Research Article

To Make Good Decision: A Group DSS for Multiple Criteria Alternative Rank and Selection

Chen-Shu Wang,¹ Heng-Li Yang,² and Shiang-Lin Lin²

¹Graduate Institute of Information Management, National Taipei University of Technology, Taiwan

²Department of Management Information Systems, National Chengchi University, Taiwan

Correspondence should be addressed to Shiang-Lin Lin; shiang0623@gmail.com

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Decision making is a recursive process and usually involves multiple decision criteria. However, such multiple criteria decision making may have a problem in which partial decision criteria may conflict with each other. An information technology, such as *the decision support system* (DSS) and group DSS (GDSS), emerges to assist decision maker for decision-making process. Both the DSS and GDSS should integrate with a symmetrical approach to assist decision maker to take all decision criteria into consideration simultaneously. This study proposes a GDSS architecture named hybrid decision-making support model (HDMSM) and integrated four decision approaches (Delphi, DEMATEL, ANP, and MDS) to help decision maker to rank and select appropriate alternatives. The HDMSM consists of five steps, namely, criteria identification, criteria correlation calculation, criteria evaluation, critical criteria selection, and alternative rank and comparison. Finally, to validate the proposed feasibility of the proposed model, this study also conducts a case study to find out the important indexes of corporate social responsibility (CSR) from multiple perspectives. As the case study demonstrates the proposed HDMSM enables a group of decision makers to implement the MCDM effectively and help them to analyze the relation and degree of mutual influence among different evaluation factors.

1. Introduction

People are making decision all the time. Typically, decision making is a recursive process in which decision maker may repeatedly move back and forth among multiple decision steps, such as objective clarification, decision criteria identification, alternative rank, and selection. For decision maker, the primary concern is to pick up an appropriate choice from a group of candidate alternatives [1]. Such decision making process usually involves multiple decision criteria [2], so called as multiple criteria decision making (MCDM) [3]. Lots of researches are devoted to resolve sorts of MCDM problem. For example, Hung et al. provide a novel MCDM approach to solve the knowledge management (KM) adoption problem and rank the gaps of the KM aspects in control items to achieve the aspired level of performance. The findings demonstrate that the KM gaps within the service industry are higher than the gaps within the integrated circuit and

banking industries [4]. Also, Hsu et al. combine DEMATEL on ANP with VIKOR to solve the recycled materials vendor selection problems of multiple dimensions and criteria that are interdependent, instead of the independent assumption of an analytic hierarchy process, for mimicking the real world [5]. Besides, Chiu et al. focus on assessing e-store strategies to reduce the gaps in the resulting customer satisfaction and combine several multicriteria decision methodologies to conduct three real cases [6]. As mentioned above, MCDM is a complicated problem but can reflect real world precisely and therefore we should pay more attention to resolve MCDM issue.

However, unfortunately, most people are much poorer at decision making than they think. For illustration, there is a misconception that the decision maker thought they do not have enough information to make good decision [7]. Contrarily, in most cases, they spend much time to collect relative (or even irrelevant) information and trap themselves

in the huge amount of information. Decision making is a sophisticated art and decision makers indeed require some help.

An information technology, as known as decision support system (DSS), emerges to assist decision maker to accelerate the convergence of decision-making process. DSS is interactive computer-based information system which helps decision-makers utilize knowledge base and models to solve ill-structured problems [8]. For these decades, DSS has been widely applied among domains as follows. Koo et al. developed a DSS based on case-based reasoning approach for determining the optimal size of new expressway service areas [9]. Gottschlich and Hinz proposed a DSS design that enables investors to include the crowd's recommendations in their investment decisions and use it to manage a portfolio [10]. Hu and Sheng also proposed a DSS for public logistics information service management and optimization for vehicle drivers and owners, logistics customers, and related logistics service providers and management institutes [11]. Then, to respond accordingly to the requirement of group decision making, DSS further evolves into group DSS (GDSS) to help group of decision makers with efficiency decision making [12–16]. A group decision support system (GDSS) is a hybrid system that uses an elaborate communications infrastructure and quantitative models to help a team of decision makers solve problems and make choices [17, 18]. However, the decision process is a classical multiple criteria problem that partial decision criteria may conflict with each other. Both the DSS and GDSS should integrate with a symmetrical approach to assist decision maker to take all decision criteria into consideration simultaneously.

In this research, we proposed a hybrid GDSS architecture, named HDMSM, integrated four decision approaches (Delphi, DEMATEL, ANP, and MDS) to help decision maker with alternative rank and selection issue. HDMSM consists of four steps. In Step 1, HDMSM adopts Delphi to collect the decision criteria from domain experts. After that, in Step 2, domain experts use DEMATEL approach to evaluate the relevant among the selected criteria (in Step 1) and then generate a correlation matrix of these decision criteria. Then, in Step 3, HDMSM adopts ANP to calculate the correlation and important weight for each decision criteria in Step 4. Finally, in Step 5, the MDS can rank all available alternatives according to these important weights and visualize the similarity (or difference) of all available alternatives.

