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Article

Low Carbon Supplier Selection in the Hotel Industry

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Abstract: This study presents a model for evaluating the carbon and energy management performance of suppliers by using multiple-criteria decision-making (MCDM). By conducting a literature review and gathering expert opinions, 10 criteria on carbon and energy performance were identified to evaluate low carbon suppliers using the Fuzzy Delphi Method (FDM). Subsequently, the decision-making trial and evaluation laboratory (DEMATEL) method was used to determine the importance of evaluation criteria in selecting suppliers and the causal relationships between them. The DEMATEL-based analytic network process (DANP) and VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) were adopted to evaluate the weights and performances of suppliers and to obtain a solution under each evaluation criterion. An illustrative example of a hotel company was presented to demonstrate how to select a low carbon supplier according to carbon and energy management. The proposed hybrid model can help firms become effective in facilitating low carbon supply chains in hotels.

Keywords: supplier selection; carbon management; hotel industry; FDM; DANP; VIKOR

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1. Introduction

With the increased consciousness on the issue of climate change, the implementation of energy conservation and carbon reduction in the hotel industry has become significant to address global warming [1–5]. The hotel industry, a major sub-sector of the tourism industry, consumes a significant amount of energy, which equates to the amounts of indirect greenhouse gas (GHG) emissions associated with the energy consumption of the hotel sector [6,7]. The Taiwan Green Productivity Foundation [8] reports that the top 50 most intensive energy users in Taiwan's hospitality industry, mostly tourist hotels, produced 363,810 tons of carbon emissions in 2008. To achieve the target of low-carbon operations, hotel companies have adopted either ISO 50001 (energy management systems) or ISO 14064 (greenhouse gas systems) to increase energy efficiency and mitigate carbon emission. These companies include the Marriott Washington DC Hotel, Regal Airport Hotel in Hong Kong, NH Hotels, Miramar Garden Hotels, and Evergreen Hotels in Taiwan.

The World Business Council for Sustainable Development and the World Resources Institute indicate that at least 80% of carbon emissions are produced in the total supply chain [9]. This finding is consistent with that of Sundarakani *et al.* [10], who emphasized that carbon emission across stages in a supply chain constitutes a significant threat that warrants careful attention in the design phase of the supply chain. In controlling the carbon footprint across a supply chain, Wittneben and Kiyar [11] underlined that GHG emissions from suppliers need to be considered to adequately assess the contributions of businesses to climate change. The 2010 supply chain report of the Carbon Disclosure Project states that more than half of its surveyed members expressed that in the future, they will cease doing business with suppliers that do not manage their carbon emissions [12]. This finding implies that carbon footprint can affect the optimal choice on sourcing decisions [13,14], operations decisions in inventory management [15], and product development [16].

Low-carbon supplier management is clearly a critical activity in purchasing management to achieve low-carbon operations within the hotel industry. Bonilla-Priego *et al.* [17] pointed out that tour operators are required to measure and manage the carbon performance of their suppliers. Teng *et al.* [5] stated that selecting a supplier that adopts energy conservation and carbon reduction, working with local farmers or vendors to reduce food miles, and purchasing local or seasonal food and products/materials can facilitate low-carbon hotel operations. Accor launched Accor Procurement Charter 21 and integrated sustainable development criteria into all phases of its supplier relations, from specifications in its calls for bids to specific clauses integrated into supplier certification contracts. At the end of 2012, more than 2000 certified suppliers—60% of the total—signed Accor Procurement Charter 21. Accor Hotels requires their suppliers to evaluate the environmental impact that their sites, products, and services exert on the environment and to set objectives on the quantitative reduction of GHG emissions [18]. Reflecting these trends, companies in the hotel industry must therefore require their suppliers to oversee their GHG emissions and energy management for a long-term collaborative partnership in the low-carbon supply chain.

Recently, supplier selection and evaluation of carbon management has become important in making low carbon purchasing decisions [5,19–24]. Nevertheless, to the best of our knowledge, supplier selection that specifically considers carbon or energy management competence in the hotel industry is rarely found in previous literature. A few studies have attempted to incorporate carbon management into the process of supplier selection in specific manufacturer industries [20,25,26]. By incorporating the carbon performance into the supplier selection process, Hsu *et al.* [20] proposed a framework that develops a carbon management model with 13 criteria used to manage suppliers in the Taiwanese electronics industry. Their study used the Decision-making Trial and Evaluation Laboratory (DEMATEL) approaches to recognize the influential criteria of carbon management and improve the overall carbon performance of suppliers. Later, Shaw *et al.* [24] included the criterion of carbon emission in supplier selection to develop a low carbon supply chain in the Indian garment manufacturing. The fuzzy analytic hierarchy process was applied before analyzing the weights of criteria, and the fuzzy multi-objective liner programming was used for supplier selection. This formulation integrates carbon emission into the objective function and takes the carbon emission cap (Ccap) of sourcing as a constraint while selecting a supplier. Similarly, in terms of optimizing green suppliers, Peng [26] integrated the criterion of energy consumption into green supplier selection in a large manufacturing enterprise. The analytical hierarchy process (AHP) and grey relational analysis were used to evaluate green suppliers. To construct a green and low carbon supplier evaluation model, Lee *et al.* [25] used the fuzzy analytic network process to evaluate various aspects of suppliers. Goal programming was then applied to allocate the most appropriate amount of orders to each of the selected supplier. Choi [27] proposed a two-stage optimal supplier selection scheme in which phase one filters the inferior suppliers and phase two helps to select the best supplier among the set of non-inferior suppliers by multi-stage stochastic dynamic programming. The impacts brought by different formats of carbon emission tax are explored.

Supplier selection and evaluation is a multi-criteria decision-making (MCDM) problem [28,29] that provides an effective framework for comparing suppliers. In the current study, a hybrid MCDM model is proposed to identify the evaluation criteria of carbon performance using the Fuzzy Delphi Method (FDM). By considering the interrelationship between criteria, the decision-making trial and evaluation laboratory (DEMATEL) method is used to recognize cause-effect relationships and to construct the cognition map of the evaluation criteria. The DEMATEL based on an analytic network process (ANP), also called the DANP method, is used to calculate the influence weights of the criteria. Finally, the VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) with DANP weights is used for the evaluation of the carbon performance of suppliers and to determine performance scores and gaps. An illustrative example of a hotel firm in Taiwan is used to demonstrate the proposed framework for appropriate supplier selection in terms of carbon management.

The remainder of this paper is organized as follows. Section 2 reviews the literature on supplier selection based on carbon performance. Sections 3 briefly describes the FDM method, the DEMATEL method, the DANP influential weights, and the VIKOR technique, which are used to build a hybrid MCDM model for selecting a low-carbon supplier. An empirical case of a hotel company is used to demonstrate the proposed model in Section 4. We present and discuss the results of proposed framework in Section 5. The conclusion and suggestion for future research are presented in Section 6.

2. Carbon Management Criteria in Supplier Selection

Several useful criteria associated with carbon management and their categories are pointed out in the literature. Information about them was utilized to construct a framework for competency in carbon management aware supplier selection in hotel supply chain. Twelve criteria were finally included.

2.1. Energy Efficiency of Products

In implementing energy management systems of ISO 50001-certified, organizations will require their suppliers to provide energy efficiency information on their products or equipment [30]. Green hotel associations and some government websites provide information on the energy efficiency of products, such as printing paper, toilet/tissue paper, computers, refrigerators, air conditioners, and employee uniforms [5]. With the availability of energy efficiency information on products, hotel operators can purchase highly efficient products and facilities instead of those with high-energy consumption to achieve low carbon operation.

