Strengthen Financial Holding Companies' Business Sustainability by Using a Hybrid Corporate Governance Evaluation Model

Jim-Yuh Huang [1], **Kao-Yi Shen** [2,*], **Joseph C.P. Shieh** [3], and **Gwo-Hshiung Tzeng** [4]

[1] Graduate Institute of Management, National Taiwan University of Science and Technology, Taipei 10607, Taiwan; d10216009@mail.ntust.edu.tw
[2] Department of Banking & Finance, Chinese Culture University, Taipei 11114, Taiwan; atrategy@gmail.com
[3] Graduate Institute of Finance, National Taiwan University of Science and Technology, Taipei 10607, Taiwan; jshieh@mail.ntust.edu.tw
[4] Graduate Institute of Urban Planning, National Taipei University, New Taipei City 23741, Taiwan; ghtzeng@gm.ntpu.edu.tw

* Correspondence: atrategy@gmail.com; Tel.: +886-2-2700-5858 ext. 8676

Abstract: While the importance of corporate governance has been broadly acknowledged in global financial markets and academic research, how to devise a practical evaluation system is relatively unexplored. This paper attempts to refine the Corporate Governance Evaluation System (CGES), constructed by the Taiwan Stock Exchange (TWSE) since 2014. The current CGES has several debatable issues in its complicated design (e.g., it comprises over 80 indicators in different types). To resolve those issues, this study invited ten senior domain experts (including several CEOs of financial holding companies) to retrieve 13 essential criteria from the CGES in four dimensions. And this study integrates several multiple criteria decision-making (MCDM) methods (i.e., Decision-making trial and evaluation laboratory (DEMATEL), modified VIKOR, DEMATEL-based analytical network process (DANP)) and the fuzzy evaluation technique to rank the exemplary companies. The obtained ranking is consistent with the one released from the CGES in 2017. This study conducted additional experiments to ensure the robustness of the findings. The newly devised model not only supports the ranking decisions but also provides a managerial guidance for companies to pursue systematic improvements. These findings enrich the understanding of corporate governance and contribute to gaining business sustainability for financial holding companies.

Keywords: Corporate governance; Business sustainability; Multiple criteria decision-making (MCDM); Decision-making trial and evaluation laboratory (DEMATEL); VIKOR; DEMATEL-based analytical network process (DANP); Fuzzy set theory

1. Introduction

The first extensive survey of corporate governance might be the one conducted by Shleifer and Vishny in 1997 [1]. They stated that: "Corporate governance deals with the ways in which suppliers of finance to corporations assure themselves of getting a return on their investment." [1]. Academic research regarding this issue has surged significantly over the past several decades. Corporate governance received special attention during the financial crisis in emerging markets since 1998 [2]. Afterwards, a series of business scandals in the US and the EU took place in the early 21st century, which rendered corporate governance to become the focus of public attention again. The recent financial crisis (2008-2009) further enforced regulators, in the major financial markets, to renovate and devise new guidelines to strengthen corporate governance in multiple aspects; its impact on the global financial systems is apparent.

Due to the importance of corporate governance, several mainstream research topics have emerged related to this critical subject. Examples are the relationship between corporate governance and shareholders' rights [3], equal treatment of shareholders [4], the role of stakeholders [5], information disclosure [6], the relation between transparency and valuation [7-8], corporate social responsibility (CSR) [9], and the influence of corporate governance on business performance [10].

The Taiwan Stock Exchange (TWSE) was aware of its crucial role and established a Corporate Governance Evaluation System (CGES) since 2014 [11], to facilitate the understanding and objective evaluations of the listed companies regarding corporate governance. The key purposes of CGES are twofold: (1) support the listed companies to identify their shortcomings and conduct the associated improvements and (2) increase outside investors' confidence. To be more specific, the evaluation system's objectives are to forming the culture of pursuing superior corporate governance among management teams and board members, guiding the sustainable business developments of companies, complying with international standards, and thus improving the Taiwan stock market's overall efficiency and reputation.

The CGES of Taiwan has attained remarkable results since its debut in 2014. The listed companies refer to various indicators of the CGES to undertake required actions, and the overall awareness of corporate governance—from board members to management teams—has increased significantly ever since. For example, in the dimension of protecting shareholders' rights and interests, the listed companies that chose the case-by-case vote approach has grown 44% in the past three years (i.e., from 2015 to 2017). The companies that adopted the candidate nomination mechanism to elect all directors and supervisors also increased by 67% until 2017.

In the dimension of enhancing board composition and operation, the proportion of listed companies that have set up audit committees to comply with the TSE's regulations has reached 45%. Also, the companies that have compiled corporate social responsibility (CSR) reports have also grown year by year, and the number of CSR reports issued has reached 439 in 2017 [11]. All the aforementioned outcomes suggest that most of the listed companies have shown their willingness and made tangible efforts to pursue corporate governance. The CGES has paved a solid ground for the listed companies to move ahead.

The framework of the CGES referred six principles of corporate governance released by the Organization for Economic Co-operation and Development (OECD) in 2004 [12]. The TWSE's current evaluation framework comprises four major dimensions: (1) Protecting shareholder rights and interests and treating shareholders equitably, (2) Enhancing board composition and operation, (3) Increasing information transparency, and (4) Putting CSR into practice. The included number of indicators (or termed as criteria in this study) reached up to 85 in the four dimensions. The TWSE assigned a different weighting for each dimension, and the total weights sum up to 100% from the four dimensions. Its hierarchical framework that considers multiple aspects is in line with commonly observed multiple criteria decision-making (MCDM) problems; thus, the present study attempts to explore the rationality and fairness of its design of (i.e., the CGES) from the MCDM perspective.

Although the 85 indicators seem to cover a wide spectrum of measures, the system's design is complicated and inconsistent in its hierarchical design. The TWSE defined five types of indicators, namely A, B, AA, A+, and the EXTRA ones (see **Table 1**). Type A applies for all the listed companies where type B only applies to certain industries. Most of the indicators (i.e., types A and B) are to be gauged and assigned as either "yes (1)" or "no (0)," a binary approach to determine a company's performance outcome on a single indicator. If an indicator can meet the requirement, the system will assign one point for it; zero otherwise.

However, for some other indicators (i.e., types AA and A+), the scoring mechanism is different. If additional requirements are satisfied, not only one credit will be awarded for the AA or A+ indicator within its dimension, but also another credit will be added to the company's overall evaluation. The EXTRA type has two indicators, which can contribute or penalize indefinite scores (e.g., +3 or -5) directly to a company's final evaluation result. The two EXTRA indicators would cause heterogeneous impacts to a company's overall evaluation, which is not included in the four dimensions. Its evaluation

system seems to be an inadequate design from the perspective of MCDM modeling. The detail numbers of the TWSE's 2017 corporate governance evaluation dimensions and weightings, the number of indicators and the associated types of indicators of each dimension, are reported in **Table 1**.

Table 1. Dimensions and Associated Indicators of the CGES in 2017.

Dimensions	Number of each type of indicator			Number of indicators	Weighting (%)
	A & B	AA	A+		
Protecting shareholder rights and interests and treating shareholders equitably (D_1)	15	1	1	17	20
Enhancing board composition and operation (D_2)	26	1	3	30	35
Increasing information transparency (D_3)	15	2	3	20	24
Putting CSR into practice (D_4)	14	2	2	18	21
Total	70	6	9	85	100
EXTRA Plus	--	--	--	1	--
EXTRA Minus	--	--	--	1	--

(Source: http://cgc.twse.com.tw/frontEN/index)

As mentioned earlier, the CGES exhibits the mission to lead those public listed companies to pursue superior corporate governance, which intends to encourage those front runners and exhort those who are lagging. Therefore, its scoring mechanism should be scrutinized to ensure this goal. The framework of the current CGES (the 2017 version), as shown in **Table 1**, has at least four issues that deserve a second thought:

(1) The weighting of each dimension seems to have a direct tie with the number of indicators, which might contort the relative importance of each dimension (e.g., in the first dimension, the number of indicators is 17, and $17/85 = 20\%$ reflects its weighting);

(2) The "yes (1)" or "no (0)" approach to judge the performance of a company on an indicator would be difficult for experts to express their opinions that consider the different degree or level of satisfaction;

(3) The additional credit brought by a type AA or A+ indicator to the final score (i.e., not just within a dimension) might distort the actual performance of a company compared with the other ones;

(4) The two EXTRA indicators that do not belong to the four dimensions are lack of a clear guidance to assign objective scores, and the extra plus indicator might even cause the aggregated score to overpass 100%.

In addition, the CGES model adopts the additive type aggregation approach, which presumes the independence among the dimensions; it seems to be unlikely. For example, the 3rd dimension (increasing information transparency) should have relation with the first dimension (protecting shareholder rights and interests and treating shareholders equitably). As a result, an evaluation system that can model the interdependence or mutual influence relationship among the dimensions would be more realistic in practice.

Thus, this study attempts to propose a hybrid approach, based on the modeling concept of MCDM, to resolve the mentioned issues above. In the first step, we attempt to distill from the existing 87 (i.e., 85 + 2 EXTRA) indicators, to identify the key factors to forming a concise corporate governance evaluation model. This step may simplify the CGES, which will be helpful to support decision makers (DMs) focusing on manageable numbers of indicators (criteria). According to the renowned theory—bounded rationality—proposed by the Nobel Laureate Herbert A. Simon [13], DMs would encounter obstacles to make rational judgments while overwhelmed by too many factors. With the help of experienced domain experts on corporate governance, the present study adopts the Delphi method [14] to eliminate the unnecessary or redundant indicators in each dimension.

In the next step, the decision-making trial and evaluation laboratory (DEMATEL) is adopted to decompose the influential relations among the dimensions; the assumption or limitation of the

independence among the dimensions can thus be removed. The DEMATEL technique was proposed to model complex social problems [15], which presumes that every factor or criterion in a system has more or less influence on the others. The DEMATEL technique also has the capability to analyze the directional influence between dimensions (or criteria), which is often applied to identify the root cause of an under-performed criterion for conducting systematic improvements. This technique has been widely applied in many fields, ranging from social science [16] to engineering [17], to pursue sustainability in various applications [18].

In the third step, based on the distilled criteria from the 87 indicators from the first step, we propose a hybrid MCDM approach to explore the relative influence of each criterion, and the consensus of the aggregated influence of each criterion within a dimension, from the knowledge of domain experts, can be reached. This step intends to overcome the previously mentioned issue of how to determine the weighting of each dimension, which should not be solely depended on the number of indicators of a dimension. The hybrid approach applies the DEMATEL technique and the concept of the renowned analytic network process (ANP) [19], to identify the influential weight of each indicator, termed as DANP [20]. And the modified VIKOR [21-22], is integrated with the DANP influential weight of each indicator/criterion, to form a novel corporate governance evaluation system. Unlike the conventional simple additive weighting (SAW) aggregation, the modified VIKOR has the advantage to underline the highest weighted performance gap of a company. The identified gap can be cross-referenced with the cause-effect influences from the DEMATEL analytics, which can serve for systematic improvements.

In the present study, considering the critical role of financial holding companies to the stability of economy, three Taiwanese financial holding companies are to be examined by the proposed approach. During the evaluation phase, it applies the fuzzy measurement technique, which enable experts to denote their linguistic opinions, which is more intuitive. By doing so, we may avoid the problematic "Yes (1)" or "No (0)" scoring approach applied by the CGES; instead, the degree of satisfaction can be expressed. The hybrid approach plays an active role that aims at guiding financial holding companies to pursue continuous and systematic improvements regarding corporate governance. We manage to benchmark the ranking from the CGES for comparison. Also, an exemplary case will be illustrated to discuss the plausible improvements, for the long-term business sustainability, of a financial holding company in Taiwan.

Thus, five major contributions can be expected: (1) Simplify the complicated and debated CGES model constructed by the TWSE; (2) Identify the critical factors regarding the evaluation of corporate governance; (3) Explore the interrelations among the included criteria by devising a hybrid MCDM model based on domain experts' knowledge and circumspect judgments; (4) Evaluate the performance of corporate governance of three sample financial holding companies and compare our finding with the outcome of the CGES; and (5) Support financial holding companies to pursue business sustainability by a systematic improvement guidance.

The remainder of the study is organized as follows: In Section 2, this study reviews the major related studies of corporate governance. Also, certain MCDM methodologies applied in this model are briefly introduced. In Section 3, it proposes a hybrid MCDM approach model and evaluate corporate governance. Section 4 provides an empirical example, ranking three financial holding companies in Taiwan and comparing the result with the one from the CGES. Section 5 discusses the interrelationships among the assessed dimensions and criteria of the obtained evaluation model and provides management implications on business sustainability with concluding remarks.