The priorities of decision criteria imply the preference of domain expert and therefore, to make better decision, and decision maker can make their choice according to the alternative rank via HDMSM. Also, the visual abilities of HDMSM enable decision maker to compare all available alternative form perspective and then improve decision making quality. Finally, we provide a system demonstration section to illustrate that how HDMSM aggregated the opinion from a group of domain experts. How to appropriately integrate a variety of MCDM approaches is an important issue in decision science [19]. HDMSM provides a valuable recommendation for decision maker to optimize multiple criteria decision making.

The remainder of this paper is organized as follows. Section 2 briefly reviews four decision analysis methodologies adopted in this study. Section 3 presents the proposed hybrid decision-making support model (HDMSM) and details the operational process of HDMSM. To validate the feasibility of HDMSM, according to five steps of HDMSM, a case study in Section 4 illustrates how decision makers appropriately select multiple decision criteria for corporate social responsibility (CSR) implementation step by step. Finally, Section 5 concludes some interest finding and proposes possible future research opportunities.

2. Literature Review

The HDMSM proposed in this study integrates four decision approaches, namely, Delphi, DEMATEL, ANP, and MDS, to help decision maker with criteria selection and alternative ranking when facing a decision problem. Four methodologies are briefly introduced below.

2.1. Delphi Method. Delphi method relies mainly on a panel of experts' experiences, intuition, and value judgment. The experts participate in multiple rounds of questionnaire interviews and are given ways to understand one another's viewpoints on the same question. The experts are encouraged to revise their previous opinions, so that the experts as a group can finally reach a consensus on the goal of decision making [19]. To perform the Delphi method, the following procedures are included.

2.1.1. Choose a Panel of Decision-Making Experts and Select the Criteria for Decision Making. Determine the goal of decision making and list relevant evaluation criteria for the decision making, choose experts in the related field to form an expert group, and invite the experts to answer in a Delphi expert questionnaire interview for multiple rounds. The experts must judge the importance and suitability for each evaluation criteria and give each criterion a score between 0 and 100.

2.1.2. Test the Expert Group Consensus. To enable expert group to gradually reach a general agreement of opinion, a consensus deviation index (CDI) for each evaluation criteria is calculated as a round of the Delphi expert questionnaire finished. A smaller CDI indicates a higher consensus among the experts. In general, a CDI threshold is set to 0.05. That is, when the last round of Delphi expert questionnaire is completed and the CDI for all of the evaluation criteria is smaller than 0.05, this indicates a consensus of experts has been reached [20]. Herein, the score of the j th criterion rated by the h th expert in the t th round of Delphi questionnaire is defined as X_{jht} , and the CDI is calculated by the formula:

$$CDI_{jt} = \frac{S_{jt}}{\max_j \bar{X}_{jt}}, \quad \forall j, t, \quad (1)$$

where $\bar{X}_{jt}$ is the mean of the scores of the j th criterion rated by all the experts in the t th round of Delphi expert

questionnaire, and S_{jt} is the standard deviation of the scores of the j th evaluation criterion rated by all the experts in the t th round of Delphi expert questionnaire.

2.1.3. Normalize the CDI and Choose the Evaluation Criteria. The CDI calculated based on the last round of Delphi expert questionnaire has to be normalized to derive the relative weight W_j of each of the evaluation criteria. A small weight indicates the criterion does not have sufficient influence on the decision problem. In other words, when the weight of a particular criterion is less than a threshold set by the decision maker, the criterion is deleted from the candidate decision criteria, wherein W_j is calculated by the following formula:

$$W_j = \frac{\bar{X}_j}{\sum_{j=1}^M \bar{X}_j}, \quad \forall j. \quad (2)$$

The evaluation criteria involved in decision making problem can be identified via Delphi. Then, DEMATEL is adopted to analyze the direct/indirect effects among these evaluation criteria detailed below.

2.2. Decision-Making Trial and Evaluation Laboratory. Decision making trial and evaluation laboratory (DEMATEL) was originated from the Geneva of the Battelle Memorial Institute in 1973. It effectively observes the level of mutual influence among different factors and understands the complicated cause-and-effect relationship in the decision problem [21]. The analytic processes are listed below.

2.2.1. Define the Correlation among Evaluation Factors. List the factors that may affect the decision-making problem through literature review or brainstorming and interview with the domain experts to determine the correlation between any two factors.

2.2.2. Establish Direct Relation Matrix. As the decision problem has n evaluated factors, an $n * n$ direct relation matrix showing the scores of influencing degree is established, which is presented as Z -matrix in formula (3). Element z_{ij} represents the degree by which the factor z_i affects factor z_j :

$$Z = \begin{matrix} & \begin{matrix} C_1 & C_2 & \cdots & C_n \end{matrix} \\ \begin{matrix} C_1 \\ C_2 \\ \vdots \\ C_n \end{matrix} & \begin{bmatrix} 0 & z_{12} & \cdots & z_{1n} \\ z_{21} & 0 & \cdots & z_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ z_{n1} & z_{n2} & \cdots & 0 \end{bmatrix} \end{matrix}. \quad (3)$$