2.2. Eco-labeling of Products

Hotel operators that adopt green purchasing can reduce energy consumption and simultaneously reduce operating costs [31]. For example, the Energy Star program has significantly reduced economic costs and CO_2 emissions associated with electricity consumption [32]. The products of suppliers are qualified by eco-labels, such as the energy-saving label, green mark, and water-saving label, hotel operators can implement green purchasing to reduce energy consumption.

2.3. Carbon Accounting and Inventory

Carbon accounting and inventory is an essential step in developing strategies for controlling GHG emissions and evaluating its progress in the operations of a company, in products, and in supply chain, as companies need to know their current situation [33]. Cogan *et al.* [34] found that more than 60% of the evaluated companies conducted a GHG emissions inventory.

2.4. Energy Reduction of Food Processing

In the food industry, high levels of energy consumption are necessary for key operations, such as food preservation, sanitation, processing, and storage [35]. For example, the U.S. food industry consumes 7% of the total electricity used by the manufacturing sector. Therefore, about 15% of the total energy requirements of the food industry are from electricity [36]. To show an example of fictitious slaughter and meat processing, Fritzson and Berntsson [37] performed different energy efficiency measures, such as increasing the heat exchanger networks and heat pumps, to achieve the target reduction of 5% and 35% of the total CO_2 emissions. Considering the low carbon supply of food available in the hotel industry, suppliers from food processing suppliers must embrace different measures to save energy and reduce carbon emissions.

2.5. Carbon Governance

Over 90% of Carbon Disclosure Project (CDP) members have tasked either a board committee or another executive body with the overall responsibility of climate change management to ensure that the strategy is effectively implemented [12]. Companies that integrate climate change into their board and executive structures, as well as their public reporting mechanisms, are far more likely to maintain long-term commitments and the comprehensive approaches necessary to effectively address climate change risks and opportunities across their entire business structure [34].

2.6. Carbon Policy

The CDP [10] reveals that its members have integrated carbon policies into their procurement departments and that majority of these companies (90%) have a carbon emission reduction plan in place. Accordingly, companies can facilitate carbon management practices by establishing a carbon policy as a manifestation of its position on carbon emissions disclosure, carbon reduction targets, and carbon emissions certification, among others. Moreover, by implementing the energy management systems standard ISO 50001, companies will be able to implement an energy policy [38].

2.7. Carbon Reduction Targets

In terms of the mitigation of climate change, Weinhofer and Hoffmann [39] argue that GHG reduction targets reflect a long-term need to decrease emissions. Setting targets to reduce GHG emissions has become the norm in corporate climate change strategies, which include quantitative emission reduction targets for their Scopes 1 and 2, and occasionally even Scope 3, GHG emissions [34]. A company must set its carbon reduction target at a sufficiently high level to enable authentic and measurable progress in addressing climate change.

2.8. Carbon and Energy Management Systems

To mitigate carbon emissions, firms attempt to acquire different certified standards associated with carbon and energy management systems. Recently, most companies have applied various standards on carbon management, such as ISO 14064-Parts I and II and PAS 2050, to conduct inventories and account for GHG emissions. Energy management is the combination of energy efficiency activities and techniques, and the management of related processes that result in lower energy costs and CO_2 emissions [40]. Ates and Durakbasa [38] point out that the energy management system ISO 50001 is expected to compel industrial organizations to examine the systems and processes required to increase their energy performance, energy efficiency, and intensity.

2.9. Transport Efficiency

The energy efficiency and carbon emissions of transportation should be considered to facilitate the creation of a low carbon supply chain within the hotel industry, as transportation is required for the mass delivery of food, consistent with Teng *et al.* [5]. Their study argues that food and beverage operators should be aware of their carbon footprint and reduce it, as well as improve the energy efficiency of road freight transport. For example, the energy requirement contribution of transporting foodstuffs for breakfast is significant [2].

2.10. Collaboration of Suppliers

Working with suppliers to green supply chain in hotel sector, International Tourism Partnership [41] argued that hotel operators should encourage local businesses to cut down on transport energy by sourcing locally. Climate change is not a single issue that can be addressed by only one company or even one sector. Companies need to collaborate with their supplier to climate change of adaptation and mitigation. According to Scott and Becken [42], Carla Aguirre from VisitSweden reported on their experience to encourage and motivate potential suppliers, and show leadership on sustainability and climate change issues.

2.11. Carbon Reduction and Energy Conservation Measures

To mitigate carbon emissions, most companies no longer concentrate solely on influencing policy debates. Instead, they have begun to pursue various firm-specific practical actions against climate change within the framework of a corporate climate strategy [43]. Companies can take internal and external measures on their carbon dioxide emissions [33,44,45]. Internal measures are usually defined as activities within the business operations of the company, whereas external measures represent emission compensation measures [39].

2.12. Food Mile Management

Food miles are usually explicitly linked to carbon accounting and climate change [46]. Internationally, the demand of the tourism sector for food and its associated food miles have a significant impact on GHG emissions and thus have implications for climate change [47]. Through the tracking of food miles and associated sources, Pratt [48] concludes that ecotourism operations, such as those within the hotel industry, have identified and improved their sustainability and ecological footprint by minimizing GHGs.

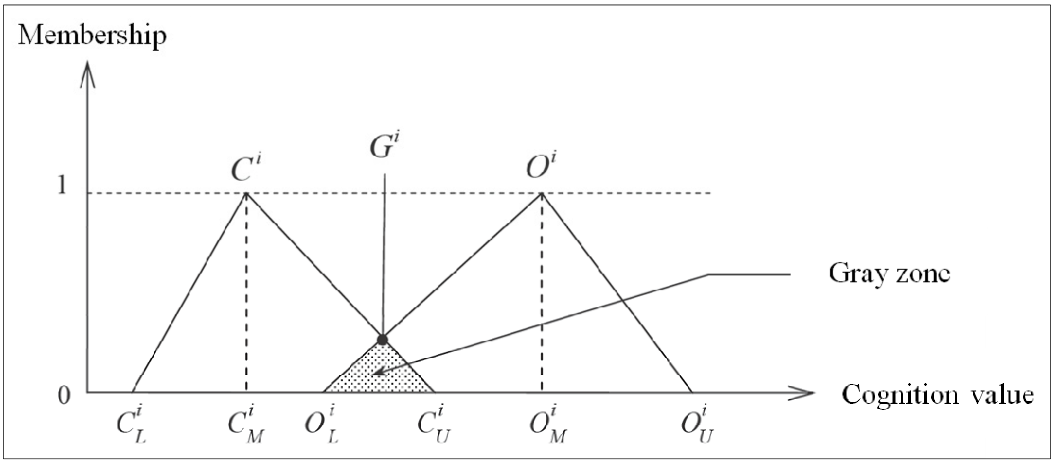
3. Building a Hybrid MCDM Model of Low Carbon Supplier Selection

The methodology of constructing an evaluation framework for selecting a low carbon supplier in the hotel industry for this study has three phases. The first phase emphasizes the identification of criteria to evaluate the carbon management competence of suppliers. In this study, five managers from hotel firms and three university professors were invited to screen and fit the criteria using FDM techniques. In the second phase, after identifying the consistency of criteria, the DANP method was used to examine the interrelationship between and the influential weights among the criteria. Finally, VIKOR was used to rank the suppliers of an illustrative hotel company in terms of carbon management competence.