2. Literature Review

This section discusses the major research topics related to corporate governance (subsection 2.1) and its impacts to the financial and banking industries (subsection 2.2). Also, the limitations of commonly adopted research methods (i.e., statistics) regarding corporate governance are briefly explained in subsection 2.3, which leads to the reasons of why the concept of MCDM methodology should be more suitable to devise a system comparing with the statistical approach.

2.1 Mainstream research topics of corporate governance

Because the serious repercussions caused by corporate scandals and failures, such as those from the Enron and Worldcom [23], most countries with an open economy have become wary of corporate governance ever since. The potential consequences of impotent corporate governance, especially in the banking and financial sector, would even cause financial crises, impede the sustainability of vulnerable companies during a drastic market downturn. The mainstream research on the corporate governance can be roughly categorized in the following topics: (1) ownership structure, (2) board of directors, (3) CEO compensation, (4) managerial style, (5) agency problem, (6) enterprise risk management, (7) accounting and auditing, (8) company performance, and (9) CSR.

The ownership structure of banks matters significantly in their corporate governance; large owners with substantial cash flows have the tendency and capability to influence bank managers to take high-risk investments [24]. Some studies have found that controlling (voting) rights and cash flow rights affect company performance [25]. While there is a large gap between cash flow and voting rights, controlling shareholders tend to manipulate the business through a poor operating model, which may increase the possibility of insolvency [26]. Anderson and Fraser [27] showed that controlling shareholder participation in bank management has a significant impact on total risk and company-specific risk, which is detrimental to company performance. In China, however, family involvement management has had a positive impact on business performance due to family support for long-term goals [28]. The above-mentioned studies though took samples in different regions, suggested that ownership structure plays an influential role in mangers on risk-taking activities, which deserves special attention for the financial and banking industry.

Kiel and Nicholson [29] found that the board size is positively correlated with company value and the composition of the board impacts company performance. Also, by examining the Australian market, they found that a stronger board and supervisory committee correspond to a higher level of corporate governance. Brenes et al. [30] stated that family and non-family board members have different functions and each contributes in disparate ways to improving company performance. Klein [31] believes that the separation of the roles of CEO and board chairman can enhance effective monitoring of management practices. Chiou et al. [32] suggested a negative correlation between the proportion of collateralized shares and the company's operating performance. If directors and supervisors use stocks as collateral to get funding for personal usage, while their stock prices fall, the companies will suffer from declining corporate value and rising business risk. Research done by Musteen et al. [33] showed that board characteristics significantly influence the business community's assessment of corporate reputation. The potential impact caused by different compositions of the board seems to be highly influential on corporate governance, suggested by the previous research.

The managerial style is also an interesting topic in corporate governance research. Corporate leaders' ethics may affect corporate governance mechanisms and corporate governance performance. The characteristics of a CEO can lead to good employee behavior, such as obeying the law and conducting ethical behavior [34]. The recent turbulence caused by the founder of Tesla is a fresh example of how reckless announcements from the CEO might hurt the value of a world-class company. The honesty and ethics of senior management can also enhance a company's reputation and valuation; effective corporate governance mechanisms need to gain strong support from senior management [35]. Campbell et al. [36] shown that a confident CEO can create value to shareholders, but over-confident behavior, such as unthoughtful investment, often jeopardize the value of a company. Therefore, managerial style should be taken into consideration for devising a monitoring and controlling mechanism, to pursue superior corporate governance.

The agency problem is a well-known management issue, which partially explains the importance of corporate governance to shareholders and potential investors [37]. Previous studies have focused on how executive compensation plans can help mitigate agency problems for listed companies. However, with executive compensation, it must be recognized that the design of compensation arrangements is also a part of the agency problem [38]. Controlling owners often rig a company through pyramid control structures and cross-shareholdings. These ownership structures create a series of agency

problems for a gigantic company, which might lead to resource misallocation. In terms of macroeconomics, inferior corporate governance—while the agency problem exists—would affect the rate of innovation, resource allocation, and economic growth. Nontransparent business operations and the complexity of the capital structure of banks deserve special attention from the authority [39].

Claimed by McCrae & Balthazor [40], effective risk management can enhance a company's competitive advantage and improve its corporate governance. Companies that embrace risker business strategies or investments might mislead uninformed investors or shareholders. Thus, stated principles should be implemented and integrated into the operations of a company [41]. In the previous financial crises, both banks and investors had suffered from the illusion of "too-big-to-fail" of those gigantic financial institutions, suggested by the findings of Anginer et al. [42] highlighted the importance of a financial safety net, and regulations should be enforced to secure effective risk management, especially for the banking sector.

Accounting and auditing are essential for companies to communicate with their stakeholders [43]. However, creditable auditing is not always available. A previous study mentioned that the Big Four accounting firms often provide unqualified auditing opinions on the financial statements of those problematic financial companies [44]. It is worth noting that improving a company's accounting and auditing system is the main mechanism to strengthen its corporate governance. Bushman and Smith [45] claimed unveiling consistent and reliable financial accounting information can improve the effectiveness of corporate governance and reduce the likelihood of a company getting into insolvency. Superior disclosure systems can increase the transparency of a company; in this regard, its costs of capital can be further reduced.

The topic of performance is probably the most widely discussed consequence of good or bad corporate governance [46]. Previous studies found that corporate governance has a strong correlation with stock returns, companies with stronger (superior) shareholder rights earn higher company value, higher sales growth rates, higher profit margins, lower capital expenditures, and fewer chances to be acquired. [47].

Until recently, the relationship between corporate performance and CSR also gains increasing interests. Investors inclined to support those companies with a high awareness of CSR, which implies the effectiveness of increasing company value or enhancing corporate performance by devoting CSR actions [48]. To conclude, most of the research in different continents corroborated the positive influence of corporate governance or CSR on improving performance [49].

Table 2. Corporate research topics and the associated CGES dimensions.

Dimensions	Associated Research Topics
Protecting shareholder rights and interests and treating shareholders equitably (D_1)	Agency problem, Managerial style Enterprise risk management
Enhancing board composition and operation (D_2)	Agency problem, Ownership structure Board of directors, Managerial style
Increasing information transparency (D_3)	Agency problem, Accounting and auditing
Putting CSR into practice (D_4)	Company performance and CSR

To summarize, the above-discussed topics related to the four dimensions of the CGES directly or indirectly; some research topics could be associated with even over one aspect. **Table 2** illustrates the corresponding topics in each CGES dimension. In other words, the CGES has taken the major influential topics of corporate governance in its design.

2.2 Impacts of corporate governance to financial institutions

Though corporate governance applies to all kinds of businesses, financial institutions have been under increasing pressure, from investors to regulators, to scrutinize and improve their corporate governance in the long run, owing to their high impacts to the stability of a nation's economy [50]. Due to the relevance of financial institutions in the economic system and the nature of the business of

financial institutions, the issues involved in corporate governance of financial institutions are complicated, as is the mechanism for dealing with such issues.

The complexity of a financial institution's business increases the asymmetry of information and undermines the ability of stakeholders to monitor a financial institution managers' decisions effectively. Besides, financial institutions are usually highly leveraged companies, a significant portion of their assets often comes from customer deposits and insurance premiums. Consequently, financial institutions are subject to stricter regulations than other companies, owing to the facts they are responsible for protecting depositors and investors, ensuring the stability of payment and trading systems, and reducing the systemic risk of financial markets [51].

Financial institutions with inadequate management and supervision not only hurt their own values but also have various negative influences on the markets during financial crises [52]. Thus, regulators should pay special attention to monitor the adoption and compliance of corporate governance of those financial and banking companies [53]. Although the CGES has been introduced in Taiwan since 2014, its effectiveness and capability to supervise and guide those listed financial companies are still debatable, owing to its complicated and somewhat inconsistent design (refer those issues underscored below **Table 1**). A well-devised and comprehensible evaluation system or model that can reveal the status of corporate governance of financial institutions is critical to increasing the financial market's confidence, which is also the reason why we chose this industry as the main theme to illustrate the proposed approach.

2.3 MCDM methods adopted in this corporate governance evaluation model

There are two types of commonly adopted research methodologies to examine corporate governance. On one hand, research methods used in the previous works that explored various issues of corporate governance (refer **Table 2**) are mainly based on statistics. On the other hand, while devising a corporate governance evaluation model (system), their frameworks are usually hierarchical, such as the one from the OECD and the CGES of the TWSE.

The conventional statistical models are constrained by certain unrealistic assumptions. For instance, the most commonly used regression model is based on the assumption that all the considered variables (factors) are independent, which seems to be unrealistic. Furthermore, most statistical methods required to presume the probabilistic distribution of a model. It is also unconvincing in practice.

The present study belongs to the second type that attempts to improve the design of CGES, by proposing a hybrid MCDM model. The existing CGES, as discussed in Section 1, has a two-layer structure with four dimensions and 87 indicators, which is close to the typical framework of MCDM research. Only a few studies (e.g., the one by Hu et al. [54]) have adopted the MCDM approach to analyzing the evaluation of corporate governance during financial crises. Until so far, we have found no academic research that focuses on refining an existing official corporate governance model designed by the authority, which would be the unique contribution of this study.

In this work, there are several adopted research methods, and each of them plays a different role. First, the Delphi method, introduced by the Rand company [14], is applied to refine the CGES by soliciting domain experts' opinions to eliminate unnecessary or redundant indicators. This method plays the role of refining the indicators of the CGES, and the process might require several rounds of anonymous voting to reach the consensus.

Second, the Decision-Making and Trial Evaluation Laboratory (DEMATEL) technique has the capability to analyze cause-effect influence among the dimensions of a system, which was proposed to model complicated social problems. The DEMATEL technique was developed by the Battelle Memorial Institute at Geneva for the Science and Human Affairs Program in the early 1970s, which received surging interest from researchers in the past decade [20]. This technology helps decision makers explore the interrelationships among the dimensions or criteria, which also helps identify the directional influences of an MCDM model [55-57].

Third, inspired by the concept of the ANP method, the DEMATEL technique can be transformed into a weighting system, which was proposed by Prof. Tzeng's research team, termed as the DEMATEL-based ANP (DANP) [20]. The DANP method requires experts' opinions to calculate the influential weight of each criterion, and the details will be explained in Section 3.

Fourth, after forming a corporate governance evaluation model by the DNAP method, the influential weight of each criterion needs to be aggregated to obtain the final performance score. Also, during the evaluation phase before the final aggregation, the performance of each financial holding company on each criterion will be graded by experts using the fuzzy technique [58], which is more intuitive and closer to how human beings make judgments. Though there are several common aggregation methods, this study adopts the modified VIKOR, which has the advantage of ranking and selecting among a set of alternatives in the presence of conflict criteria [22]. The modified-VIKOR adopted the aspired level to replace the best performance of the alternatives on each criterion from the original VIKOR, to derive a compromised outcome.

Integrating of the DANP and the modified VIKOR not only supports the ranking of alternatives but also highlights the priority of performance gaps of alternatives [59]. Even the best alternative may pursue continuous improvements by focusing on the performance gaps in an orderly manner. The details will be illustrated in Section 4 with explanations and discussions. The proposed hybrid model can be regarded as a managerial tool for board members to plan for improvement directions.

3. Combined VIKOR-DANP Decision Model for Corporate Governance Evaluation

This section introduces the conceptual framework and proposes a hybrid approach to evaluate the performance of the corporate governance of companies, including the DEMATEL technique, the DANP, and the modified VIKOR methods. Also, the fuzzy set technique, proposed by Zadeh [58] is adopted to transform domain experts' verbal expressions for modeling the impreciseness of their opinions. To construct a hybrid evaluation model for assessing corporate governance comprises four phases as follows.

In the first phase, as a typical MCDM problem, we have to identify the most relevant dimensions and the associated criteria for forming the framework of an evaluation model. In the present study, we attempt to leverage the existing CGES (devised by the TWSE) and redefine the critical criteria related to each dimension (refer to **Tables 1** and **2**) by the Delphi method. The involved procedures will be further explained in Section 4, and the invited experts all have over 30 years' experience in this domain.