2.2.3. Establish Direct/Indirect Relation Matrix. In order to understand whether two evaluation criteria relate to each other indirectly, formula (4) produces a direct/indirect relation matrix T , where I is the identity matrix:

$$T = [X(I - X)^{-1}]. \quad (4)$$

2.2.4. Calculate the Prominence Score. If t_{ij} is an element of matrix T , where $i, j = 1, 2, \dots, n$, the sum of the column and the row are denoted by D_i and R_j , respectively. Among them, D_i represents the sum of the criterion i influencing other criteria, R_j represents the sum of the criterion j being affected by other criteria, and $D + R$ represents the prominence degree of each criterion in the decision-making problem. A prominence score can reveal both the importance and mutual effects among these criteria. In other words, DEMATEL analyzes the direct and indirect effect of these evaluation criteria on decision problem. The analysis results can be further plotted as a network structure via ANP approach.

2.3. Analytic Network Process. ANP is a decision-making analytical method that uses network and nonlinear structure to represent a decision problem. ANP is developed in response to the fact that many decision problems in the realistic environment could not be presented with the structured hierarchy. The main objective of ANP is to correct the traditional AHP, with which the problems of dependence and feedback might occur between the criteria or the layers [22].

ANP can decompose a decision problem into multiple types of dimensions, and each dimension can include multiple criteria. The dimensions and the criteria are correlated with one another to form a network structure of the evaluation framework, and arrows are used to indicate their mutual influence.

Through the pairwise comparison of among each two criteria, ANP is calculated to acquire the eigenvectors of criteria and to form a Supermatrix, as shown in

$$W = \begin{bmatrix} W_{i_1 j_1} & W_{i_1 j_2} & \cdots & W_{i_1 j_n} \\ W_{i_2 j_1} & W_{i_2 j_2} & \cdots & W_{i_2 j_n} \\ \vdots & \vdots & \ddots & \vdots \\ W_{i_m j_1} & W_{i_m j_2} & \cdots & W_{i_m j_n} \end{bmatrix}. \quad (5)$$

Through normalization of the Supermatrix and complex matrix multiplication, a limit supermatrix containing the weights of the evaluation criteria can be obtained. According to these weights, the decision maker can figure out the priority of evaluation criterion for decision problem solving.

2.4. Multidimensional Scaling. Multidimensional scaling (MDS) is a data reduction method, which uses the distance or similarity between data points to locate the spatial coordinates and the relative positions of several given data in the low-dimensional space [23].

MDS computes the Euclidean distance between each two factors and shows all factors in perceptual map which has two dimensions. If the similarity between two factors is more stronger, the configuration of two factors would be more close in the map. As a result, through the illustration of perceptual map, the spatial relation among factors can be visualized more clearly. The classification results of factors can be achieved via spatial difference analysis that helps decision maker to easily grasp the concept of factors.

To obtain the perceptual map, the Euclidean distance (D_{ij}) between each two factors should be computed first. Further, the Euclidean distance matrix of the factors is generated. The Euclidean distance equation is shown as

$$D_{ij} = \sqrt{(x_{i1} - x_{j1})^2 + (x_{i2} - x_{j2})^2 + \cdots + (x_{ik} - x_{jk})^2}, \quad (6)$$

where x_i denotes the perceived value of factor a and x_j denotes the coordinate of factor b .

For decision making, decision maker must locate important decision criteria and evaluate the fitness of all possible alternatives. To increase decision process, decision maker needs to compare these alternatives as soon as possible. Via MDS, the visualization of candidate alternative enables decision maker to quickly grasp the similarities and dissimilarities among the alternatives.

3. Hybrid Decision-Making Support Model (HDMSM)

This study proposes a GDSS architecture named hybrid decision-making support model (HDMSM) as shown in Figure 1. According to the decision-making procedures, HDMSM consists of five steps, namely, criteria identification, criteria correlation calculation, criteria evaluation, critical criteria selection, and alternative rank and comparison, which are detailed below.

Step 1 (criteria identification). To make MCDM, some appropriate evaluation dimensions and criteria are selected as candidate decision criteria. Then, a domain expert group is organized via Delphi for conducting multiple rounds of questionnaire interviews. To finally establish a consensus score for each of the criteria, the experts group gradually reaches a consensus in their opinions. Based on the consensus scores, the top n decision criteria that with the highest important weight are chosen from the candidate criteria as evaluation criteria. Finally, these decision criteria are, respectively, given a detailed definition according to the opinions from the interviewed expert group.

Step 2 (criteria correlation calculation). To understand the correlation among the selected evaluation criteria in Step 1, it is necessary to further create a correlation matrix. According to the prominence of these criteria, for each criterion, DEMATEL evaluates the correlation among these criteria and calculates the prominence score.

Step 3 (criteria evaluation). To show the direct relation among these evaluation criteria, HDMSM plots a network structure of the evaluation framework. And then, an ANP expert questionnaire is designed based on the plotted evaluation framework. The domain experts fulfilled the ANP questionnaire and the collected questionnaires are further analyzed via ANP method to derive the absolute weight. Thereafter, for each decision criterion, it cross-multiplies the absolute weight by the consensus score (in Step 1) and the

prominence score (in Step 2), to obtain a composite important weight. Finally, according to the composite importance weights, HDMSM can rank the decision criteria for MCDM.