3.1. Recognizing the Evaluation Criteria by FDM Method

The Delphi Method has been widely used and recognized for making predictions and for decision-making since its introduction in 1963 by Dalkey and Helmer at the RAND Corporation [49]. The Delphi Method was conceived as a group technique that aims to obtain the most reliable consensus of a group of experts using a series of intensive questionnaires with controlled opinion feedback [50]. Despite its recognition as a valuable tool, it has some drawbacks. The tool is time consuming, and converging results through repetitive surveys is costly [51–53]. Further, the problems of ambiguity and uncertainty remain in the responses of experts [51,53,54]. To solve these defects, Murray *et al.* [55], combined the concepts of the traditional Delphi Method and the fuzzy set to alleviate the ambiguity of the Delphi Method. Kaufmann and Gupta [56] proposed a more complete FDM procedure, in which the fuzzy set theory is used by asking participants to give a three-point estimate (*i.e.*, pessimistic, moderate, and optimistic values). Triangular fuzzy numbers (TFNs) were then formed, and their means were computed. This study applied paired TFNs to locate three points in the extent of importance (*i.e.*, minimum, medium, and maximum values) on a scale of 0 to 10 points. Wei and Chang [57] adopted the same concept to calculate and represent these "group average" values. The paired TFNs were categorized into two, namely, the conservative TFN (C_L, C_M, C_U) and the optimistic TFN (O_L, O_M, O_U). The intersection of the fuzzy opinions of experts implies the convergence of consensus, as shown in Figure 1. Finally, the geometric means of conservative, moderate, and optimistic values (C^i, a^i, O^i) were computed to acquire the consensus values (G^i) of each item. In view of the advantages of FDM in evoking expert-group opinion, various studies [57–59] have embraced FDM in the creation of performance indicators or evaluation criteria. Some essential FDM steps are as follows [57,60]:

Figure 1. TFNs formed in the FDM.



Step 1. The questionnaires are distributed. An appropriate panel group of experts is organized to express the experts' most conservative (minimum) and optimistic (maximum) values for each item on a scale of 0 to 10.

Step 2. The most conservative (minimum) and optimistic (maximum) values from each expert for each item are gathered, and the geometric mean of the expert group's opinions is computed. A group average is calculated for the pessimistic (optimistic) index of sub-criterion *i*, and the abnormal value, which is outside the two standard deviations, is eliminated. The rest of the values, namely, the minimum (C_L^i), geometric mean (C_M^i), and the maximum (C_U^i) of the remaining conservative values; and the minimum (O_L^i), geometric mean (O_M^i), and maximum (O_U^i) of the remaining optimistic values, are calculated.

Step 3. The two TFNs as the most conservative TFN (C_L^i, C_M^i, C_U^i) and the most optimistic TFN (O_L^i, O_M^i, O_U^i) are determined based on "group average" values.

Step 4. The expert opinions are examined to determine if they are consistent. The consensus significance value (G_i) for each item is calculated.

(1) If the paired TFNs do not overlap (*i.e.*, $C_U^i \le O_L^i$), then a consensus for item *i* exists. The consensus significance value is calculated as follows:

$$G_i = \frac{C_M^i + O_M^i}{2} \tag{1}$$

(2) If the paired TFNs overlap (*i.e.*, $C_U^i > O_L^i$) and the gray zone interval value $\left(Z^i = C_U^i - O_L^i\right)$ is less than the interval value of C^i and O^i $\left(M^i = O_U^i - C_M^i\right)$, then the consensus significance value of each item is calculated as follows:

$$G_i = \frac{\left[\left(C_U^i \times O_M^i\right) - \left(O_L^i \times C_M^i\right)\right]}{\left[\left(C_U^i - C_M^i\right) + \left(O_M^i - O_L^i\right)\right]} \tag{2}$$

If the paired TFNs overlap (*i.e.*, $C_U^i > O_L^i$) and the gray zone interval value $\left(Z^i = C_U^i - O_L^i\right)$ is more than the interval value of C^i and O^i $\left(M^i = O_U^i - C_M^i\right)$, then the expert opinions have discrepancies. Steps 1 to 4 should be repeated until each item converges and G_i is calculated.

3.2. Building a Network Relation Map Using DEMATEL

DEMATEL is a comprehensive tool for building and analyzing a structural model that involves causal relationships between complex factors [61]. Developed by the Science and Human Affairs Program of the Battelle Memorial Institute of Geneva from 1972 and 1976, DEMATEL has been used to research and solve a group of complicated and intertwined problems. DEMATEL was developed with the belief that pioneering scientific research methods and their appropriate use could improve the understanding of a specific problematic cluster of intertwined problems, thus contributing to the identification of workable solutions using a hierarchical structure. The methodology, according to the concrete characteristics of objective affairs, can confirm the interdependence among variables/attributes and restrict the relationship reflecting their characteristics using an essential system and a development trend [62,63]. The product of the DEMATEL process is a visual representation (*i.e.*, an individual map of the mind) that the respondent uses to organize his/her own actions. The DEMATEL method is increasingly being used to determine the interrelationships between factors through a cause-effect relationship diagram, particularly to determine the critical factors of reverse supply chains [64], SaaS adoption [65], airline safety management systems [66], and performance evaluation in hotel industry [67]. Therefore, DEMATEL modeling fits the problem examined in the present study best and offers the advantage of providing a systematic approach to determine the relationships of low carbon supplier management in hotel industry.

The following steps show the DEMATEL process:

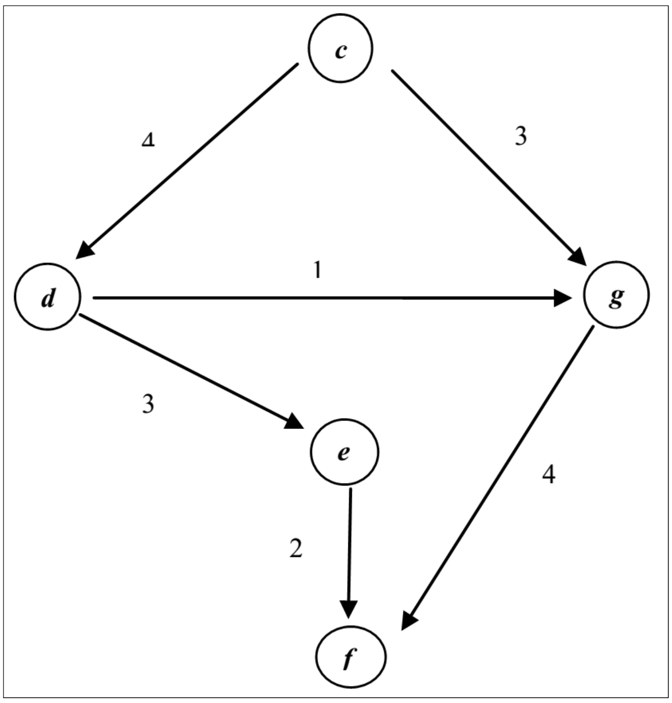
Step 1. The average matrix is calculated.