In the next phase, the obtained criteria from the first stage are analyzed to explore the degree of influence of each dimension (criterion) on the other dimensions (criteria). These obtained criteria are applied to form a DEMATEL questionnaire to soliciting domain experts' opinions. The obtained and averaged opinions from domain experts, forming an initial average matrix $\boldsymbol{A}$ (refer to Eq. (1)), is used to conduct a cause-effect analysis. The outcome of the DEMATEL analytics can be further processed to derive the weight of each criterion by the DANP method. In this phase, the influential weight of each dimension and criteria of the new corporate governance evaluation model can be determined. The mathematical formulae, from the DEMATEL to the DANP, are explained in subsection 3.2.

The third phase involves two steps: (1) Evaluate sample companies' performance on each criterion and (2) Aggregate the final score of each company by using the modified VIKOR method. The first step requires experts to define their verbal (semantic) expressions in the form of the fuzzy triangular membership function, one of the most widely applied fuzzy membership functions. The second step integrates the DANP influential weights with the evaluated companies' performance scores from the first step, to determine the final ranking result.

The fourth phase puts emphasis on pursuing business sustainability, by identifying the weighted performance gaps of a company on corporate governance. Since a company has only limited resources to pursue improvements, the identified performance gaps from the third step can be combined with the analytics from the DEMATEL technique, to devise a systematic improvement plan.

The hybrid approach can calculate the weighted performance gaps to the aspiration levels using the modified VIKOR method, also termed as the "aspired-worst" approach, as benchmarks. The four

phrases are explained in the following subsections 3.1 to 3.4 respectively. The conceptual research flows are shown in **Figure. 1**, and an exemplary case with three financial holding companies in Taiwan are analyzed and illustrated for the proposed hybrid MCDM model.

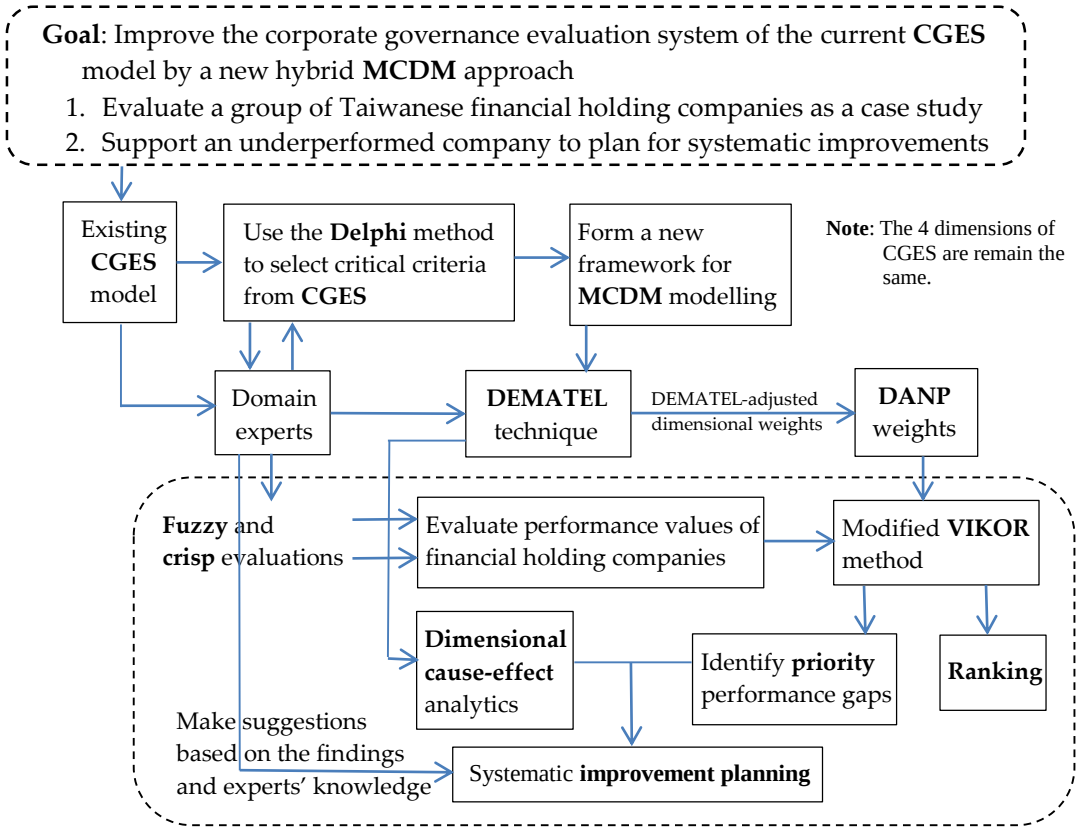

Figure. 1 Illustration of the research flows

3.1. Delphi method

The Delphi method was proposed by the Rand company in the early 1960s [60], to resolve the issue of different opinions from a group of experts, to reach a consensus anonymously. Though there are various approaches to conduct the Delphi method, the study adopts the threshold-based approach, by setting a consensus threshold to select the relatively important factors (indicators) from the existing evaluation system of the CGES. One thing that we have to report in here, those two EXTRA indicators will not be included.

In the beginning, each expert will be requested to fill in the importance of all the 85 indicators (exclude the two EXTRA ones, refer **Table 1**), ranging from 0 (Insignificant) to 10 (Very Important). By setting a threshold, the indicators that are above the threshold (after averaging the scores provided from all the experts) will be reserved for the next round. Since we merely intend to identify the candidates (indicators or criteria) in the first round, the indicators with diverse opinions will not be further investigated.

Similarly, in the second round, each expert provides their opinions about the importance of those selected indicators from the first round. Since the second round involves fewer indicators, if any arguable indicator exists (i.e., with diverse opinions regarding its importance from experts) will be reviewed by requesting the minority to express their reasoning that supports his or her opinion. Then, the minority's explanations will be provided to other experts to collect their opinions again. In this study, we presume to reserve 12~15 criteria for constructing an MCDM model in the next stage. The details will be provided in Section 4.

3.2. DEMATEL technique and DEMATEL-based ANP (DANP) method

The DEMATEL technique presumes that each criterion has influence to the other criteria of a system (or model), which is commonly observed in a social problem. The required computational steps are as follows [20].

Step 1 : Form an intial influence matrix $\boldsymbol{A}$

The initial influence matrix $\boldsymbol{A}$ can be obtained by asking experts questions such as: "What is the direct influence of criterion i on criterion j?" The influencial scale ranges from 4 (very high influence) to 0 (no influence), and the averaged influence of criterion i on criterion j can be denoted as a_{ij}. The other elements in $\boldsymbol{A}$ can be obtained follow the same logic (for $i, j = 1,...,n$ in $\boldsymbol{A}$), and the averaged influence adopts the arithmetic mean of all experts' feedbacks, shown in Eq. (1):

$$\boldsymbol{A} = \begin{bmatrix} a_{11} & \cdots & a_{1j} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ a_{i1} & \cdots & a_{ij} & \cdots & a_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nj} & \cdots & a_{nn} \end{bmatrix}_{n \times n} \tag{1}$$

The matrix $\boldsymbol{A}$ indicates the extent of how each criterion affects the other criteria and the degree of total influences received from the other criteria.

Step 2: Normalize $\boldsymbol{A}$ to form the matrix $\boldsymbol{D}$

The normalized initial direct influence-relation matrix $\boldsymbol{D}$ is transformed from the initial average matrix $\boldsymbol{A}$. By referring equations Eq. (2) and Eq. (3), the matrix $\boldsymbol{D}$ is obtained by multiplying η with $\boldsymbol{A}$, and all diagonal elements in $\boldsymbol{A}$ are equal to zero.

$$\boldsymbol{D} = \eta \boldsymbol{A} \tag{2}$$

$$\eta = \min\left\{ \frac{1}{\max_i \sum_{j=1}^{n} a_{ij}}, \frac{1}{\max_j \sum_{j=1}^{n} a_{ij}} \right\} \quad , \quad i, j \in \{1, 2, \cdots, n\} \tag{3}$$

Step 3: Transform $\boldsymbol{D}$ into a total influence relation matrix $\boldsymbol{T}$

To calculate the total influence-relation matrix $\boldsymbol{T}$ is similar to the concept of Markov Chain, which can be derived by summing up the matrices with increasing power of $\boldsymbol{D}$, as shown in Eq. (4).

$$\boldsymbol{T} = \boldsymbol{D} + \boldsymbol{D}^2 + ... + \boldsymbol{D}^{\varpi} = \boldsymbol{D}(\boldsymbol{I} - \boldsymbol{D}^{\psi})(\boldsymbol{I} - \boldsymbol{D})^{-1} \tag{4}$$

$$\boldsymbol{T}_{n \times n} = \boldsymbol{D} \times (\boldsymbol{I} - \boldsymbol{D})^{-1} = [t_{ij}]_{n \times n}, \text{ when } \psi \to \infty, \ \boldsymbol{D}^{\psi} \cong [0]_{n \times n} \tag{5}$$

While ψ increases to infinity, $\boldsymbol{D}^{\psi}$ will be very close to a null matrix with $n \times n$ elements, and matrix $\boldsymbol{T}$ can be obtained by referring Eq. (5).

Eq. (6) and Eq. (7) are used to obtain each row sum and column sum in the total influence-relation matrix $\boldsymbol{T}$, respectively. In here, the superscript $'$ denotes the transpose of a vector. Since in the matrix $\boldsymbol{T}$ is a square matrix, the total number of elements in each vector equals to n. Thus, the two column vectors in Eq. (6) and Eq. (7) can be used to calculate $\boldsymbol{r}^C + \boldsymbol{c}^C$ and $\boldsymbol{r}^C - \boldsymbol{c}^C$, where $\boldsymbol{r}^C - \boldsymbol{c}^C$ (for $i, j = 1,...,n$) may divide the involved criteria into two groups: the cause and the effect groups. If $r_i^C - c_i^C > 0$, then criterion i belong to the cause group; otherwise (e.g., $r_j^C - c_j^C < 0$), criterion j the effect group (i.e., receives a net influence from the other criteria).

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 December 2018 doi:10.20944/preprints201812.0146.v1

Peer-reviewed version available at Sustainability 2019, 11, 582; doi:10.3390/su11030582

$$\boldsymbol{r}^C = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} = \left(r_1^C, \cdots, r_i^C, \cdots, r_n^C\right)' \tag{6}$$

$$\boldsymbol{c}^C = \left[\sum_{i=1}^{n} t_{ij}\right]_{1\times n} = \left(c_1^C, \cdots, c_j^C, \cdots, c_n^C\right)' \tag{7}$$

Step 4: Transform the DEMATEL analytics into a DANP weighting system

Suppose that there are p dimensions and n criteria of a total influence-relation matrix $\boldsymbol{T}$; in this step, the matrix $\boldsymbol{T}$ can be shown as $\boldsymbol{T}_C^D$ to indicate the associated elements within each dimension in Eq. (8).

$$\boldsymbol{T}_C^D = \begin{array}{c} \\ \boldsymbol{D_1} \\ \vdots \\ \boldsymbol{D_i} \\ \vdots \\ \boldsymbol{D_p} \end{array} \begin{array}{c} \begin{array}{cccccc} \boldsymbol{D_1} & & \boldsymbol{D_j} & & \boldsymbol{D_p} \\ c_{11}\cdots c_{1m_1} & \cdots & c_{j1}\cdots c_{jm_j} & \cdots & c_{n1}\cdots c_{nm_n} \end{array} \\ \begin{bmatrix} \boldsymbol{T}_c^{D11} & \cdots & \boldsymbol{T}_c^{D1j} & \cdots & \boldsymbol{T}_c^{D1n} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{T}_c^{Di1} & \cdots & \boldsymbol{T}_c^{Dij} & \cdots & \boldsymbol{T}_c^{Din} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{T}_c^{Dn1} & \cdots & \boldsymbol{T}_c^{Dnj} & \cdots & \boldsymbol{T}_c^{Dnn} \end{bmatrix}_{\boldsymbol{n}\times\boldsymbol{n}} \end{array} \quad \text{for } 1 < i, j \le n \tag{8}$$

In the matrix $\boldsymbol{T}_C^D$, each $\boldsymbol{T}_c^{Dij}$ denotes a sub-dimensional matrix of $\boldsymbol{T}_C^D$ that associates with dimensions i and j. By averaging all the elements in each $\boldsymbol{T}_c^{Dij}$ $(1 < i, j \le n)$, the matrix $\boldsymbol{T}_C^D$ can be simplified to become a dimentioal influence matrix $\boldsymbol{T}^D$, referring Eq. (9). Take t_{11}^D for instance, which is the averaged result of all the elements of $\boldsymbol{T}_c^{D11}$ in $\boldsymbol{T}_C^D$. As a result, $\boldsymbol{r}^D = \left[\sum_{j_d=1}^{p} t_{i_d j_d}^D\right]_{p\times 1}$ and $d^D = \left[\sum_{i_d=1}^{p} t_{i_d j_d}^D\right]_{1\times p}$ for $i_d, j_d = 1, \ldots, p$ and $p < n$, which form two dimensional vectors (similar to Eqs. (6) and (7)).