Step 4 (critical criteria selection). To evaluate the feasibility for each alternative, multiple decision criteria are usually taken into consideration simultaneously. Therefore, in this step, according to the analysis results in Step 3, a decision maker sets a threshold for the composite important weight. If the evaluation criteria with a higher composite important weight, decision maker can pick them out and conduct pairwise comparison with alternatives to find out the priority of each alternative.

Step 5 (alternative rank and comparison). For particular complex case, appropriate alternative might be a combination of several alternatives. Therefore, the decision maker must understand the effect of each of the evaluation criteria. Additionally, they need to analyze the structural similarity among different alternatives. Therefore, in Step 5, MDS analysis is used to analyze the results from Step 4 for allocating the positions of the alternatives in a perceptual map of second dimension, so as to present the similarity and dissimilarity among the alternatives through visualization.

HDMSM adopts four methodologies that complement each other. Delphi summarizes the opinion from expert group and then generates appropriate evaluation factors for a multicriteria decision making. DEMATEL reveals the correlation among these decision factors. ANP implements pairwise comparison of these factors and derives the important weights for all evaluation factors. By importance ranking, ANP provides decision maker with the insight into the decision problem. Based on the analysis results, MDS generates the perceptual map to improve the representation of alternative analysis. The visualization representation enables decision maker to quick-grasp the similarity and dissimilarity among alternatives and increase decision making process.

4. Case Study: To Select the Evaluation Factors of Corporate Social Responsibility

A case study is implemented based on the proposed HDMSM. In this case study, we intend to find out the important indexes of corporate social responsibility (CSR) from multiple perspectives. CSR involves the conduct of a business so that it is economically profitable, law abiding, ethical, and socially supportive. To be socially responsible, profitability and obedience to the law are foremost conditions to discuss the firm's ethics and the extent to which it supports the society in which it exists with contributions of money, time, and talent. Thus, CSR is composed of four dimensions: economic, legal, ethical, and philanthropic [24, 25] and the selection of the evaluation factor for each dimension would be a complicated issue. According to these four dimensions, some appropriate evaluation indexes are identified via Delphi method in Step 1, and the correlation among the evaluation indexes is calculated via DEMATEL method in Step 2. Then, in Step 3, HDMSM adopts ANP to evaluate the important

FIGURE 1: Hybrid decision-making support model (HDMSM).

ranking of these evaluation indexes for an enterprise to implement its corporate social responsibility and for different interested parties in connection with the enterprise. Finally, in Step 4, HDMSM selects 10 critical indexes through composite important weight and compares the similarity and dissimilarity among the interested parties via MDS in Step 5.

4.1. Criteria Identification. To make complicate multicriteria decision, like evaluation factors of CSR, it is necessary to select dimensions, criteria, and available alternatives as evaluation factors. Table 1 summarized some previous researches related to CSR. In total, there are 4 groups of evaluation dimensions and 28 evaluation indexes (i.e., evaluation criteria). Furthermore, five clusters of interested parties are chosen, namely, suppliers (A1), shareholders (A2), employees (A3), customers (A4), and the general public (A5), as the alternatives in this study.

To implement the case study, five domain experts were invited to form a decision-making team and fulfill a Delphi expert questionnaire that consists of 28 CSR evaluation criteria. The expert gave each criterion a score between 0 and 100 points. Then, for two discussion rounds, the experts gradually reached a consensus on the target decision problem (i.e., $CDI < 0.05$). According to the average score of decision criteria (the threshold is set 60-points), some criteria are deleted from the candidate pool of decision criteria.

For the remained criteria, to uniform evaluation scale, the normalization process was conducted to obtain the rating weight for each CSR evaluation criteria as shown in Table 2. For illustration, some evaluation criteria (such as P1, P2, and L5) are more influential for business to solve CSR decision problem.

4.2. Establishment of Criteria Correlation. After the CSR evaluation criteria were identified via Delphi method in Step 1, DEMATEL expert questionnaire interview was implemented to determine the relation and the degree of mutual influence among the criteria to generate a direct relation matrix. The questionnaire scaling is 0 to 3 points in which 0 indicates no relation and 3 indicates a significant relation among the decision criteria [21]. A DEMATEL questionnaire sample is shown in Table 3.

4.3. Calculate Prominence of Criteria. After obtaining the direct relation matrix, formula (4) can be used to calculate and generate a direct/indirect relation matrix as shown in Table 4.

According to the direct/indirect relation matrix in Table 4, the sum of the column and the row is denoted by D_i and R_j , respectively. D_i represents the sum of the criterion i influencing other criteria, R_j represents the sum of the criterion j being affected by other criteria, and the

TABLE 1: CSR dimensions and criteria selection.