Suppose we have H experts in this study and n factors to consider. Each respondent is asked to indicate the degree to which he/she believes a factor, i, affects factor j. Pairwise comparisons between any two factors are denoted by x^k_{ij} and are given an integer score of 0 to 4, representing "No influence (0)", "Low influence (1)", "Medium influence (2)", "High influence (3)" and "Very high influence (4)" [68]. Figure 2 shows an example of an influence map. Each letter represents a factor in the system. An arrow from c to d shows the effect that c has on d; the strength of its effect is 4 (very high influence). DEMATEL can convert the structural relations between the factors of a system into an intelligible map of the system. The scores provided by each respondent provide an $n \times n$ non-negative answer matrix $\boldsymbol{X}^k = [x^k_{ij}]$, with $k = 1, 2, ..., H$. Therefore, $\boldsymbol{X}^1, \boldsymbol{X}^2, \ldots, \boldsymbol{X}^H$ are the answer matrices for each of the H experts, with each element of $\boldsymbol{X}^k = [x^k_{ij}]_{n \times n}$ being an integer denoted by x^k_{ij}. The diagonal elements of each answer matrix $\boldsymbol{X}^k = [x^k_{ij}]_{n \times n}$ are all set to 0. The $n \times n$ average matrix $\boldsymbol{A}$ for all expert opinions can then be computed by averaging the scores of the $\boldsymbol{H}$ experts as follows:

$$a_{ij} = \frac{1}{H} \sum_{k=1}^{H} x^k_{ij} \tag{3}$$

The average matrix $\boldsymbol{A} = [a_{ij}]_{n \times n}$ is also called the original average matrix. $\boldsymbol{A}$ shows the initial direct effects a factor has on and receives from other factors. The causal effect between each pair of factors in a system can be outlined by drawing an influence map, as shown in Figure 2.

Figure 2. Example of an influence map.



Step 2. Calculate the direct influence matrix.

The normalized initial direct-relation matrix $\boldsymbol{D}$ is obtained by normalizing the average matrix $\boldsymbol{A}$ in the following method:

$$\text{Let } S = \min\left(\max_{1 \le i \le n} \sum_{j=1}^{n} a_{ij}, \max_{1 \le j \le n} \sum_{i=1}^{n} a_{ij} \right) \tag{4}$$

Thus,

$$\boldsymbol{D} = \frac{\boldsymbol{A}}{s} \tag{5}$$

As the sum of each row j of matrix $\boldsymbol{A}$ represents the direct effects of factor on others, $\max_{1 \le i \le n} \sum_{j=1}^{n} a_{ij}$ represents the one with the highest direct influence. Likewise, as the sum of each column i of matrix $\boldsymbol{A}$ represents the direct effects received by factor i, $\max_{1 \le j \le n} \sum_{i=1}^{n} a_{ij}$ represents the one most influenced by other factors. The positive scalar s is equal to the larger of the two extreme sums. Matrix $\boldsymbol{D}$ is obtained by dividing each element of A by the scalar. Note that each element d_{ij} of matrix $\boldsymbol{D}$ is between 0 and 1.

Step 3. Compute the total relation matrix.

Indirect effects between factors are measured by powers of $\boldsymbol{D}$. Continuous decrease in the indirect effects of factors, including the powers of matrix $\boldsymbol{D}$, namely, $\boldsymbol{D}^2, \boldsymbol{D}^3, \ldots, \boldsymbol{D}^\infty$, guarantees convergent solutions to the matrix inversion similar to an absorbing Markov chain matrix. Note that $\lim_{m \to \infty} \boldsymbol{D}^m = [0]_{n \times n}$ and $\lim_{m \to \infty} (\boldsymbol{I} + \boldsymbol{D} + \boldsymbol{D}^2 + \boldsymbol{D}^3 + \ldots + \boldsymbol{D}^m) = (\boldsymbol{I} - \boldsymbol{D})^{-1}$, where *0* is the $n \times n$ null matrix and I is the $n \times n$ identity matrix. The total relation matrix $\boldsymbol{T}$ is an $n \times n$ matrix and is defined as follows:

$$\boldsymbol{T} = [t_{ij}] := \sum_{i=1}^{\infty} \boldsymbol{D}^i = \boldsymbol{D}(I - \boldsymbol{D})^{-1} \quad i, j = 1, 2, \ldots, n \tag{6}$$

As $\lim_{k \to \infty} \boldsymbol{D}^k = [0]_{n \times n}$ where $\boldsymbol{D} = [d_{ij}]_{n \times n}$, $0 \le d_{ij} < 1$, and $0 \le \left(\sum_i d_{ij}, \sum_j d_{ij} \right) < 1$. At least one column sum $\sum_j d_{ij}$ or one row sum $\sum_i d_{ij}$ equals 1.

We also define $\boldsymbol{r}$ and $\boldsymbol{c}$ as $n \times 1$ vectors representing the sum of the rows and the sum of the columns of the total relation matrix $\boldsymbol{T}$ as follows:

where superscript $'$ denotes transposition.

$$\boldsymbol{r} = [r_i]_{n \times 1} = \left(\sum_{j=1}^{n} t_{ij} \right)_{n \times 1} \tag{7}$$

$$\boldsymbol{c} = [c_j]'_{1 \times n} = \left(\sum_{i=1}^{n} t_{ij} \right)'_{1 \times n} \tag{8}$$

Let r_i be the sum of the i-th row in matrix $\boldsymbol{T}$. Therefore, r_i shows the total effects, both direct and indirect, of the i-th factor on other factors. Let c_j denote the sum of the j-th column in matrix $\boldsymbol{T}$.

The value c_j shows the total effects, both direct and indirect, received by factor j from other factors. Therefore, the sum ($r_i + c_i$) gives an index (*i.e.*, the position) representing the total effects both given and received by the i-th factor. In other words, ($r_i + c_i$) shows the degree of importance that the i-th factor plays in the system (*i.e.*, total sum of effects given and received). Moreover, the difference ($r_i - c_i$, also called the relation) shows the net effect; the i-th factor contributes to the system. When ($r_i - c_i$) is positive, the i-th factor is a net causer; when ($r_i - c_i$) is negative, the i-th factor is a net receiver [69,70].

Step 4. Set the Threshold Value and Obtain the Cognition Map.

To obtain the cognition map from the factors, a threshold value p should be established to extricate negligible effects from the total influence of matrix $\boldsymbol{T}$ [71]. Only some criteria, whose effect in matrix $\boldsymbol{T}$ is greater than the threshold value, should be chosen and shown in a network relationship map (NRM) for influence [70].

3.3. Combining DEMATEL and ANP to Calculate the Evaluation Weights by NRM

ANP is the general form of AHP, which is used in MCDM to address restrictions on hierarchical structures [72]. However, the survey questionnaire of ANP is too difficult for interviewees to accomplish [67,73]. Moreover, the traditional ANP assumption, that is, each cluster is of equal weight in obtaining a weighted supermatrix, is not reasonable [74–76]. To improve this shortcoming, we used a novel combination of DEMATEL and ANP technique called DANP to determine the influential weights of the criteria based on the NRM of DEMATEL. Recently, DANP has been widely applied in different areas of tourism policy [77], best vendor selection [75], performance evaluation for hot spring hotels [67], and web sites of national parks [78]. The DANP process has the following steps:

Step 1. Establishing an unweighted super matrix.