$$\boldsymbol{T}^D = \begin{bmatrix} t_{11}^D & \cdots & t_{1p}^D \\ \vdots & \ddots & \vdots \\ t_{p1}^D & \cdots & t_{pp}^D \end{bmatrix}_{p\times p} \tag{9}$$

The dimentioal influence matrix $\boldsymbol{T}^D$ needs to be further normalized. Again, take the first row of $\boldsymbol{T}^D$ for example, all of the first row's elements in $\boldsymbol{T}^D$ should be divided by $\sum_{k=1}^{p} t_{1k}^D$. Thus, the normalized dimentioal influence matrix $\boldsymbol{T}_{\mathrm{N}}^D$ can be shown in Eq. (10). Since p denotes the number of dimensions, it should be smaller than the total number of criteria.

$$\boldsymbol{T}_{\mathrm{N}}^D = \begin{bmatrix} t_{11}^D / \sum_{k=1}^{p} t_{1k}^D & \cdots & t_{1p}^D / \sum_{k=1}^{p} t_{1k}^D \\ \vdots & \ddots & \vdots \\ t_{p1}^D / \sum_{k=1}^{p} t_{pk}^D & \cdots & t_{pp}^D / \sum_{k=1}^{p} t_{pk}^D \end{bmatrix}_{p\times p} \tag{10}$$

The transpose of $\boldsymbol{T}_C^D$ is regarded as an unweighted super-matrix $\boldsymbol{W}$ (i.e., $\boldsymbol{W} = \left(\boldsymbol{T}_C^D\right)'$). Then, the DANP method adopts the normalized dimentioal influence matrix $\boldsymbol{T}_{\mathrm{N}}^D$ to multple with the unweighted super-matrix $\boldsymbol{W}$ and forms the initial DEMATEL-adjusted initial super-matrix $\boldsymbol{W}_{ini}^{DEM}$ (i.e., $\boldsymbol{W}_{ini}^{DEM} = \boldsymbol{T}_{\mathrm{N}}^D \times \boldsymbol{W}$). The influential weight of each criterion, by using the DANP method, can be obtained by multipling $\boldsymbol{W}_{ini}^{DEM}$ with itself multiple times until the the super-matrix becomes stable. After making normalization of the derived stable super-matrix, the sum of the influential weights of all the criteria should equal to one.

3.3. Modified VIKOR method for aggregating perfomrance scores

While facing multiple criteria, it is usually difficult to compare the overall performance and make a ranking for a group of alternatives (e.g., 10 alternations) precisely. For instance, alternative *k* might outperform all the others on criterion *i*; however, it usually performs inferiorly on some other criteria. There are several approaches in conventional MCDM methods that may deal with this ranking problem.

One of the mainstream approaches is to measure the performance gaps that each alternative has on every criterion, and to aggregate the overall performance gaps for all the alternatives. Conventional methods, such as the technique for order preference by similarity to ideal solution (TOPSIS) proposed by Hwang and Yoon [61], sets an ideal point and the worst point for each criterion to measure the shortest distance to the ideal point and the longest distance toward the worst one. Thus, by defining a goal in the form of a performance gap function, the best alternative can be selected by identifying the best one with the shortest overall performance gap. The obtained result is also termed as the compromised solution [21].

Nevertheless, those conventional methods have two potential problems: (1) they do not consider the relative importance of each criterion and (2) the ideal point of each criterion is assigned by using the best performed value from a group of given alternatives. The second issue sometimes may even cause unwanted ranking reversal [62]. The two mentioned issues can both be resolved by the modified VIKOR method [21]. In the modified VIKOR method, it suggests to set an aspired point to replace the ideal point in those conventional approaches, which may avoid to be constraint by a group of poorly performed alternatives.

The concept of the modified VIKOR method, begins with a predefined *Lp-metric* to serve as an aggregate function by the compromise programming method [21-22]. Suppose there are *q* alternatives, denoted as $A_1,\ldots,A_k,\ldots,A_z$. For alternative *k*, its performance on the *j*th criterion is denoted as p_{kj}, and the relative influential weight of criterion *j* (i.e., w_j) is obtained from the DANP method ($j = 1,2,\ldots,n$, and *n* is the number of the involved criteria of a problem). The *Lp-metric* indicates the aggregated performance gap of alternative *k* on all criteria, is shown in Eq. (11):

$$L_k = \left\{ \sum_{j=1}^{n} \left[w_j \left(\left| p_j^{\uparrow} - p_{kj} \right| \right) / \left(p_j^{\uparrow} - p_j^{\downarrow} \right) \right]^q \right\}^{1/q}, \text{ for } 1 \le q < \infty \text{ and } j = 1,\ldots,n. \tag{11}$$

In Eq. (11), the aspired and the worst performance values on the *j*th criterion are denoted as $p_j^{\uparrow}$ and $p_j^{\downarrow}$, respectively. To leverage the advantage of the modified VIKOR mentioned earlier, the aspired and the worst performance values on each criterion are set to be 10 and 0 (i.e., $0 \le p_{kj} \le 10$ for alternative *k* on the *j*th criterion and $j = 1,\ldots,n$) in this study. Therefore, after aggregation, even the best alternative can measure its performance gap to the aspired value (i.e., $p_j^{\uparrow} = 10$ in here).

Before moving forward, one thing that needs to be noticed in here; the fuzzy performance evaluation [18], [20], [55], [59], [63-64] will be adopted and compared with the crisp evaluation in the next Section. Since the fuzzy linguistic expression is closer to how experts making judgments, the present study adopts a 3-scale linguistic intervals (i.e., Bad, Mid, and Good) for the invited experts by using the fuzzy triangular membership function, ranging from 0 to 10.

According to the modified VIKOR method, the following three indices— S_k, R_k, and Q_k for alternative *k*—should be derived based on different settings of a parameter *v*. The indices S_k and R_k can be obtained by setting $q = 1$ (i.e., $S_k = L_k^{q=1} = \sum_{j=1}^{n} \left[w_j \left(\left| p_j^{\uparrow} - p_{kj} \right| \right) / \left(p_j^{\uparrow} - p_j^{\downarrow} \right) \right]$) and $q \to \infty$ (i.e., $R_k = L_k^{q \to \infty} = \max_j \left\{ w_j \left(\left| p_j^{\uparrow} - p_{kj} \right| \right) / \left(p_j^{\uparrow} - p_j^{\downarrow} \right) \mid j = 1,2,\ldots,n \right\}$) for alternative *k*.

The indices S_k and R_k have specific managerial meanings, suggested by a highly cited study [21]; in which, S_k stands for the weighted group utility and R_k the individual regret on a specific

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 December 2018 doi:10.20944/preprints201812.0146.v1

Peer-reviewed version available at Sustainability 2019, 11, 582; doi:10.3390/su11030582

criterion. The different combinations of S_k and R_k can be applied to forming a compromise ranking index Q_k, based on the choice of a decision maker for alternative *k*, is shown in Eq. (12).

$$Q_k = v \times \frac{\left(S_k - S^{best}\right)}{\left(S^{worst} - S^{best}\right)} + (1-v) \times \frac{\left(R_k - R^{best}\right)}{\left(R^{worst} - R^{best}\right)} \quad (12)$$

By setting $p_j^{\uparrow}$ to the aspired level (i.e., $p_j^{\uparrow} = 10$) and $p_j^{\downarrow}$ to the worst value (i.e., $p_j^{\downarrow} = 0$), then $S^{best} = R^{best} = 0$ and $S^{worst} = R^{worst} = 1$. Therefore, Eq. (12) can be simplified and rewritten as: $Q_k = v \times S_k + (1-v) \times R_k$.

3.4. The integration of DEMATEL analytics and modified VIKOR for improvement planning

The modified VIKOR method can select and rank alternatives based on putting different emphases on the weighted group utility and the individual regret, to identify the biggest weighted performance gap on a specific dimension or criterion. Usually, the poorly performed criterion of an alternative would attract the decision maker's attention. However, since we may learn the cause-effect relations among the dimensions (criteria) by the DEMATEL's analytics, we may identify the source dimension/criterion that leads to the poorly performed criterion of an alternative, for conducting a systematic improvement planning. A short example will be illustrated in the next Section.

4. Empirical Case for Evaluating Financial Holding Companies in Taiwan

In this section, an empirical study that applied the hybrid MCDM model is reported, and it discusses the evaluations and analyses of three financial holding companies in Taiwan.

4.1 Framework and the latest developments of Corporate Governance Evaluation System (CGES)

The framework of the CGES, devised by the TWSE, is based on the corporate governance principles published by the OECD in 2004 [12]. The TWSE further combined "Protecting Shareholder Rights and Interests" and "Treating Shareholders Equitably" into one dimension and made minor adjustments in 2017. The latest version of the CGES comprises four dimensions and 87 indicators (refer to **Table 1**). According to the TWSE, this framework also adapts the most recent global developments and research trends related to corporate governance while devising the measuring indicators in each dimension.

Since the debut of the CGES, the top 20% performed companies in Taiwan's stock market were announced and honored in 2015. Later on, in 2016, the second corporate governance evaluation report revealed half of the listed companies in the TWSE. The latest report was conducted in 2017, which categorize nearly all the listed companies in seven layers: (1) the top 5% (43 companies), (2) the 6% to 20% (126 companies), (3) the 21% to 35%% (126 companies), (4) the 36% to 50% (127 companies), and (5) the 51% to 65% (126 companies), (6) the 66% to 80% (126 companies), and (7) the remaining 20% (169 companies). Within each layer, the detailed ranking was not openly announced to the public. Also, owing to some specific concerns (e.g., newly listed companies), 56 listed companies were not included in the latest report.

4.2 Data description

As mentioned in Section 1, this study attempts to refine the current version of the CGES model by a hybrid MCDM approach. Since the financial holding companies play a crucial role in supporting the stability and healthy growth of Taiwan's economy, the present study chose three public listed ones as an exemplary case to show the hybrid approach. The three financial holding companies' basic information are reported in **Table 3**.

The financial holding companies are usually convoluted in their shareholder structures, which demand competent domain experts to decipher their publicly released information. Therefore, this study invited ten experts, all have served in the banking or the financial field for over 30 years, to

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 December 2018 doi:10.20944/preprints201812.0146.v1

Peer-reviewed version available at Sustainability 2019, 11, 582; doi:10.3390/su11030582

contributing their assessments (knowledge) for the hybrid model and bringing their opinions during the evaluation stage. To cover different perspectives, some invited experts are from the academia and the government. But, it is worthwhile to mention that all the professors had served as a CEO in the financial industry.

Table 3. Basic information of the three selected financial holding companies in 2017.

Company Names	Codes	Major Businesses	Number of Employees	Share Capital
Cathay	2882	Insurance, Securities & Banking	55,541	125.63 B (NT dollars)
CTBC	2891	Insurance, Securities & Banking	22,609	194.97 B (NT dollars)
Sinopac	2890	Securities & Banking	8,682	112.71 B (NT dollars)

(Note: Most of the information are from the official website of TWSE, and the "number of employees" were retrieved from each company's website in Oct 2018.)

Also, the three experts from the government agencies have direct ties and experience on supervising the financial holding companies in Taiwan. It is one of the significant contributions of the present study. The ten experts' previous or current titles are reported in **Table 4**. One thing needs to be explained in here, not every expert attended all the phases in the subsequent analyzes. For instance, 10 experts took part the two rounds of the Delphi selection of criteria, but only nine experts joined the subsequent DEMATEL investigation. This phenomenon was owing to the availability of those experts, and the final performance evaluation of each company only involved five experts from the pool (also because of interest of conflict).

Table 4 Invited experts' backgrounds.

Backgrounds	Number of Experts	Previous or Current Job Titles (Backgrounds)
Industry	4	CEO, Vice President, Auditor General
Academia	3	Full Professor (Retired CEOs from financial holding companies)
Government	3	a. Former Director-General of Securities and Futures Bureau
		b. Senior Executive Vice President of Taiwan Stock Exchange
		c. President of Taiwan Depository & Clearing Corporation

4.3 Select critical criteria by the Delphi method

By referring to **Figure 1**, the exemplary case began by inviting the ten domain experts to select less than half of the initial 85 indicators from the four dimensions of the CGES (exclude the two EXTRA ones) in the first round, based on the Delphi method. Next, this study set a threshold that intended to reserve fewer than 15 criteria by requesting the ten experts to rate the indicators got from the first round, the rating value for each indicator ranges from 10 (very critical) to 0 (insignificant). After averaging the opinions from the ten experts, 13 criteria that earned the highest averaged values (with no dissident) were identified. The total numbers of indicators in each dimension reserved in each round of screening are reported in **Table 5**, and the description of each criterion in **Table 6**.