Dimensions		Evaluation criteria
Economic responsibilities	E1	Reasonable product prices
	E2	Transparent business operations
	E3	Avoid price collusion with any competitor
	E4	Stimulate local economic development
	E5	Increase employment opportunities
	E6	Maximum possible profits for the organization
	E7	Honour agreed-upon contracts
Legal responsibilities	L1	Implement the consumer protection act
	L2	Ensure good and safe working environment for employees
	L3	Provide employees with the newest information on pertinent laws
	L4	Provide occupational injury compensation and health insurance systems
	L5	Keep customer information confidential and protect it against illegal use
	L6	Provide proper waste disposal and reduce pollutant emissions
	L7	Actively inspect and certify products
Ethical responsibilities	M1	Provide consumers with customer complaint service and thorough follow-up service
	M2	Provide employees with ways of improving their working conditions
	M3	Eschew exaggerated or false advertisements
	M4	Pay salaries and wages on time
	M5	Provide employees with a good working environment
	M6	Provide employees with fair selection, promotion, termination, and retirement systems
	M7	Provide employees with reasonable welfare and protection
	M8	Provide employees with educational training and living-related assistance
	M9	Cooperate with the government in energy-saving and carbon-reduction policy
	M10	Ensure transparent production processes
Philanthropic responsibilities	P1	Protect vulnerable social groups
	P2	Engage in charitable activities
	P3	Provide for community welfare
	P4	Use company resources efficiently

prominence score ($D_i + R_i$) of each criterion can be obtained. The prominence scores are shown in Table 5. As an evaluation criterion has a higher prominence score ($D_i + R_i$), it indicates that the evaluation criterion has a higher prominence

for decision-making problem. For example, in Table 5, the decision criteria M7 (providing employees with reasonable welfare and protection) with the highest prominence score is identified as the strongest influence decision criteria in the CSR case study.

4.4. Construct the Network Structure of Evaluation Framework. In the previous step, DEMATEL generated the direct relation among the CSR evaluation criteria, as shown in Table 3, and the direct relation was then used to plot a network structure of evaluation framework, as shown in Figure 2.

Next, an ANP expert questionnaire was designed based on the network structure of evaluation framework. Total 15 interviewers finished the ANP questionnaires. The 15 interviewers included 3 middle-high level managers from different companies. Taking economic responsibility dimension as an example, the pairwise comparisons for the criteria E1–E5 were conducted, and the 9-point paired-comparison scaling was used for rating [26] as shown in Table 6. The answers to the questionnaires must conform to the logic of transitivity. That is, for illustration, in a questionnaire, when $E1 > E2$ and $E2 > E3$, then the condition of $E1 > E3$ must exist. If not, the questionnaire is considered an invalid questionnaire.

4.5. Criteria Weighting and Priority Ranking. The collected questionnaires were further analyzed and processed using ANP to create an unweighted super matrix as shown in Table 7. The values in the matrix are the relative weights of the CSR evaluation criteria under each question in the ANP expert questionnaire. For instance, based on E3, the relative weights of L1 and M1 obtained from the pairwise comparison are 0.75 and 0.25, respectively.

We cross-multiplied the values in each row of the unweighted super matrix by the weight of the dimension, respectively, and then a weighted super matrix can be obtained as shown in Table 8. The weight of each dimension is determined according to the expert's feedback. In this case, the weights of the four dimensions of economic responsibility, legal responsibility, moral responsibility, and philanthropic responsibility are 0.25, 0.4, 0.2, and 0.15, respectively.

To get a uniform weighted scale of super matrix, the normalization is implemented. A limit super matrix is shown in Table 9. The normalized matrix (in Table 8) is multiplied by itself repeatedly to convert the values (by row) into a limit value and generate the limit super matrix, wherein the values of each row are the importance weights of the CSR evaluation criteria.

According to the above MCDM method, the importance weights or scores for three groups of the CSR evaluation criteria are derived. However, the use of the results from one single decision-making analytic method to determine the importance level of each of the evaluation criteria to the overall decision problem seems to be too arbitrary and less persuasive and might even cause bias in determining the target decision, which obviously deviates from the initial purpose of employing different decision-making analytic

TABLE 2: CDI and rating weights of CSR criteria.