The total-influenced matrix is obtained from DEMATEL. Each column is summed up for normalization. The total-influenced matrix $\boldsymbol{T_c} = \left[\boldsymbol{t_{ij}}\right]_{nxn}$ is obtained by the criteria, and $\boldsymbol{T_D} = \left[\boldsymbol{t_{ij}^D}\right]_{mxm}$ is obtained by the dimensions (clusters) from $\boldsymbol{T_c}$. Next, the supermatrix $\boldsymbol{T_c}$ is normalized for the ANP weights of the dimensions (clusters) using the influence matrix $\boldsymbol{T_D}$.

$$\boldsymbol{T_c} = \begin{array}{cc} & \begin{array}{ccccc} \boldsymbol{D_1} & & \boldsymbol{D_j} & & \boldsymbol{D_n} \\ c_{11}\ldots c_{1m_1} & \cdots & c_{j1}\ldots c_{jm_j} & \cdots & c_{n1}\ldots c_{nm_n} \end{array} \\ \begin{array}{cc} \boldsymbol{D_1} & \begin{array}{c} c_{11} \\ c_{12} \\ \vdots \\ c_{1m_1} \end{array} \\ \vdots & \\ \boldsymbol{D_i} & \begin{array}{c} c_{21} \\ c_{22} \\ \vdots \\ c_{2m_2} \end{array} \\ \vdots & \vdots \\ \boldsymbol{D_3} & \begin{array}{c} c_{n1} \\ c_{n2} \\ \vdots \\ c_{nm_n} \end{array} \end{array} & \left[\begin{array}{ccccc} \boldsymbol{T}_c^{11} & \cdots & \boldsymbol{T}_c^{1j} & \cdots & \boldsymbol{T}_c^{1n} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{T}_c^{i1} & \cdots & \boldsymbol{T}_c^{ij} & \cdots & \boldsymbol{T}_c^{in} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{T}_c^{n1} & \cdots & \boldsymbol{T}_c^{nj} & \cdots & \boldsymbol{T}_c^{nn} \end{array}\right] \end{array} \quad (9)$$

After normalizing the total-influence matrix $\boldsymbol{T}_c$ through the dimensions (clusters), a new matrix $\boldsymbol{T}_c^{\alpha}$ is obtained, as shown in Equation (8).

$$\boldsymbol{T}_c^{\alpha} = \begin{array}{c} \\ D_1 \\ \vdots \\ D_i \\ \vdots \\ D_n \end{array} \begin{array}{c} \\ c_{11} \; c_{12} \cdots c_{1m_1} \\ c_{21} \; c_{22} \cdots c_{2m_2} \\ \vdots \\ c_{n1} \; c_{n2} \cdots c_{nm_n} \end{array} \overset{\begin{array}{ccccc} D_1 & & D_j & & D_n \\ c_{11}...c_{1m_1} & & c_{j1}...c_{jm_j} & \cdots & c_{n1}...c_{nm_n} \end{array}}{\begin{bmatrix} \boldsymbol{T}_c^{\alpha 11} & \cdots & \boldsymbol{T}_c^{\alpha 1j} & \cdots & \boldsymbol{T}_c^{\alpha 1n} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{T}_c^{\alpha i1} & \cdots & \boldsymbol{T}_c^{\alpha ij} & \cdots & \boldsymbol{T}_c^{\alpha in} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{T}_c^{\alpha n1} & \cdots & \boldsymbol{T}_c^{\alpha nj} & \cdots & \boldsymbol{T}_c^{\alpha nn} \end{bmatrix}} \tag{10}$$

The normalization $\boldsymbol{T}_c^{\alpha 11}$ is explained and that of the other $\boldsymbol{T}_c^{ann}$ is the same as above.

$$d_{ci}^{11} = \sum_{j=1}^{m_1} t_{ij}^{11}, \; i = 1,2,...,m_1 \tag{11}$$

$$\boldsymbol{T}_c^{\alpha 11} = \begin{bmatrix} t_{c11}^{11}/d_{c1}^{11} & \cdots & t_{c1j}^{11}/d_{c1}^{11} & \cdots & t_{c1m_1}^{11}/d_{c1}^{11} \\ \vdots & & \vdots & & \vdots \\ t_{ci1}^{11}/d_{ci}^{11} & \cdots & t_{cij}^{11}/d_{ci}^{11} & \cdots & t_{cim_1}^{11}/d_{ci}^{11} \\ \vdots & & \vdots & & \vdots \\ t_{cm_11}^{11}/d_{cm_1}^{11} & \cdots & t_{cm_1j}^{11}/d_{cm_1}^{11} & \cdots & t_{cm_1m_1}^{11}/d_{cm_1}^{11} \end{bmatrix} = \begin{bmatrix} t_{c11}^{\alpha 11} & \cdots & t_{c1j}^{\alpha 11} & \cdots & t_{c1m_1}^{\alpha 11} \\ \vdots & & \vdots & & \vdots \\ t_{ci1}^{\alpha 11} & \cdots & t_{cij}^{\alpha 11} & \cdots & t_{cim_1}^{\alpha 11} \\ \vdots & & \vdots & & \vdots \\ t_{cm_11}^{\alpha 11} & \cdots & t_{cm_1j}^{\alpha 11} & \cdots & t_{cm_1m_1}^{\alpha 11} \end{bmatrix} \tag{12}$$

Let the total-influence matrix match and fall into the interdependence clusters. The result is the unweighted supermatrix, which is based on the transposition of the normalized influence matrix $\boldsymbol{T}_c^{\alpha}$ by the dimensions (clusters), that is, $\boldsymbol{W} = (\boldsymbol{T}_c^{\alpha})'$.

$$\boldsymbol{W} = (\boldsymbol{T}_c^{\alpha})' = \begin{array}{c} \\ D_1 \\ \vdots \\ D_i \\ \vdots \\ D_n \end{array} \begin{array}{c} \\ c_{11} \; c_{12} \cdots c_{1m_1} \\ c_{21} \; c_{22} \cdots c_{2m_2} \\ \vdots \\ c_{n1} \; c_{n2} \cdots c_{nm_n} \end{array} \overset{\begin{array}{ccccc} D_1 & & D_j & & D_n \\ c_{11}...c_{1m_1} & & c_{j1}...c_{jm_j} & \cdots & c_{n1}...c_{nm_n} \end{array}}{\begin{bmatrix} \boldsymbol{W}^{11} & \cdots & \boldsymbol{W}^{i1} & \cdots & \boldsymbol{W}^{n1} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{W}^{1j} & \cdots & \boldsymbol{W}^{ij} & \cdots & \boldsymbol{W}^{nj} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{W}^{1n} & \cdots & \boldsymbol{W}^{in} & \cdots & \boldsymbol{W}^{nn} \end{bmatrix}} \tag{13}$$

If the matrix $\boldsymbol{W}^{11}$ is blank or 0 as shown as Equation (14), then the matrix between the clusters or the criteria is independent and has no interdependent. The other $\boldsymbol{W}^{nn}$ value are as above.

$$\boldsymbol{W}^{11} = (\boldsymbol{T}^{11})' = \begin{array}{c} \\ \boldsymbol{c}_{11} \\ \vdots \\ \boldsymbol{c}_{1j} \\ \vdots \\ \boldsymbol{c}_{1m_1} \end{array} \begin{array}{c} \begin{array}{ccccc} \boldsymbol{c}_{11} & \cdots & \boldsymbol{c}_{1i} & \cdots & \boldsymbol{c}_{1m_1} \end{array} \\ \begin{bmatrix} t_{c11}^{\alpha 11} & \cdots & t_{ci1}^{\alpha 11} & \cdots & t_{cm_1 1}^{\alpha 11} \\ \vdots & & \vdots & & \vdots \\ t_{c1j}^{\alpha 11} & \cdots & t_{cij}^{\alpha 11} & \cdots & t_{cm_1 j}^{\alpha 11} \\ \vdots & & \vdots & & \vdots \\ t_{c1m_1}^{\alpha 11} & \cdots & t_{cim_1}^{\alpha 11} & \cdots & t_{cm_1 m_1}^{\alpha 11} \end{bmatrix} \end{array} \quad (14)$$