Table 5 Continuous screening results by Delphi method.

Dimensions	Number of criteria (indicators)		
	Initial CGES	1st round	2nd round
Protecting shareholder rights and interests and treating shareholders equitably (D_1)	17	10	3
Enhancing board composition and operation (D_2)	30	15	4
Increasing information transparency (D_3)	20	9	4
Putting CSR into practice (D_4)	18	6	2
Total	85	40	13

Since the TWSE devised the CGES indicators for examining "Yes" or "No," this study kept the original definition from the CGES but changed in the description slightly for each criterion in **Table 6**.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 December 2018 doi:10.20944/preprints201812.0146.v1

Peer-reviewed version available at Sustainability 2019, 11, 582; doi:10.3390/su11030582

Thus, experts may express their judgments (e.g., performance degree in the form of crisp or fuzzy evaluations) in the following stages.

Table 6 The 13 criteria reserved for forming the hybrid model.

Dimensions	Criteria
Protecting shareholder rights and interests and treating shareholders equitably (D_1)	In the case of undistributed dividends, Directors and Supervisors' Remuneration as a Percentage of the Company's Net Profit (C_1) Average ratio of pledges by directors, supervisors and substantial shareholders (C_2) The proportion of seats held by government agencies or single-listed companies and their subsidiaries in the board of directors (C_3)
Enhancing board composition and operation (D_2)	Among the members of the board of directors, general manager (executive director) and members of the board of directors, the proportion of relatives with spouses or second-degree relatives (C_4) The company exposes the opinions of independent directors on the major proposals of the board of directors and the degree of company processing (C_5) The company exposes the results of the resolution of the audit committee on the major proposals and the degree of disclosure of the company's handling (C_6) The degree that the head of internal audit/auditor general attends the board of directors and proposes the internal audit report to each supervisor and independent director (C_7)
Increasing information transparency (D_3)	The degree that the company voluntarily disclose its financial forecast quarterly and without having any corrections ordered by the competent authority or having any demerits imposed by the TWSE (C_8) The degree that the company disclose long-term and short-term business development plans in its annual report (C_9) The degree that the company disclose the remuneration details of each director and supervisor in its annual report (C_{10})
Putting CSR into practice (D_4)	The degree that the company website disclose information related to the company's finances, business and corporate governance (C_{11}) The degree that the company disclose on its website or in its annual report the identities, issues of concern to, channels of communication with, and means for responding to, stakeholders that it has identified (C_{12}) The degree that the company adopt and disclose in detail on its website a whistle blower system for company insiders and outsiders to report illegal behavior (including corruption) and unethical behavior (C_{13})

4.4 Forming a hybrid model by the DEMATEL technique and the DANP method

In the next, this study adopted the 13 criteria (see **Table 6**) to design a DEMATEL questionnaire for the 10 experts. The questions in this questionnaire are like "what is the direct influence that C_i has on C_j?" The degree of influence ranges from 0 (no influence) to 4 (very high influence), and the averaged figures formed the elements a_{ij} (for $i, j = 1,...,13$) in an initial influence matrix $\boldsymbol{A}$, reported in **Table 7**.

Referring Eq. (2) to Eq. (7), the calculations can transform $\boldsymbol{A}$ into the total influence $\boldsymbol{T}$ (in **Appendix A**). we may derive the DEMATEL cause-effect analytic for each criterion. Thus, two vectors (i.e., $\boldsymbol{r}^C$ and $\boldsymbol{c}^C$) can divide all the criteria into a cause group and an effect one. By aggregating the criteria's influences within a dimension (e.g., C_1, C_2, and C_3, belong to D_1), the cause-effect analytic among the four dimensions can be identified (**Table 8**). As a result, we can obtain an influential relationship map (INRM), which indicates the influential relations among the four dimensions (refer to **Figure 2**).

The dimensional INRM (**Figure 2**) indicates the directional influences among the four dimensions. Furthermore, this study referred Eq. (8) to Eq. (10) to transform the total influence $\boldsymbol{T}$ into a normalized dimensional influence matrix $\boldsymbol{T}_{\mathrm{N}}^{D}$ (**Table 9**). Then, the initial DEMATEL-adjusted super-matrix ($\boldsymbol{W}_{ini}^{DEM} = \boldsymbol{T}_{\mathrm{N}}^{D} \times \boldsymbol{W}$) is reported in **Table A.4**. By applying the DANP method, after multipling $\boldsymbol{W}_{ini}^{DEM}$

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 December 2018 doi:10.20944/preprints201812.0146.v1

Peer-reviewed version available at Sustainability 2019, 11, 582; doi:10.3390/su11030582

with itself multiple times until the the super-matrix becomes stable, the DANP influential weight for each criterion can be obtained (reported in **Table 11**).

Table 7 Initial influence matrix ***A***.

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}
C_1	0.00	1.67	1.11	2.89	2.22	2.11	1.22	1.67	1.11	3.56	2.00	2.44	2.00
C_2	2.33	0.00	1.56	2.89	2.00	2.00	1.00	1.22	1.44	2.78	2.00	2.44	2.22
C_3	3.00	1.67	0.00	3.00	2.89	2.67	2.67	2.33	2.44	3.11	2.78	3.44	3.22
C_4	3.44	1.89	2.11	0.00	3.22	3.11	2.78	2.44	2.67	3.67	2.78	3.22	3.22
C_5	2.56	1.33	1.00	1.44	0.00	3.22	3.22	2.56	2.22	2.44	2.33	2.44	2.67
C_6	2.44	1.22	0.78	1.11	3.44	0.00	2.89	2.44	2.11	2.44	2.33	2.44	2.56
C_7	0.78	0.11	0.44	0.67	2.56	2.78	0.00	2.11	1.44	1.11	1.89	1.89	2.56
C_8	1.00	0.56	0.89	1.11	2.22	2.22	2.67	0.00	1.89	1.44	2.33	2.00	2.22
C_9	0.89	0.67	0.78	0.89	1.89	2.00	1.56	1.89	0.00	1.56	2.44	1.56	1.44
C_{10}	3.67	1.89	1.67	2.67	2.78	2.56	1.56	1.67	1.44	0.00	2.11	2.11	2.11
C_{11}	2.89	1.78	1.67	1.89	3.00	2.89	2.44	2.22	2.33	2.89	0.00	2.89	2.78
C_{12}	2.33	2.00	1.56	2.00	2.89	2.89	2.44	2.11	1.67	2.67	2.78	0.00	2.67
C_{13}	2.33	2.00	1.67	2.33	3.00	3.11	2.78	2.56	1.67	2.44	2.67	3.00	0.00

Table 8 Cause and effect analysis for each criterion and dimension by DEMATEL.

Dimensions	$r_{j_d}^D$	$c_{j_d}^D$	$r_{j_d}^D + c_{j_d}^D$	$r_{j_d}^D - c_{j_d}^D$	**Criteria**	r_i^C	c_i^C	$r_i^C + c_i^C$	$r_i^C - c_i^C$
D_1	0.99	0.74	1.73	0.25	C_1	2.88	3.23	6.11	-0.35
					C_2	2.88	2.01	4.90	0.87
					C_3	3.87	1.81	5.68	2.05
D_2	0.95	1.04	1.99	-0.09	C_4	3.98	2.64	6.62	1.34
					C_5	3.14	3.74	6.88	-0.61
					C_6	3.01	3.69	6.69	-0.68
					C_7	2.16	3.23	5.39	-1.07
D_3	0.85	0.97	1.82	-0.12	C_8	2.40	2.99	5.39	-0.59
					C_9	2.07	2.63	4.71	-0.56
					C_{10}	3.11	3.47	6.57	-0.36
D_4	1.02	1.06	2.08	-0.04	C_{11}	3.43	3.30	6.73	0.13
					C_{12}	3.27	3.44	6.71	-0.17
					C_{13}	3.43	3.43	6.87	0.00

Table 9 Normalized dimensional matrix $\boldsymbol{T}_{\mathrm{N}}^D$

Dimensions		D_1	D_2	D_3	D_4
Protecting shareholder rights and interests and treating shareholders equitably	D_1	0.18	0.27	0.25	0.29
Enhancing board composition and operation	D_2	0.18	0.25	0.25	0.27
Increasing information transparency	D_3	0.17	0.24	0.21	0.24
Putting CSR into practice	D_4	0.21	0.29	0.26	0.26

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 December 2018 doi:10.20944/preprints201812.0146.v1

Peer-reviewed version available at Sustainability 2019, 11, 582; doi:10.3390/su11030582

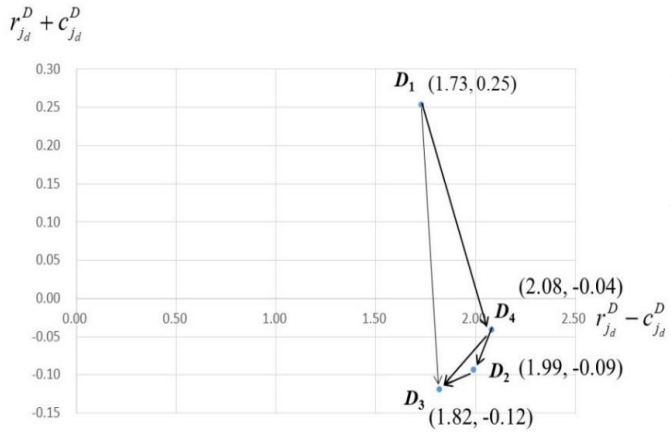

Figure 2. Dimensional influential relationship map (INRM)

4.5 Integrating DANP influential weights and modified-VIKOR for performance ranking

As mentioned in subsection 4.2, this study chose three financial holding companies: (1) Cathay financial holding company (*A*, code: 2882); (2) CTBC financial holding company (*B*, code: 2891); (3) Sinopac financial holding company (*C*, code: 2890). The present study asked five experts (from the pool reported in **Table 3**, based on their availability) to evaluate the corporate governance performance of the three companies. To make a comparison, the study requested the five experts to express their opinions in two forms: (1) the crisp (from 0 to 10; 0 the worst and 10 the best) and (2) the fuzzy ones (in the semantic form: Bad (B), Middle (M), and Good (G)). The fuzzy parameters of the five experts, by adopting the fuzzy triangular membership function, are in **Table 10**.

Table 10 The fuzzy semantic parameters (triangular membership function) of the five experts.

Fuzzy parameters of the three semantic scales	**Expert 1** (L, M, R)*	**Expert 2** (L, M, R)	**Expert 3** (L, M, R)	**Expert 4** (L, M, R)	**Expert 5** (L, M, R)
Bad (B)	(0.0, 0.0, 3.5)	(0.0, 0.0, 3.5)	(0.0, 0.0, 3.5)	(0.0, 0.0, 3.5)	(0.0, 0.0, 3.0)
Middle (M)	(3.0, 5.0, 7.0)	(3.0, 5.0, 7.0)	(3.2, 5.0, 6.5)	(3.0, 5.0, 7.0)	(2.5, 5.0 7.5)
Good (G)	(6.5, 10.0, 10.0)	(6.5, 10.0, 10.0)	(6.0, 10.0, 10.0)	(6.5, 10.0, 10.0)	(7.0, 10.0, 10.0)

*Note: In here, the full scale is the same as the crisp (from 0 to 10). And (L, M, R) denotes the Left (L), Middle (M), and Right (R) parameters of a fuzzy triangular membership function. Thus, if Expert 1 feels that the performance of *A* company on C_1 is Good (G), then the associated fuzzy triangular parameters will be (6.5, 10.0, 10.0).

In here, we have to make a supplementary explanation regarding how the experts made their judgments for each company. At first, we scrutinized the relevant information associated with the 13 criteria of the three companies in their 2017's annual reports and the TWSE's official website. In the next, we organized a table to highlight the associated figures and statements from the disclosed information for each company on the 13 criteria in 2017. Then, the experts referred those figures and descriptions to give their opinions as both the crisp and fuzzy evaluations (refer to **Appendix B**), for each company on each criterion.