(D)	(C)	Score of final round					σ	CDI	Means	Rating weight by normalization
		1	2	3	4	5				
Economic	E1	90	90	80	85	90	4.47	0.050	87.0	0.053
	E2	90	95	85	85	90	4.18	0.047	89.0	0.054
	E3	75	70	75	70	80	4.18	0.047	74.0	0.045
	E4	75	70	70	75	75	2.74	0.031	73.0	0.045
	E5	85	80	80	80	75	3.54	0.040	80.0	0.049
	E6	55	60	60	55	50	4.18	0.047	56.0	(deleted)
	E7	55	60	60	55	55	2.74	0.031	57.0	(deleted)
Sum of nondeleted mean:									403.0	—
Legal	L1	85	80	85	90	85	3.54	0.038	85.0	0.052
	L2	75	85	80	80	77	3.78	0.041	79.4	0.048
	L3	75	78	70	80	80	4.22	0.046	76.6	0.047
	L4	70	75	72	78	75	3.08	0.034	74.0	0.045
	L5	90	95	90	90	95	2.74	0.030	92.0	0.056
	L6	85	87	90	93	95	4.12	0.045	90.0	0.055
	L7	75	70	80	76	73	3.70	0.040	74.8	0.046
Sum of nondeleted mean:									571.8	—
Ethical	M1	85	80	83	88	90	3.96	0.044	85.2	0.052
	M2	61	62	55	54	55	3.78	0.042	57.4	(deleted)
	M3	55	54	50	45	53	4.04	0.045	55.0	(deleted)
	M4	70	65	68	73	70	2.95	0.033	69.2	0.042
	M5	45	53	52	50	47	3.36	0.037	49.4	(deleted)
	M6	70	77	75	73	80	3.81	0.042	75.0	0.046
	M7	65	63	60	70	66	3.70	0.041	64.8	0.040
	M8	45	48	45	52	50	3.08	0.034	48.0	(deleted)
	M9	90	93	85	88	95	3.96	0.044	90.2	0.055
	M10	85	88	90	93	90	2.95	0.033	89.2	0.054
Sum of nondeleted mean:									473.6	—
Philanthropic	P1	98	90	95	95	100	3.78	0.040	95.6	0.058
	P2	95	90	92	96	95	2.51	0.026	93.6	0.057
	P3	55	60	56	58	55	2.17	0.023	56.8	(deleted)
	P4	61	63	55	54	55	4.10	0.043	57.6	(deleted)
Sum of nondeleted mean:									189.2	1.000

D denotes dimension, C denotes criterion, σ denotes standard deviation, and CDI denotes consensus deviation index.

methods. To avoid the above condition and to upgrade the accuracy of results from decision-making analysis, this study further multiplied the importance weights of the criteria derived with Delphi and ANP by the prominence scores of the criteria found by DEMATEL. However, since some criteria have a prominence score less than 1 (i.e., $D_i + R_i < 1$) that would result in an even smaller value after multiplication, it is necessary to add 1 to each of the prominence scores before multiplying the importance weights by the prominence scores. Finally, a composite importance weight

was obtained for each of the CSR evaluation criteria, and a priority ranking of all criteria was obtained according to their composite importance weights. The calculation results are shown in Table 10.

As shown in Table 10, the ranking of the criteria based on the composite importance weights is not exactly the same priority ranking for all three MCDM methods, and some criteria have quite different importance levels in different ways of ranking. For instance, referring to the prominence score of DEMATEL, E2 is the third important index. However,

TABLE 3: Direct relation matrix.

Criteria	E1	E2	E3	E4	E5	L1	L2	L3	L4	L5	L6	L7	M1	M4	M6	M7	M9	M10	P1	P2
E1	0	0	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E2	1	0	3	0	0	0	0	0	0	1	2	3	0	0	2	0	0	3	0	0
E3	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
E4	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L1	3	0	2	0	0	0	0	0	0	3	0	3	2	0	0	0	0	1	0	0
L2	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0
L3	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	1	0	0	0	0
L4	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	3	0	0	1	0
L5	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M4	0	0	0	0	1	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
M6	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
M7	0	0	0	0	0	0	3	3	3	0	0	0	0	1	2	0	0	0	0	0
M9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M10	0	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0	3	0	0	0
P1	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
P2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0

TABLE 4: Direct/indirect relation matrix.

Criteria	E1	E2	E3	E4	E5	L1	L2	L3	L4	L5	L6	L7	M1	M4	M6	M7	M9	M10	P1	P2
E1	0.00	0.01	0.21	0.14	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2	0.07	0.01	0.22	0.01	0.01	0.03	0.02	0.00	0.00	0.07	0.18	0.25	0.02	0.00	0.14	0.00	0.04	0.20	0.00	0.00
E3	0.02	0.07	0.03	0.00	0.00	0.07	0.00	0.00	0.00	0.02	0.01	0.03	0.08	0.00	0.01	0.00	0.00	0.02	0.00	0.00
E4	0.00	0.00	0.00	0.01	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E5	0.00	0.00	0.00	0.07	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L1	0.21	0.01	0.19	0.03	0.01	0.05	0.00	0.00	0.00	0.21	0.02	0.23	0.15	0.00	0.00	0.00	0.01	0.07	0.00	0.00
L2	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.14	0.00	0.07	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.01	0.00
L3	0.00	0.00	0.00	0.00	0.02	0.00	0.02	0.06	0.02	0.00	0.00	0.00	0.00	0.22	0.01	0.07	0.00	0.00	0.00	0.00
L4	0.00	0.00	0.00	0.01	0.02	0.00	0.26	0.05	0.08	0.00	0.02	0.00	0.00	0.02	0.03	0.22	0.00	0.00	0.07	0.01
L5	0.04	0.00	0.04	0.01	0.00	0.21	0.00	0.00	0.00	0.04	0.00	0.05	0.03	0.00	0.00	0.00	0.00	0.01	0.00	0.00
L6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M4	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.01	0.00	0.00	0.00	0.00
M6	0.00	0.00	0.00	0.00	0.07	0.00	0.14	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M7	0.00	0.00	0.00	0.00	0.02	0.00	0.28	0.24	0.25	0.00	0.02	0.00	0.00	0.12	0.14	0.07	0.00	0.00	0.02	0.00
M9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00
P1	0.00	0.00	0.00	0.08	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.14
P2	0.00	0.00	0.00	0.02	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.03

if taken the composite weight into consideration, the same index of E2 is the eleventh. For another example, according to the Delphi weight, P1 and P2 are the top two important CSR evaluation criteria but only rank last two in the priority ranking based on the composite weight. As demonstration, both the analysis results of all MCDM methodologies and composite weights have the reference values.