Step 2. Obtaining the weighted supermatrix

Each column is added for normalization.

$$\boldsymbol{T}_D = \begin{bmatrix} t_D^{11} & \cdots & t_D^{1j} & \cdots & t_D^{1n} \\ \vdots & & \vdots & & \vdots \\ t_D^{i1} & \cdots & t_D^{ij} & \cdots & t_D^{in} \\ \vdots & & \vdots & & \vdots \\ t_D^{n1} & \cdots & t_D^{nj} & \cdots & t_D^{nn} \end{bmatrix} \quad (15)$$

The total-influence matrix $\boldsymbol{T}_D$ is normalized, and a new matrix $\boldsymbol{T}_D^{\alpha}$ is obtained, where $t_D^{\alpha ij} = t_D^{ij} / d_i$.

$$\boldsymbol{T}_D^{\alpha} = \begin{bmatrix} t_D^{11}/d_1 & \cdots & t_D^{1j}/d_1 & \cdots & t_D^{1n}/d_1 \\ \vdots & & \vdots & & \vdots \\ t_D^{i1}/d_i & \cdots & t_D^{ij}/d_i & \cdots & t_D^{in}/d_i \\ \vdots & & \vdots & & \vdots \\ t_D^{n1}/d_n & \cdots & t_D^{nj}/d_n & \cdots & t_D^{nn}/d_n \end{bmatrix} = \begin{bmatrix} t_D^{\alpha 11} & \cdots & t_D^{\alpha 1j} & \cdots & t_D^{\alpha 1n} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha i1} & \cdots & t_D^{\alpha ij} & \cdots & t_D^{\alpha in} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha n1} & \cdots & t_D^{\alpha nj} & \cdots & t_D^{\alpha nn} \end{bmatrix} \quad (16)$$

Let the normalized total-influence matrix $\boldsymbol{T}_D^{\alpha}$ complete the unweighted supermatrix to obtain the weighted supermatrix.

$$\boldsymbol{W}^{\alpha} = \boldsymbol{T}_D^{\alpha} \boldsymbol{W} = \begin{bmatrix} t_D^{\alpha 11} \times \boldsymbol{W}^{11} & \cdots & t_D^{\alpha i1} \times \boldsymbol{W}^{1j} & \cdots & t_D^{\alpha n1} \times \boldsymbol{W}^{1n} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha 1j} \times \boldsymbol{W}^{i1} & \cdots & t_D^{\alpha ij} \times \boldsymbol{W}^{ij} & \cdots & t_D^{\alpha nj} \times \boldsymbol{W}^{in} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha 1n} \times \boldsymbol{W}^{n1} & \cdots & t_D^{\alpha in} \times \boldsymbol{W}^{nj} & \cdots & t_D^{\alpha nn} \times \boldsymbol{W}^{nn} \end{bmatrix} \quad (17)$$

Step 3. Limiting the weighted supermatrix.

The weighted supermatrix is limited by raising it to a sufficiently large power k until the supermatrix converges and becomes a long-term stable supermatrix to obtain the global priority vectors (called the DANP weights), such as $\lim_{\boldsymbol{h}\to\infty}(\boldsymbol{W}^{\alpha})^{\boldsymbol{h}}$.

3.4. Ranking the Alternatives Using the VIKOR Method

The compromise ranking method (known as VIKOR) was introduced as an applicable technique to implement in MCDM [79]. It is based on the concept of the positive- and negative-ideal solution to evaluate the standard of different projects competing with the MCDM model [80]. The positive-ideal solution represents the alternative with the highest value, whereas the negative-ideal represents that with the lowest value. Similar to some MCDM methods, such as TOPSIS, VIKOR relies on an aggregating function that represents closeness to the ideal. In contrast to TOPSIS, however, VIKOR introduces a ranking index based on the particular measure of closeness to the ideal solution; this method uses linear normalization to eliminate units of criterion functions [80]. VIKOR ranks and selects from a set of alternatives, determines compromise solutions for a problem with conflicting criteria, and assists decision makers in generating the final decision [81]. Various studies regarded VIKOR as a suitable technique to evaluate each alternative for each criterion function [80,82]. The compromise ranking algorithm VIKOR has the following steps [81–83]:

Step 1. Determine the best and the worst values.

The best value is f_j^* and the worst is f_j^-. These two values can be computed by Equations (18) and (19), respectively.

$$f_j^* = \max_i f_{ij}, i = 1, 2, ...m \tag{18}$$

$$f_j^- = \min_i f_{ij}, i = 1, 2, ...m \tag{19}$$

where, f_j^* is the positive-ideal solution and f_j^- is the negative-ideal solution for the *j*th criterion.

Step 2. Calculate the distance.

In this step, the distance from each alternative to the positive ideal solution is computed.

$$S_i = \sum_{j=1}^{n} w_j \left(\left|f_j^* - f_{ij}\right|\right) / \left(\left|f_j^* - f_j^-\right|\right) \tag{20}$$

$$Q_i = \max_i \left\{w_j \left(\left|f_j^* - f_{ij}\right|\right) / \left(\left|f_j^* - f_j^-\right|\right) \middle| j = 1, 2, ...n\right\} \tag{21}$$

where w_j represents the weights of the criteria from DANP, S_i indicates the mean of group utility and represents the distance of the *i*th alternative achievement to the positive ideal solution; and Q_i represents the maximal regret of each alternative.

Step 3. Calculate the values R_i by the relation [80].

$$R_i = v\left[\frac{S_i - S^*}{S^- - S^*}\right] + (1 - v)\left[\frac{Q_i - Q^*}{Q^- - Q^*}\right] \tag{22}$$

where $S^* = \min_i S_i$, $S^* = \min_i S_i$, $S^- = \max_i S_i$, $Q^* = \min_i Q_i$, $Q^- = \max_i Q_i$.

Equation (22) can be rewritten as $R_i = vS_i + (1-v)Q_i$, when $S^* = 0$ and $Q^* = 0$ (*i.e.*, all criteria achieve the ideal level) and $S^- = 1$ and $Q^- = 1$ (*i.e.*, the worst situation). In the equation, v is introduced as the weight for the strategy of maximum group utility, and *1-v* is the weight of the individual regret. In Equation (22), when $v = 1$, it indicates the decision-making process that can use the strategy of maximum group utility. Conversely, when $v = 0$, it indicates the decision-making process that can use the strategy of minimum individual regret. In general, $v = 0.5$ will be used if the decision process involves both maximum group utility and individual regret [82,83]. The compromise solution is determined by VIKOR, and it can be accepted by the decision makers based on a maximum group utility of the majority and a minimum of the individual regret of the opponent.