After averaging the five experts' opinions on all the criteria of the three financial holding companies, this study adopted the centroid method to defuzzify the performance value on each criterion for each company. Also, the crisp performance evaluations on the three companies were averaged on each criterion; the averaged crisp and the fuzzy evaluation outcomes, for the three companies, are both shown in **Table 11**. Besides, to test the robustness of the hybrid DANP-VIKOR model, different values of v (refer to Eq. (12)) were assigned and compared in **Table 11**. One thing should be noted in here, if v was set as one, the meaning should be the same as using the SAW (simple additive weighting) method. In **Table 11**, by adopting different values of v, both the crisp and fuzzy evaluations for the three companies reveal the same final ranking (i.e., $A \succ B \succ C$).

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 December 2018 doi:10.20944/preprints201812.0146.v1

Peer-reviewed version available at Sustainability 2019, 11, 582; doi:10.3390/su11030582

Though both the crisp and fuzzy evaluations indicate the same ranking result, the meaning of the aggregated final values are disparate. The crisp evaluation and the DANP influential weights revealed the aggregated performance score, the higher the better. On the contrary, the fuzzy evaluation and the modified VIKOR method reported the aggregated performance gap of each company, the smaller the better. In this case, the modified VIKOR method adopted 10 as the aspired value and zero the worst one. Thus, take the performance of Company A on C_1 for example, the raw score is 8.83, and the weighted performance gap is $8.73\% \times (10-8.83)/(10-0) = 1.02\%$. The index R_k shows the highest weighted performance gap of Company k. Take Company B for instance, we can find that its highest weighted gap is on C_{13} (6.90%). Those findings are useful for supporting a diligent company that attempts to improve its overall corporate governance performance by identifying a priority list. Even gigantic financial holding companies are constraint by limited resources; an improvement priority list may set a series of goals with a priority for a company to pursue.

Aside from the aforementioned robust test (i.e., not only used by the crisp and fuzzy evaluation approach but also assigned different values of v to examine the ranking by the modified VIKOR method), we also compared our findings with the latest report from the CGES. In 2017, the CGES reported that Company A belongs to the top category, Company B the third one, and Company C at the bottom; it is fully consistent with our findings. This consistency implies the validity of the proposed hybrid approach. The original 87 indicators were refined to be the 13 essential criteria, and it also unraveled the relative influence of each dimension and criterion by a scientific and reasonable approach (compared with the CGES evaluation model). This hybrid MCDM model can be regarded as a transparent managerial guidance, which improves multiple aspects of the existing CGES model.

Table 11 Final ranking by applying DANP-VIKOR model in crisp and fuzzy evaluations in 2017.

(DANP + SAW)						**(DANP + Modified VIKOR)**					
Crisp evaluation (Criteria)	**DANP weights**	***A*** p_{kj}	***B*** p_{kj}	***C*** p_{kj}	**Fuzzy evaluation** (Criteria)		***A*** p_{kj}	***A*** Weighted gaps	***B*** p_{kj}	***B*** Weighted gaps	***C*** p_{kj}	***C*** Weighted gaps
C_1	8.73%	9.16	4.96	5.30	C_1		8.83	1.02%	4.27	5.00%	5.01	4.36%
C_2	5.62%	7.24	4.80	8.30	C_2		7.30	1.52%	4.23	3.25%	8.07	1.09%
C_3	5.11%	7.14	5.72	3.56	C_3		7.25	1.40%	5.78	2.15%	2.67	3.74%
C_4	6.12%	6.16	6.04	6.34	C_4		5.75	2.60%	5.78	2.58%	6.55	2.11%
C_5	7.59%	6.90	6.20	5.80	C_5		6.51	2.65%	5.75	3.23%	4.98	3.81%
C_6	7.29%	7.70	6.00	7.40	C_6		7.27	1.99%	6.55	2.51%	7.30	1.97%
C_7	6.53%	8.30	5.90	5.20	C_7		8.83	0.76%	6.55	2.25%	4.98	3.28%
C_8	6.12%	8.30	3.60	2.50	C_8		8.07	1.18%	2.70	4.47%	1.13	5.43%
C_9	5.33%	7.70	7.02	6.94	C_9		8.07	1.03%	8.07	1.03%	8.07	1.03%
C_{10}	7.06%	8.20	5.10	5.10	C_{10}		8.83	0.83%	5.03	3.51%	5.01	3.52%
C_{11}	6.79%	8.40	6.20	5.90	C_{11}		8.83	0.79%	5.75	2.89%	4.98	3.41%
C_{12}	13.91%	8.50	6.12	5.00	C_{12}		8.83	1.63%	5.75	5.91%	4.98	6.98%
C_{13}	13.79%	8.40	5.50	4.10	C_{13}		8.83	1.61%	5.00	6.90%	3.47	9.01%
Final performance		7.86	5.65	5.63	S_k			19.02%		45.68%		49.73%
	Rank	1st	2nd	3rd	R_k			2.65%		6.90%		9.01%
					Q_k	($v = 0.95$)		18.20%		43.74%		47.70%
						Rank		1st		2nd		3rd
					Q_k	($v = 0.90$)		17.39%		41.80%		45.66%
						Rank		1st		2nd		3rd
					Q_k	($v = 0.85$)		16.57%		39.86%		43.63%
						Rank		1st		2nd		3rd
					Q_k	($v = 0.80$)		15.75%		37.92%		41.59%
						Rank		1st		2nd		3rd

5. Result and Discussions

In Section 4, this study examined the three financial holding companies' openly disclosure information on corporate governance, and several robust tests support the validity and consistency of the obtained ranking outcome. Until here, the proposed hybrid MCDM approach has fulfilled its key missions: (1) Refine the complex and somewhat inadequately designed CGES model, (2) Solicit senior domain experts' knowledge to form a transparent weighting system regarding the evaluation of corporate governance, and (3) Explore the cause-effect influential relationship among the dimensions.

The aforementioned findings are mainly appealing to external (or potential) investors and supervisors. Once a company that attempts to strengthen its corporate governance to solicit investors' interests and increases shareholders' confidence, the proposed hybrid approach could also support board members to pursue a systematic improvement. For instance, take Company *B* (CTBC financial holding company) for example, it was ranked beneath Company *A* (Cathay financial holding company) in 2017, and its top two weighted performance gaps were C_{12} (5.91%) and C_{13} (6.90%), all belong to D_4. Company *B* should focus on strengthening its performance on D_4 (i.e., Putting CSR into practice). However, if Company *B* ignores the source factor (dimension) that influence D_4, it might solve its temporary problem rather than devise a systematic improvement planning. According to the analytics from the DEMATEL and **Figure 2** (i.e., the dimensional INRM), D_1 (Protecting shareholder rights and interests and treating shareholders equitably) should be the source that influences D_4. Thus, not only the symptoms of its weakness have been identified the board members can also decipher the root-cause that leads to its inferior performance. At the top managerial level, such as among a group of board members, they should guide a company to use its limited resources on making the most effective improvement actions. The combination of the DEMATEL analytics and the modified VIKOR method paved a road to reach this goal.

To enrich the practical insights of this illustrated case, the present study conducted additional interviews with several domain experts (from the same pool, refer to **Table 4**) regarding how to improve Company *B* based on the obtained findings. The experts suggested that CTBC should reduce its proportion of directors and supervisors' compensation to net profit, which falls in the category of D_1. The issued cash dividends of Company *B* were $1.08 (NT) per share in 2017. Under this circumstance, it is suggested to reduce its proportion of directors and supervisors' compensation to net profit, form 0.95% (in 2017) to between 0.3% and 0.1%, to be closer to some other financial holding companies that announced more than NT $1.08 dividends per share in 2017. Also, abusive self-dealing should be prohibited. That is to say, CTBC should reduce its average share pledge ratio of its directors, supervisors, and substantial shareholders significantly (e.g., from 37.64% to less than 10%), not to affect the rights and interests of the company's shareholders.

From the aspect of C_{12} (The degree that the company discloses on its website or in its annual report the identities, issues of concern to, channels of communication with, and means for responding to, stakeholders it has identified) in D_4, CTBC's official website already has a "Center for Stakeholders." However, it merely plays a passive role to release important information. To enhance its effectiveness, the experts suggested CTBC to assign a dedicated team (or department) to communicate with stakeholders actively. Constructive advices or sound (reasonable and influential) questions from stakeholders deserve more attention and direct responses. The board members and the management team of CTBC should have the right to access those questions or suggestions timely. It may even set up a "President's Contact Window" or an "Internal Communication Network" to encourage the first line staffs to relay customers' feedbacks to its core management team. Also, in C_{13} (The degree that the company adopts and disclose on its website a whistleblower system for company insiders and outsiders to report illegal behavior (including corruption) and unethical behavior), the experts suggested CTBC set up a whistleblower system to handling plausible illegal and unethical conducts related to the company. A third party or independent department might be more persuasive to investigate those reported cases. If this mechanism could be implemented stringently, it will not only benefit the company but also fulfill its CSR to the whole society.

To conclude, this study reached four major contributions. Aside from the three mentioned substantial findings at the beginning of this Section, the proposed approach also provided a managerial tool to guide a company on how to improve its corporate governance, for the sake of business sustainability, in a systematic approach. The discussions on Company *B* also offer in-depth managerial insights for its stakeholders (including its management team, shareholders, customers, and authority). It's our hope to contribute our findings for the authorities and the listed companies to refer on how to attain long-term competitiveness and business sustainability through this practical approach.

Acknowledgments: This study received financial from the Ministry of Science and Technology (MOST) of Taiwan (MOST-105-2410-H-034-019-MY2); the authors are grateful for the funding supports. Also, we appreciate the time and efforts that those senior experts spent for filling the questionnaires and providing their opinions.

Author Contributions: Jim-Yuh Huang jointly designed the research framework, identified the crucial data from the CGES and each financial holding company's annual report, made several rounds of interviews with the experts, collected all the questionnaires, and wrote the paper. As the first author, Jim-Yuh Huang organized the relevant articles to position this study. Kao-Yi Shen proposed the research idea, benchmarked the CGES from the TWSE, devised the hybrid MCDM model, calculated the fuzzy evaluations, and contributed to a partial writing of this paper. Joseph C.P. Shieh helped collect the data and supervised the writing of this paper. Gwo-Hsuing Tzeng examined the research framework, suggested using the analytics to support improvements and revised this manuscript.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 December 2018 doi:10.20944/preprints201812.0146.v1

Peer-reviewed version available at Sustainability 2019, 11, 582; doi:10.3390/su11030582

Appendix A (DEMATEL and DANP Calculations)

1. Refer Eq. (2) and Eq. (3) to have **Table A.1**

Table A.1 Normalized direct-influence matrix ***D***.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}
C_1	0.00	0.05	0.03	0.08	0.06	0.06	0.04	0.05	0.03	0.10	0.06	0.07	0.06
C_2	0.07	0.00	0.05	0.08	0.06	0.06	0.03	0.04	0.04	0.08	0.06	0.07	0.06
C_3	0.09	0.05	0.00	0.09	0.08	0.08	0.08	0.07	0.07	0.09	0.08	0.10	0.09
C_4	0.10	0.05	0.06	0.00	0.09	0.09	0.08	0.07	0.08	0.11	0.08	0.09	0.09
C_5	0.07	0.04	0.03	0.04	0.00	0.09	0.09	0.07	0.06	0.07	0.07	0.07	0.08
C_6	0.07	0.04	0.02	0.03	0.10	0.00	0.08	0.07	0.06	0.07	0.07	0.07	0.07
C_7	0.02	0.00	0.01	0.02	0.07	0.08	0.00	0.06	0.04	0.03	0.05	0.05	0.07
C_8	0.03	0.02	0.03	0.03	0.06	0.06	0.08	0.00	0.05	0.04	0.07	0.06	0.06
C_9	0.03	0.02	0.02	0.03	0.05	0.06	0.05	0.05	0.00	0.05	0.07	0.05	0.04
C_{10}	0.11	0.05	0.05	0.08	0.08	0.07	0.05	0.05	0.04	0.00	0.06	0.06	0.06
C_{11}	0.08	0.05	0.05	0.05	0.09	0.08	0.07	0.06	0.07	0.08	0.00	0.08	0.08
C_{12}	0.07	0.06	0.05	0.06	0.08	0.08	0.07	0.06	0.05	0.08	0.08	0.00	0.08
C_{13}	0.07	0.06	0.05	0.07	0.09	0.09	0.08	0.07	0.05	0.07	0.08	0.09	0.00