4.6. Alternative Comparison. In general, there are more than one alternative for decision maker to choose for problem solving. For each alternative, they may have levels of effect on different evaluation criteria. Therefore, according to described analytic results, in the study, the importance weight threshold is set to 0.05 for top 10 CSR critical criteria selection. And then, a second pairwise comparison is

TABLE 5: Prominence of CSR evaluation criteria.

	CSR evaluation criteria	R_i	D_i	$D_i + R_i$
E1	Reasonable product prices	0.35	0.43	0.78
E2	Transparent business operations	0.11	1.30	1.41
E3	Avoid price collusion with any competitor	0.58	0.36	0.94
E4	Stimulate local economic development	0.39	0.22	0.61
E5	Increase employment opportunities	0.82	0.08	0.90
L1	Implement the consumer protection act	0.38	1.03	1.41
L2	Ensure good and safe working environment for employees	0.85	0.31	1.16
L3	Provide employees with the newest information on pertinent laws	0.56	0.42	0.98
L4	Provide occupational injury compensation and health insurance systems	0.53	0.80	1.32
L5	Keep customer information confidential and protect it against illegal use	0.35	0.41	0.76
L6	Provide proper waste disposal and reduce pollutant emissions	0.53	0.00	0.53
L7	Actively inspect and certify products	0.67	0.00	0.67
M1	Provide consumers with customer complaint service and thorough follow-up service	0.29	0.00	0.29
M4	Pay salaries and wages on time	0.41	0.36	0.76
M6	Provide employees with fair selection, promotion, termination, and retirement systems	0.34	0.41	0.74
M7	Provide employees with reasonable welfare and protection	0.41	1.18	1.59
M9	Cooperate with the government in energy-saving and carbon-reduction policy	0.26	0.00	0.26
M10	Ensure transparent production processes	0.31	0.60	0.91
P1	Protect vulnerable social groups	0.34	0.47	0.81
P2	Engage in charitable activities	0.18	0.29	0.47

conducted for the five interested clusters (i.e., the alternatives used in this study). To facilitate the subsequent alternative similarity analysis, the 9-point paired-comparison scaling was also used for measurement. Finally, the relative weights

of the interested clusters under the selected 10 critical criteria were obtained as shown in Table 11.

Based on Table 11, the Euclidean distance between any two of the interested clusters is further calculated and the Euclidean distance matrix is created as shown in Table 12. In the Euclidean distance matrix, the smaller the value between two alternatives (such as the interested parties), the closer the distance between them, meaning a higher similarity between two alternatives. Then, according to this matrix, the positions of the interested clusters in a two-dimensional coordinate system can be located, and a perceptual map of alternative allocation can be plotted.

From the perceptual map shown in Figure 3, the similarity and dissimilarity among the clusters (such as three elliptic areas in Figure 3) can be clarified clearly. For CSR example in Section 4, the perceptual map can visualize the evaluation criteria for CSR from different perspectives (such as A1 to A5) and provide decision maker with detail information. As shown in Figure 3, for illustration, we can find that the consideration of shareholder is similar to supplier and employee while business is intended to plan and implement CSR issues. Referring to the analysis result of the proposed HDMSM, decision maker can develop a solution that fulfilled the most correct decision-making policy.

5. Conclusions and Further Work

MCDM has been an important issue and many researches are devoted to help people make better decision. Particularly, some decision-making analytic methodologies (such as ANP and DEMATEL) and information technologies (such as DSS and GDSS) can help decision makers to analyze the decision problem, collect information, indicate the available alternatives, and so on. However, the MCDM involves multiple decision criteria and, the worst, these criteria might mutually influence one another to lead to a complicated situation. Decision making is a sophisticated art and decision makers indeed require some help.

This study proposed a hybrid decision-making support model (HDMSM) that is an integrated GDSS architecture consisting of five steps, namely, criteria identification, criteria correlation, criteria evaluation, criteria selection, and alternative rank and comparison. Further, HDMSM appropriately integrates four systemic decision approaches (Delphi, DEMATEL, ANP, and MDS) to help the decision maker with alternative rank and selection issue. HDMSM consists of five steps. In Step 1, HDMSM adopts Delphi to collect and identify the decision criteria from domain experts. After that, in Step 2, domain experts use DEMATEL to evaluate the correlation among the selected criteria (in Step 1) and then generate a relation matrix of these decision criteria. Then, in Step 3, HDMSM adopts ANP to calculate the complicate correlation and importance weight for each decision criterion in Step 4. Finally, in Step 5, MDS can rank all available alternatives according to the importance weights and visualize the similarity (or difference) among all available alternatives.

