Q^{*}=\min_k Q_k$, $Q^{-}=\max_k Q_k$ and $0\le v\le 1$, where v represents the weight of the maximum group utility strategy, and 1-v denotes the individual regret weight (maximum gap for priority improvement).

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A hybrid Multiple Criteria Decision-Making model of sustainability performance evaluation for Taiwanese Certified Public Accountant Firms

Highlights

- Proposed a hybrid MCDM model to evaluate the CPA firms' sustainability performance.
- Used DEMATEL to illustrate the influential network among the evaluation criteria.
- Used DANP to provide a common set of weights of evaluation criteria.
- Used modified VIKOR to indicate the sustainability performance gap for Taiwanese CPA firms.
- Client Orientation may be a right strategy for Taiwanese CPA firms.