2. Refer Eq. (4), Eq. (5), and Eq. (8) to obtain **Table A.2**

Table A.2 Total-influential matrix (with dimensional sub-matrices) $\boldsymbol{T}_C^D$.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	r_i^C
C_1	0.18	0.16	0.13	0.23	0.27	0.26	0.22	0.21	0.18	0.29	0.24	0.26	0.25	2.88
C_2	0.25	0.12	0.15	0.23	0.26	0.26	0.21	0.20	0.19	0.27	0.24	0.26	0.25	2.88
C_3	0.32	0.20	0.14	0.28	0.36	0.35	0.31	0.29	0.26	0.34	0.32	0.35	0.34	3.87
C_4	0.34	0.21	0.20	0.20	0.37	0.37	0.32	0.30	0.27	0.36	0.33	0.35	0.35	3.98
C_5	0.26	0.16	0.14	0.20	0.23	0.31	0.28	0.25	0.22	0.27	0.26	0.27	0.28	3.14
C_6	0.25	0.15	0.13	0.18	0.31	0.22	0.27	0.24	0.21	0.27	0.25	0.26	0.27	3.01
C_7	0.16	0.09	0.09	0.13	0.23	0.23	0.14	0.18	0.15	0.17	0.19	0.19	0.21	2.16
C_8	0.18	0.11	0.11	0.15	0.23	0.23	0.22	0.14	0.17	0.20	0.22	0.21	0.22	2.40
C_9	0.15	0.10	0.09	0.13	0.20	0.20	0.17	0.17	0.11	0.18	0.20	0.18	0.18	2.07
C_{10}	0.29	0.17	0.16	0.23	0.30	0.29	0.24	0.23	0.20	0.21	0.26	0.27	0.26	3.11
C_{11}	0.29	0.18	0.17	0.23	0.33	0.32	0.28	0.26	0.24	0.31	0.22	0.31	0.30	3.43
C_{12}	0.27	0.18	0.16	0.22	0.32	0.31	0.27	0.25	0.21	0.29	0.28	0.22	0.29	3.27
C_{13}	0.28	0.19	0.17	0.24	0.33	0.33	0.29	0.27	0.22	0.30	0.29	0.31	0.23	3.43
c_i^C	3.23	2.01	1.81	2.64	3.74	3.69	3.23	2.99	2.63	3.47	3.30	3.44	3.43	

3. Refer Eq. (8) and Eq. (9) to have **Table A.3**, and the normalized dimensional matrix is reported in **Table 9**.

Table A.3 Dimensional matrix $\boldsymbol{T}^D$.

	D_1	D_2	D_3	D_4
D_1	0.18	0.27	0.25	0.29
D_2	0.18	0.25	0.25	0.27
D_3	0.17	0.24	0.21	0.24
D_4	0.21	0.29	0.26	0.27

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 December 2018 doi:10.20944/preprints201812.0146.v1

Peer-reviewed version available at Sustainability 2019, 11, 582; doi:10.3390/su11030582

4. Refer the explanation in subsection 3.2, then **Table A.4** can be obtained as below.

Table A.4 Initial DEMATEL-adjusted initial super-matrix.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}
C_1	0.069	0.088	0.089	0.090	0.089	0.094	0.091	0.090	0.089	0.094	0.091	0.088	0.088
C_2	0.060	0.041	0.054	0.055	0.057	0.056	0.057	0.055	0.057	0.056	0.057	0.060	0.060
C_3	0.050	0.052	0.037	0.055	0.054	0.050	0.052	0.055	0.054	0.050	0.052	0.052	0.052
C_4	0.063	0.064	0.058	0.077	0.058	0.083	0.082	0.050	0.051	0.061	0.055	0.055	0.056
C_5	0.075	0.074	0.074	0.075	0.079	0.058	0.083	0.078	0.080	0.079	0.080	0.079	0.078
C_6	0.073	0.073	0.072	0.066	0.072	0.071	0.050	0.077	0.080	0.077	0.078	0.078	0.078
C_7	0.059	0.059	0.065	0.061	0.065	0.064	0.069	0.074	0.069	0.063	0.068	0.068	0.069
C_8	0.060	0.058	0.062	0.061	0.065	0.064	0.069	0.046	0.063	0.061	0.061	0.062	0.065
C_9	0.050	0.054	0.056	0.056	0.057	0.056	0.056	0.057	0.039	0.053	0.056	0.053	0.053
C_{10}	0.082	0.078	0.073	0.075	0.071	0.071	0.065	0.065	0.066	0.057	0.072	0.073	0.071
C_{11}	0.068	0.069	0.069	0.068	0.068	0.068	0.071	0.071	0.072	0.069	0.051	0.071	0.070
C_{12}	0.148	0.147	0.146	0.143	0.146	0.145	0.146	0.138	0.141	0.140	0.141	0.112	0.149
C_{13}	0.142	0.143	0.144	0.147	0.144	0.145	0.144	0.142	0.139	0.140	0.139	0.148	0.111

Appendix B (Crisp and Fuzzy Semantic Evaluations of the Three Companies)

1. Crisp evaluations of the three companies

Table B.1 Crisp performance evaluation of Company *A*.

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Average
C_1	10.0	9.0	8.8	9.0	9.0	9.2
C_2	8.0	6.0	7.2	6.5	8.5	7.2
C_3	7.5	6.0	7.2	8.0	7.0	7.1
C_4	6.5	5.0	5.8	6.5	7.0	6.2
C_5	8.0	7.0	5.5	6.5	7.5	6.9
C_6	10.0	7.0	8.0	6.5	7.0	7.7
C_7	9.0	7.0	9.0	8.0	8.5	8.3
C_8	9.5	8.0	9.0	7.0	8.0	8.3
C_9	7.5	8.0	8.0	7.0	8.0	7.7
C_{10}	9.0	7.0	9.0	8.0	8.0	8.2
C_{11}	9.0	8.0	9.0	8.0	8.0	8.4
C_{12}	9.0	8.0	9.0	8.5	8.0	8.5
C_{13}	9.0	8.0	8.5	8.5	8.0	8.4

Table B.2 Crisp performance evaluation of Company *B*.

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Average
C_1	5.0	6.0	3.8	2.0	8.0	5.0
C_2	6.0	4.0	3.0	4.0	7.0	4.8
C_3	6.5	4.0	6.6	3.5	8.0	5.7
C_4	7.0	4.0	5.7	5.0	8.5	6.0
C_5	8.0	5.0	5.5	5.0	7.5	6.2
C_6	7.0	5.0	5.5	4.5	8.0	6.0
C_7	7.0	4.0	6.5	4.5	7.5	5.9
C_8	4.0	4.0	2.5	3.0	4.5	3.6
C_9	7.5	8.0	7.6	4.0	8.0	7.0
C_{10}	7.0	6.0	3.0	2.0	7.5	5.1
C_{11}	6.5	7.0	6.5	4.0	7.0	6.2
C_{12}	7.0	6.0	6.6	3.5	7.5	6.1
C_{13}	7.0	7.0	3.0	3.5	7.0	5.5

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 December 2018 doi:10.20944/preprints201812.0146.v1

Peer-reviewed version available at Sustainability 2019, 11, 582; doi:10.3390/su11030582

Table B.3 Crisp performance evaluation of Company *C*.

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Average
C_1	5.0	6.0	6.0	2.0	7.5	5.3
C_2	9.0	6.0	8.5	8.0	10.0	8.3
C_3	3.0	4.0	3.3	4.5	3.0	3.6
C_4	7.0	5.0	5.7	5.0	9.0	6.3
C_5	6.0	5.0	5.5	5.0	7.5	5.8
C_6	10.0	5.0	9.0	5.0	8.0	7.4
C_7	6.5	4.0	5.0	3.5	7.0	5.2
C_8	1.0	4.0	2.5	2.0	3.0	2.5
C_9	7.5	8.0	7.7	3.5	8.0	6.9
C_{10}	5.0	5.0	4.5	3.0	8.0	5.1
C_{11}	6.0	6.0	6.5	4.0	7.0	5.9
C_{12}	6.0	5.0	5.0	3.0	6.0	5.0
C_{13}	4.0	6.0	2.5	2.0	6.0	4.1

2. Fuzzy semantic evaluations of the three companies

Table B.4 Fuzzy semantic performance evaluation of Company *A*.

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
C_1	G	G	G	G	G
C_2	G	M	G	M	G
C_3	G	M	G	G	M
C_4	G	M	M	M	M
C_5	G	G	M	M	M
C_6	G	G	G	M	M
C_7	G	G	G	G	G
C_8	G	G	G	M	M
C_9	G	G	G	M	G
C_{10}	G	G	G	G	G
C_{11}	G	G	G	G	G
C_{12}	G	G	G	G	G
C_{13}	G	G	G	G	G

Note: G denotes "Good," M denotes "Middle," and B means "Bad".

Table B.5 Fuzzy semantic performance evaluation of Company *B*.

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
C_1	M	M	B	B	G
C_2	M	M	B	M	M
C_3	M	M	M	M	G
C_4	G	B	M	M	G
C_5	G	M	M	M	M
C_6	G	M	M	M	G
C_7	G	M	M	M	G
C_8	M	B	B	B	M
C_9	G	G	G	M	G
C_{10}	G	M	B	B	G
C_{11}	M	G	M	M	M
C_{12}	G	M	M	M	M
C_{13}	G	M	B	M	M

Note: G denotes "Good," M denotes "Middle," and B means "Bad".

Table B.6 Fuzzy semantic performance evaluation of Company *C*.

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
C_1	M	M	M	B	G
C_2	G	M	G	G	G
C_3	B	M	B	M	B
C_4	G	M	M	M	G
C_5	M	M	M	M	M
C_6	G	M	G	M	G
C_7	M	M	M	M	M
C_8	B	B	B	B	B
C_9	G	G	G	M	G
C_{10}	M	M	M	B	G
C_{11}	M	M	M	M	M
C_{12}	M	M	M	M	M
C_{13}	M	M	B	B	M

Note: G denotes "Good," M denotes "Middle," and B means "Bad".

(Please cross-refer the fuzzy semantic evaluations by the five experts in **Appendix B** with **Table 10** to generate the averaged defuzzified performance scores of the three companies in **Table 11**.)

References

1. Shleifer, A., & Vishny, R. W. A survey of corporate governance. *The Journal of Finance*, **1997,** *52*(2), 737-783. DOI: 10.1111/j.1540-6261.1997.tb04820.x
2. Claessens, S., & Yurtoglu, B. B. Corporate governance in emerging markets: A survey. *Emerging Markets Review*, **2013**, *15*, 1-33. DOI: 10.1016/j.ememar.2012.03.002
3. Dittmar, A., Mahrt-Smith, J., & Servaes, H. International corporate governance and corporate cash holdings. *Journal of Financial and Quantitative Analysis*, **2003**, *38*(1), 111-133. DOI: 10.2307/4126766
4. Belev, B. Institutional investors in Bulgarian corporate governance reform: obstacles or facilitators? *Journal of World Business*, **2003**, *38*(4), 361-374. DOI: 10.1016/j.jwb.2003.08.021
5. Cheung, Y. L., Jiang, P., Limpaphayom, P., & Tong, L. U. Does corporate governance matter in China? *China Economic Review*, **2008**, *19*(3), 460-479. DOI: 10.1016/j.chieco.2008.01.002
6. Hermalin, B. E., & Weisbach, M. S. Information disclosure and corporate governance. *The Journal of Finance*, **2012**, *67*(1), 195-233. DOI: 10.1111/j.1540-6261.2011.01710.x
7. Kim, Y., Lee, J., & Yang, T. Corporate transparency and firm performance: Evidence from venture firms listed on the Korean stock market. *Asia-Pacific Journal of Financial Studies*, **2013**, *42*(4), 653-688. DOI: 10.1016/j.jcorpfin.2013.05.005
8. Durnev, A., & Kim, E. H. To steal or not to steal: Firm attributes, legal environment, and valuation. *The Journal of Finance*, **2005**, *60*(3), 1461-1493. DOI: 10.1111/j.1540-6261.2005.00767.x
9. Jo, H., & Harjoto, M. A. Corporate governance and firm value: The impact of corporate social responsibility. *Journal of Business Ethics*, **2011**, *103*(3), 351-383. DOI: 10.1007/s10551-011-0869-y
10. Aebi, V., Sabato, G., & Schmid, M. Risk management, corporate governance, and bank performance in the financial crisis. *Journal of Banking & Finance*, **2012**, *36*(12), 3213-3226. DOI: 10.1016/j.jbankfin.2011.10.020
11. CGES official website: http://cgc.twse.com.tw/evaluationCorp/listEn, accessed in June 2018.
12. OECD Principles of Corporate Governance, **2004**, online report (69 pages): http://www.oecd.org/corporate/ca/corporategovernanceprinciples/31557724.pdf
13. Simon, H. A. Theories of bounded rationality. *Decision and Organization*, **1972**, *1*(1), 161-176.
14. Okoli, C., & Pawlowski, S. D. The Delphi method as a research tool: an example, design considerations and applications. *Information & Management*, **2004**, *42*(1), 15-29. DOI: 10.1016/j.im.2003.11.002
15. Gabus, A., & Fontela, E. World problems, an invitation to further thought within the framework of DEMATEL (a technical report), **1972**, Battelle Geneva Research Center.