A case study was implemented based on the proposed HDMSM. The case study intends to find out the important indexes of corporate social responsibility (CSR) from

TABLE 6: Sample answer in pairwise comparison (based on the dimension of economic).

		←— Equally important —→								
Scaling	9:1	7:1	5:1	3:1	1:1	1:3	1:5	1:7	1:9	Scaling
E1				V						E2
E1		V								E3
E1			V							E4
E1						V				E5
E2			V							E3
E2					V					E4
E2									V	E5
E3					V					E4
E3									V	E5
E4								V		E5

FIGURE 2: Network structure of the evaluation framework.

multiple perspectives. The case study results showed some interest findings. We found that “implementing the consumer protection act,” “providing proper waste disposal and reduce pollutant emission,” “keeping customer information confidential and protecting it against illegal use,” “providing employees with the newest information of related laws,” and “ensuring good and safe working environment for employees”

are top five critical criteria for enterprises to implement their corporate social responsibility (CSR). Further, according to the similarity analysis for interested clusters, three groups of interest clusters can be formed, including the employees and shareholder as the first one group, the shareholders and suppliers as the second one, and the suppliers and customers as the last one group. The members of the same group

[illegible]

TABLE 10: Composite important weight and priority ranking of criteria.

Criterion	DEMETAL prominence score	Delphi weight	ANP weight	Composite weight	Normalization of composite weight	General ranking
E1	0.782	0.053	0.037	0.0035	0.038	13
E2	1.407	0.054	0.031	0.0040	0.043	11
E3	0.938	0.045	0.036	0.0032	0.034	14
E4	0.606	0.045	0.038	0.0027	0.029	15
E5	0.898	0.049	0.060	0.0055	0.059	9
L1	1.407	0.052	0.082	0.0102	0.109	1
L2	1.161	0.048	0.068	0.0071	0.076	5
L3	0.980	0.047	0.078	0.0072	0.077	4
L4	1.325	0.045	0.061	0.0064	0.068	7
L5	0.755	0.056	0.074	0.0073	0.078	3
L6	0.534	0.055	0.109	0.0092	0.098	2
L7	0.667	0.046	0.086	0.0066	0.070	6
M1	0.289	0.052	0.033	0.0022	0.024	17
M4	0.762	0.042	0.050	0.0037	0.040	12
M6	0.741	0.046	0.028	0.0023	0.024	16
M7	1.591	0.040	0.040	0.0041	0.044	10
M9	0.263	0.055	0.021	0.0015	0.016	18
M10	0.913	0.054	0.059	0.0061	0.065	8
P1	0.807	0.058	0.006	0.0006	0.007	19
P2	0.472	0.057	0.003	0.0002	0.003	20
Total	—	1.000	1.000	—	1.000	—

TABLE 11: Relative weights of alternatives under CSR criteria.

Interested parties	L1	L6	L5	L3	L2	L7	L4	M10	E5	M7	Sum of weight
A1 suppliers	0.049	0.042	0.047	0.252	0.049	0.047	0.529	0.270	0.051	0.061	1.396
A2 shareholders	0.052	0.165	0.125	0.122	0.212	0.252	0.151	0.096	0.222	0.514	1.912
A3 employees	0.147	0.217	0.214	0.036	0.537	0.529	0.047	0.046	0.563	0.210	2.547
A4 customers	0.571	0.052	0.042	0.520	0.041	0.066	0.220	0.522	0.048	0.171	2.254
A5 general public	0.181	0.523	0.572	0.070	0.162	0.106	0.053	0.065	0.116	0.043	1.891
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	—

TABLE 12: Euclidean distance matrix for alternatives.

Interested parties	A1 suppliers	A2 shareholders	A3 employees	A4 customers	A5 general public
A1 suppliers	0.000				
A2 shareholders	0.257	0.000			
A3 employees	0.576	0.216	0.000		
A4 customers	0.258	0.423	0.726	0.000	
A5 general public	0.423	0.307	0.385	0.565	0.000

got closed viewpoint toward the CSR evaluation criteria. Therefore, to maximize the CSR policies effect, the reference to the analyzed results can help the enterprises to establish and develop their CSR strategies for particular interested cluster.

The proposed HDMSM can enable a group of decision makers to implement the MCDM effectively and help them to analyze the relation and degree of mutual influence among different evaluation factors. As the case study demonstrated, the HDMSM can locate the evaluation factors with relatively

FIGURE 3: Perceptual map of alternative allocation.

significant and deep influence and conduct a cross analysis for different alternatives of the decision problem. Therefore, according to the analysis result, decision maker can choose the optimal alternative for decision problem solving. In the future, the HDMSM can be applied to various domains of decision problem, such as system introducing and enterprise resource planning. Also, the proposed HDMSM can be further combined with other decision-making analytic methods, such as association rules analysis, TOPSIS, or VIKOR, to upgrade the accuracy and effectiveness of the HDMSM in handling decision problems.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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