4. A Hotel Company as an Example

In this section, an example demonstrates the proposed model for supplier selection in terms of carbon management competence. The *M* hotel, an ordinary tourist hotel with rooms priced accordingly, had its grand opening in 2006. It provides exceptional, high-quality facilities and services at reasonable prices to satisfy the demand for accommodations, food and beverages, and leisure services of local and foreign tourists. The *M* hotel also advocates three environmental visions, that is, "Environment, Energy Conservation, Carbon Reduction", including sustainable development processes. To facilitate low carbon hotel operations, the *M* hotel launched various measures of energy conservation and carbon reduction, such as food mile management, electricity monitor systems, and energy efficiency improvement. In 2011, *M* hotel also acquired the certification of Energy Management Systems-ISO 50001 to mitigate carbon emission and to manage energy effectively. However, in achieving low carbon operations, *M* hotel encountered critical challenges in determining appropriate suppliers for long-term collaborative partnership in the low carbon supply chain. At least 80% of carbon emissions are produced in the total supply chain. The ISO 50001 requires suppliers to provide energy-efficient products. Thus, the *M* hotel used the proposed framework to select low carbon suppliers. In this study, five suppliers (S1, S2, S3, S4, and S5) of the hotel company in the case study were demonstrated to assess the carbon performance of the 10 criteria identified. Three managers in the case company conducting the assessment were responsible in the fields of supplier management, procurement management, and energy management. Managers used a five-point scale (*i.e.*, 0 bad, 1 low, 2 moderate, 3 good, and 4 excellent performance) to evaluate the suppliers. After that, the authors evaluated these merchants using the hybrid MCDM model that combines DANP with VIKOR.

4.1. Identifying the Consistency of the Evaluation Criteria

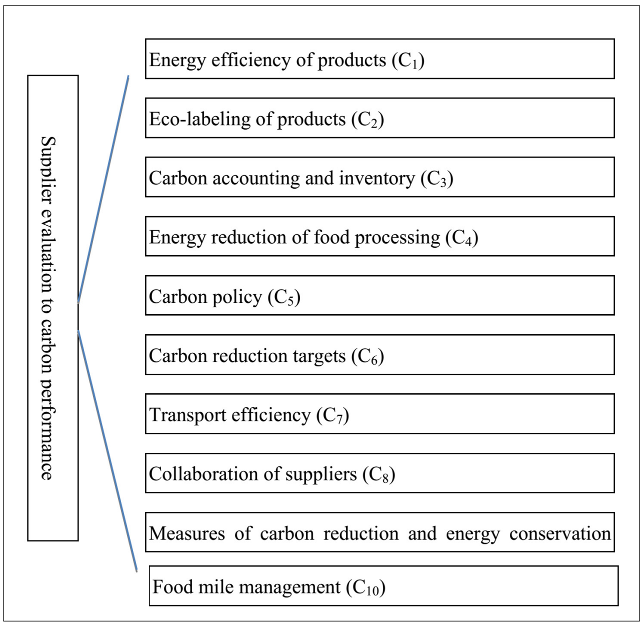
Considering the situation of carbon management of suppliers in the Taiwanese hotel industry, a draft of the evaluation framework should be confirmed first by experts. Eight experts were invited in the FDM process to express their opinions on identifying the consistency of evaluation criteria for the selection of low carbon suppliers. Considering the practice experience in the field of carbon management in the hotel industry, the study identified five managers from hotel firms, who were responsible for the implementation of green procurement and energy management, and three university professors whose research were related to carbon and energy management in the hotel industry.

The 12 initial criteria were used as the basis for questionnaire development. The FDM technique was used to screen and fit the factors. First, the expert group average was calculated for the conservative and optimistic values of each measure *i*. Anything outside the two standard deviations was eliminated. Subsequently, the minimum (C_L^i), geometric mean (C_M^i), and maximum (C_U^i) of the conservative values, as well as the minimum (O_L^i), geometric mean (O_M^i), and maximum (O_U^i) of the optimistic values, were calculated (Table 1). The values of M^i and Z^i were also calculated to determine the consistency of expert opinions. The differences were convergent, and the consensus value of G_i was calculated to screen the indicators [60,59]. The threshold value was set to 6.0. The agreed proportion of experts was more than 80%. Based on this principle, the two criteria, namely, "carbon governance" and "carbon management systems", were excluded, as shown in Table 1. These criteria were used as the basis for selecting the 10 criteria for low carbon supplier selection in the hotel industry, as shown in Figure 3.

Table 1. Results of calculation of factors with FDM.

Criteria	Pessimistic value		Optimistic value		Geometric mean		$M^i - Z^i$	Consensus value
	C_L^i	C_U^i	O_L^i	O_U^i	C_M^i	O_M^i		G^i
Energy efficiency of products	3	9	7	10	5.49	7.81	0.32	7.38 > 6.0
Eco-labeling of products	5	9	7	10	6.50	8.52	0.02	7.76 > 6.0
Carbon accounting and inventory	3	7	5	10	5.10	7.61	0.51	6.16 > 6.0
Energy reduction of food processing	3	9	7	10	6.36	8.91	0.55	7.84 > 6.0
Carbon governance	1	7	3	10	4.07	6.55	−1.52	5.19 < 6.0
Carbon policy	5	9	7	10	6.10	8.41	0.30	7.65 > 6.0
Carbon reduction targets	3	7	5	10	5.21	7.63	0.42	6.19 > 6.0
Carbon and energy management systems	3	5	5	9	4.32	6.92	2.59	5.62 < 6.0
Transport efficiency	3	9	7	10	6.43	8.79	0.36	7.82 > 6.0
Collaboration of suppliers	3	9	7	10	5.17	7.91	0.74	7.39 > 6.0
Measures of carbon reduction and energy conservation	5	9	9	10	6.93	9.49	2.56	8.21 > 6.0
Food mile management	3	9	7	10	5.84	8.50	0.66	7.64 > 6.0

Figure 3. The framework of low carbon supplier selection.



4.2. Determining the Relationships between Criteria by DEMATEL

The DEMATEL method was used to examine interdependent and influence relationships between 10 criteria using the results of FDM. The eight experts were asked to complete the questionnaires using a five-point scale (*i.e.*, 0 for no influence, 1 for low, 2 for moderate, 3 for high, and 4 for very high) to indicate the influence of each criterion on another one in their respective organization. The average initial influence 10 × 10 matrix ***A*** (Table 2) was obtained by pairwise comparison in terms of influences and directions. The normalized initial direct-relation matrix ***D*** was calculated using Equations (3) to (5) (Table 3). The total influence matrix ***T*** (Table 4) was derived by Equation (6). The NRM of the influential relationship was constructed by vectors ***r*** and ***c*** (Table 5) using Equations (7) and (8), as shown in Figure 4.

Table 2. The initial influence matrix.

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
C_1	0.000	3.600	2.400	0.200	2.400	2.800	2.600	2.000	2.800	2.000
C_2	3.600	0.000	3.200	1.800	3.200	3.400	3.000	2.600	3.000	2.000
C_3	3.000	2.400	0.000	1.400	3.600	3.800	3.000	3.000	3.200	2.600
C_4	1.400	2.200	1.000	0.000	1.600	1.800	1.200	1.800	1.800	2.000
C_5	3.000	2.600	3.000	1.200	0.000	3.200	3.400	3.400	3.800	2.800
C_6	3.200	2.600	3.000	0.400	3.600	0.000	3.400	3.600	3.400	2.800
C_7	1.600	2.600	2.800	0.800	3.000	3.000	0.000	2.800	3.000	2.000
C_8	2.600	2.800	3.000	1.000	2.800	3.200	2.200	0.000	2.600	2.200
C_9	3.000	2.800	3.600	1.200	3.400	3.400	2.800	3.200	0.000	2.800
C_{10}	1.800	2.200	2.600	2.200	2.800	2.800	2.200	3.200	2.800	0.000

Table 3. The normalized direct-influence matrix.