16. Jeng, D. J. F., & Tzeng, G. H. Social influence on the use of clinical decision support systems: revisiting the unified theory of acceptance and use of technology by the fuzzy DEMATEL technique. *Computers & Industrial Engineering*, **2012**, *62*(3), 819-828. DOI: 10.1016/j.cie.2011.12.016
17. Zavadskas, E. K., Antucheviciene, J., Turskis, Z., & Adeli, H. Hybrid multiple-criteria decision-making methods: A review of applications in engineering. *Scientia Iranica. Transaction A, Civil Engineering*, **2016**, *23*(1), 1-20. DOI: 10.24200/sci.2016.2093
18. Shen, K. Y., & Tzeng, G. H. Advances in Multiple Criteria Decision Making for Sustainability: Modeling and Applications. *Sustainability*, **2018**, *10*(5), 1-7. DOI: 10.3390/su10051600
19. Saaty, T. L. *Theory and Applications of the Analytic Network Process: Decision Making with Benefits, Opportunities, Costs, and Risks*. **2005**, RWS publication.
20. Tzeng, G. H., & Shen, K. Y. *New Concepts and Trends of Hybrid Multiple Criteria Decision Making*, **2017**, CRC Press (Taylor & Francis Group).
21. Opricovic, S., & Tzeng, G. H. Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. *European Journal of Operational Research*, **2004**, *156*(2), 445-455. DOI: 10.1016/S0377-2217(03)00020-1
22. Opricovic, S., & Tzeng, G. H. Extended VIKOR method in comparison with outranking methods. *European Journal of Operational Research*, **2007**, *178*(2), 514-529. DOI: 10.1016/j.ejor.2006.01.020
23. Parker, L. D. Corporate governance crisis down under: post-Enron accounting education and research inertia. *European Accounting Review*, **2005**, *14*(2), 383-394. DOI: 10.1080/09638180500126876
24. Laeven, L., & Levine, R. Bank governance, regulation and risk taking. *Journal of Financial Economics*, **2009**, *93*(2), 259-275. DOI: 10.1016/j.jfineco.2008.09.003
25. Michel, A., Oded, J., & Shaked, I. Ownership structure and performance: Evidence from the public float in IPOs. *Journal of Banking & Finance*, **2014**, *40*, 54-61. DOI: 10.1016/j.jbankfin.2013.11.018
26. Claessens, S., Djankov, S., Fan, J. P., & Lang, L. H. Disentangling the incentive and entrenchment effects of large shareholdings. *The Journal of Finance*, **2002**, *57*(6), 2741-2771. DOI: 10.1111/1540-6261.00511
27. Anderson, R. C., & Fraser, D. R. Corporate control, bank risk taking, and the health of the banking industry. *Journal of Banking & Finance*, **2000**, *24*(8), 1383-1398. DOI: 10.1016/S0378-4266(99)00088-6
28. Kim, Y., & Gao, F. Y. Does family involvement increase business performance? Family-longevity goals' moderating role in Chinese family firms. *Journal of Business Research*, **2013**, *66*(2), 265-274. DOI: 10.1016/j.jbusres.2012.08.018
29. Kiel, G. C., & Nicholson, G. J. Board composition and corporate performance: How the Australian experience informs contrasting theories of corporate governance. *Corporate Governance: An International Review*, **2013**, *11*(3), 189-205. DOI: 10.1111/1467-8683.00318
30. Brenes, E. R., Madrigal, K., & Requena, B. Corporate governance and family business performance. *Journal of Business Research*, **2011**, *64*(3), 280-285. DOI: 10.1016/j.jbusres.2009.11.013
31. Klein, A. (2002). Audit committee, board of director characteristics, and earnings management. *Journal of Accounting and Economics*, **2002**, *33*(3), 375-400. DOI: 10.1016/S0165-4101(02)00059-9
32. Chiou, J. R., Hsiung, T. C., & Kao, L. F. A study on the relationship between financial distress and collateralized shares. *Taiwan Accounting Review*, **2002**, *3*(1), 79-111. DOI: 10.6538/TAR
33. Musteen, M., Datta, D. K., & Kemmerer, B. Corporate reputation: Do board characteristics matter? *British Journal of Management*, **2010**, *21*(2), 498-510. DOI: 10.1111/j.1467-8551.2009.00676.x
34. Schoar, A., & Zuo, L. Does the market value CEO styles? *American Economic Review*, **2016**, *106*(5), 262-66. DOI: 10.1257/aer.p20161031
35. Stevens, J. M., Kevin Steensma, H., Harrison, D. A., & Cochran, P. L. Symbolic or substantive document? The influence of ethics codes on financial executives' decisions. *Strategic Management Journal*, **2005**, *26*(2), 181-195. DOI: 10.1002/smj.440
36. Campbell, T. C., Gallmeyer, M., Johnson, S. A., Rutherford, J., & Stanley, B. W. CEO optimism and forced turnover. *Journal of Financial Economics*, **2011**, *101*(3), 695-712. DOI: 10.1016/j.jfineco.2011.03.004
37. ElKelish, W. W. Corporate governance risk and the agency problem. *Corporate Governance: The International Journal of Business in Society*, **2018**, *18*(2), 254-269. DOI: 10.1108/CG-08-2017-0195
38. Bebchuk, L. A., & Fried, J. M. Executive compensation as an agency problem. *Journal of Economic Perspectives*, **2003**, *17*(3), 71-92. DOI: 10.1257/089533003769204362

39. De Haan, J., & Vlahu, R. Corporate governance of banks: A survey. *Journal of Economic Surveys*, **2016**, *30*(2), 228-277. DOI: 10.1111/joes.12101
40. McCrae, M., & Balthazor, L. Integrating risk management into corporate governance: the Turnbull guidance. *Risk Management*, **2000**, *2*(3), 35-45. DOI: 10.1057/palgrave.rm.8240057
41. Zagorchev, A., & Gao, L. Corporate governance and performance of financial institutions. *Journal of Economics and Business*, **2015**, *82*, 17-41. DOI: 10.1016/j.jeconbus.2015.04.004
42. Anginer, D., Demirguc-Kunt, A., Huizinga, H., & Ma, K. Corporate governance of banks and financial stability. *Journal of Financial Economics*, **2018**, *130*(2), 327-346. DOI: 10.1016/j.jfineco.2018.06.011
43. Cao, Z., Leng, F., Feroz, E. H., & Davalos, S. V. Corporate governance and default risk of firms cited in the SEC's Accounting and Auditing Enforcement Releases. *Review of Quantitative Finance and Accounting*, **2015**, *44*(1), 113-138. DOI: 10.1007/s11156-013-0401-9
44. Sikka, P. Financial crisis and the silence of the auditors. *Accounting, Organizations and Society*, **2009**, *34*(6-7), 868-873. DOI: 10.1016/j.aos.2009.01.004
45. Bushman, R. M., & Smith, A. J. Financial accounting information and corporate governance. *Journal of Accounting and Economics*, **2001**, *32*(1-3), 237-333. DOI: 10.1016/S0165-4101(01)00027-1
46. Ntim, C. G., Lindop, S., Osei, K. A., & Thomas, D. A. Executive compensation, corporate governance and corporate performance: a simultaneous equation approach. *Managerial and Decision Economics*, **2015**, *36*(2), 67-96. DOI: 10.1002/mde.2653
47. Gompers, P., Ishii, J., & Metrick, A. Corporate governance and equity prices. *The Quarterly Journal of Economics*, **2003**, *118*(1), 107-156. DOI: 10.1162/00335530360535162
48. Ali, W., Frynas, J. G., & Mahmood, Z. Determinants of corporate social responsibility (CSR) disclosure in developed and developing countries: a literature review. *Corporate Social Responsibility and Environmental Management*, **2017**, *24*(4), 273-294. DOI: 10.1002/csr.1410
49. Abdallah, A. A. N., & Ismail, A. K. Corporate governance practices, ownership structure, and corporate performance in the GCC countries. *Journal of International Financial Markets, Institutions and Money*, **2017**, *46*, 98-115. DOI: 10.1016/j.intfin.2016.08.004
50. Grove, H., Patelli, L., Victoravich, L. M., & Xu, P. Corporate governance and performance in the wake of the financial crisis: Evidence from US commercial banks. *Corporate Governance: An International Review*, **2011**, *19*(5), 418-436. DOI: 10.1111/j.1467-8683.2011.00882.x
51. De Andres, P., & Vallelado, E. Corporate governance in banking: The role of the board of directors. *Journal of Banking & Finance*, **2008**, *32*(12), 2570-2580. DOI: 10.1016/j.jbankfin.2008.05.008
52. Erkens, D. H., Hung, M., & Matos, P. Corporate governance in the 2007–2008 financial crisis: Evidence from financial institutions worldwide. *Journal of Corporate Finance*, **2012**, *18*(2), 389-411. DOI: 10.1016/j.jcorpfin.2012.01.005
53. Anginer, D., Demirguc-Kunt, A., Huizinga, H., & Ma, K. Corporate governance of banks and financial stability. *Journal of Financial Economics*, **2018**, 130(2), 327-346. DOI: 10.1016/j.jfineco.2018.06.011
54. Hu, K. H., Chen, F. H., Tzeng, G. H., & Lee, J. D. Improving corporate governance effects on an enterprise crisis based on a new hybrid DEMATEL with the MADM model. *Journal of Testing and Evaluation*, **2014,** *43*(6), 1395-1412. DOI: 10.1520/JTE20140094.
55. Tzeng, G. H., & Huang, J. J. *Multiple Attribute Decision Making: Methods and Applications*, **2011**, CRC Press (Taylor & Francis Griup).
56. Tzeng, G. H., & Huang, C. Y. Combined DEMATEL technique with hybrid MCDM methods for creating the aspired intelligent global manufacturing & logistics systems. *Annals of Operations Research*, **2012**, *197*(1), 159-190. DOI: 10.1007/s10479-010-0829-4
57. Shen, K. Y., Yan, M. R., & Tzeng, G. H. Combining VIKOR-DANP model for glamor stock selection and stock performance improvement. *Knowledge-Based Systems*, **2014**, *58*, 86-97. DOI: 10.1016/j.knosys.2013.07.023
58. Zadeh, L. A. Fuzzy logic and approximate reasoning. *Synthese*, **1975**, *30*(3-4), 407-428. DOI: 10.1007/BF00485052
59. Shen, K. Y., & Tzeng, G. H. A decision rule-based soft computing model for supporting financial performance improvement of the banking industry. *Soft Computing*, **2015**, *19*(4), 859-874. DOI: 10.1007/s00500-014-1413-7
60. Dalkey, N., & Helmer, O. An experimental application of the Delphi method to the use of experts. *Management Science*, **1963**, *9*(3), 458-467. DOI: 10.1287/mnsc.9.3.458

61. Hwang, C. L., & Yoon, K. Methods for multiple attribute decision making. In: *Multiple Attribute Decision Making* (pp. 58-191), **1981**, Springer, Berlin, Heidelberg. DOI: 10.1007/978-3-642-48318-9_3
62. García-Cascales, M. S., & Lamata, M. T. On rank reversal and TOPSIS method. *Mathematical and Computer Modelling*, **2012**, *56*(5-6), 123-132. DOI: 10.1016/j.mcm.2011.12.022
63. Shen, K. Y. Compromise between short-and long-term financial sustainability: A hybrid model for supporting R&D decisions. *Sustainability*, **2017**, *9*(3), article ID 375 (17 pages). DOI: 10.3390/su9030375
64. Shen, K. Y., Hu, S. K., & Tzeng, G. H. Financial modeling and improvement planning for the life insurance industry by using a rough knowledge based hybrid MCDM model. *Information Sciences*, **2017**, *375*, 296-313. DOI: 10.1016/j.ins.2016.09.055