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
C_1	0.000	0.131	0.088	0.007	0.088	0.102	0.095	0.073	0.102	0.073
C_2	0.131	0.000	0.117	0.066	0.117	0.124	0.109	0.095	0.109	0.073
C_3	0.109	0.088	0.000	0.051	0.131	0.139	0.109	0.109	0.117	0.095
C_4	0.051	0.080	0.036	0.000	0.058	0.066	0.044	0.066	0.066	0.073
C_5	0.109	0.095	0.109	0.044	0.000	0.117	0.124	0.124	0.139	0.102
C_6	0.117	0.095	0.109	0.015	0.131	0.000	0.124	0.131	0.124	0.102
C_7	0.058	0.095	0.102	0.029	0.109	0.109	0.000	0.102	0.109	0.073
C_8	0.095	0.102	0.109	0.036	0.102	0.117	0.080	0.000	0.095	0.080
C_9	0.109	0.102	0.131	0.044	0.124	0.124	0.102	0.117	0.000	0.102
C_{10}	0.066	0.080	0.095	0.080	0.102	0.102	0.080	0.117	0.102	0.000

Table 4. The total influence matrix.

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
C_1	0.541	0.656	0.655	0.246	0.686	0.715	0.642	0.653	0.695	0.554
C_2	**0.758**	0.641	0.785	0.340	**0.822**	**0.849**	**0.758**	**0.781**	**0.814**	0.646
C_3	0.748	0.729	0.690	0.331	**0.844**	**0.871**	**0.767**	**0.804**	**0.830**	0.673
C_4	0.426	0.451	0.437	0.167	0.477	0.496	0.429	0.471	0.482	0.408
C_5	**0.756**	0.744	**0.798**	0.330	0.737	**0.864**	**0.787**	**0.824**	**0.856**	0.686

Table 4. *Cont.*

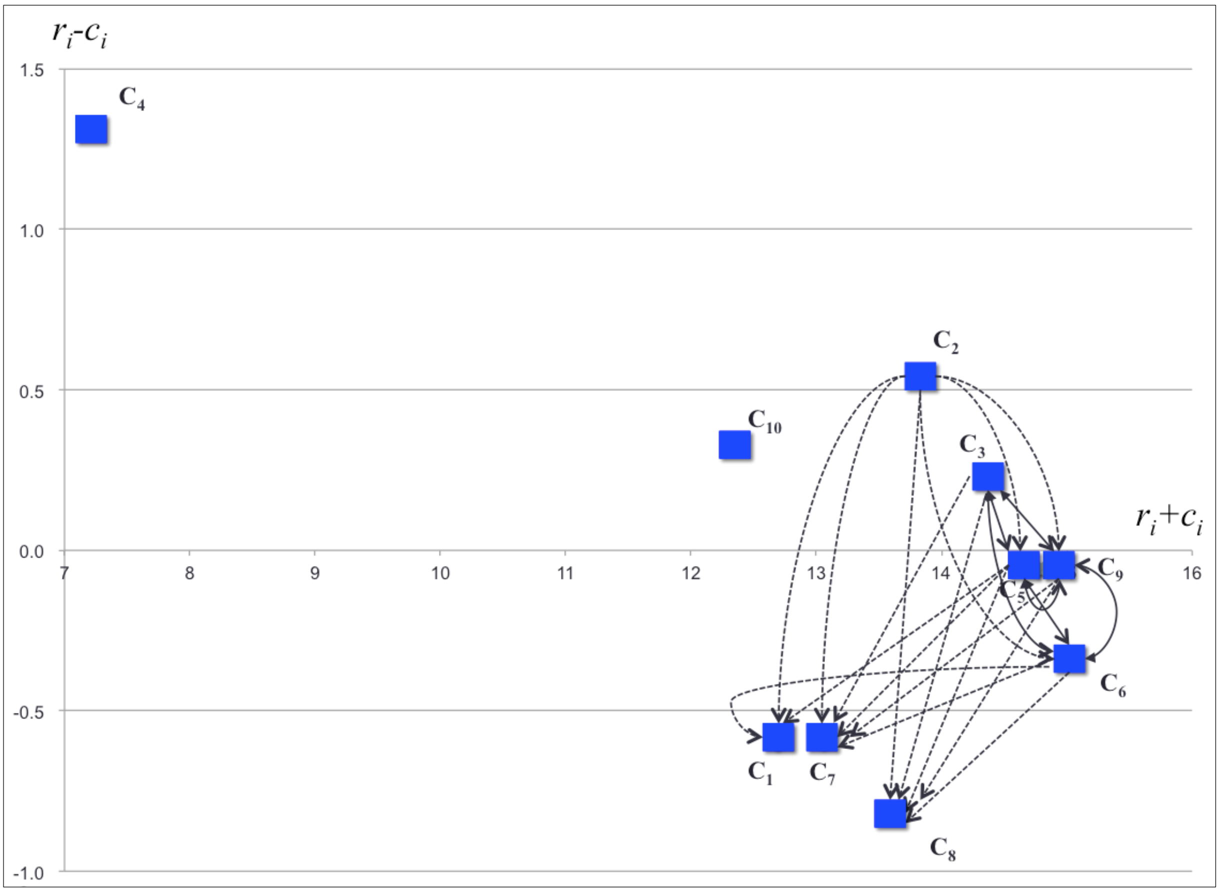
Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
C_6	**0.759**	0.741	**0.795**	0.302	**0.850**	0.756	**0.784**	**0.827**	**0.841**	0.683
C_7	0.612	0.640	0.684	0.272	0.722	0.740	0.571	0.696	0.719	0.570
C_8	0.658	0.662	0.705	0.285	0.732	0.763	0.661	0.619	0.723	0.589
C_9	0.754	0.747	**0.813**	0.329	**0.845**	**0.867**	**0.767**	**0.816**	0.731	0.684
C_{10}	0.625	0.637	0.685	0.322	0.724	0.742	0.652	0.717	0.721	0.509

Threshold value: 0.756, the values were marked when higher than the threshold value.

Table 5. The sum of influences giving and received.

Criteria	r_i	c_i	$r_i + c_i$	$r_i - c_i$
C_1	6.041	6.638	12.680	−0.597
C_2	7.194	6.648	13.842	0.546
C_3	7.287	7.045	14.332	0.242
C_4	4.244	2.924	7.168	1.320
C_5	7.382	7.440	14.822	−0.059
C_6	7.339	7.663	15.002	−0.323
C_7	6.225	6.818	13.043	−0.593
C_8	6.396	7.206	13.603	−0.810
C_9	7.353	7.411	14.764	−0.058
C_{10}	6.334	6.002	12.337	0.3320

Figure 4. The causal diagram.



4.3. Finding the Influential Weight of Criteria by DANP

This study used the DANP to obtain the weights of the 10 criteria based on the influence network of the total influence matrix ***T*** of DEMATEL. DANP was used to calculate an unweighted supermatrix (Table 6) and weighted supermatrix (Table 7). The limiting power of the weighted supermatrix to confirm the supermatrix was converged and became a long-term stable supermatrix, obtaining the weights of all criteria (Table 8). Each row represents the weights of each criterion.

Table 6. Unweighted supermatrix based on DANP.

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
C_1	0.5409	0.6556	0.6548	0.2457	0.6857	0.7152	0.6422	0.6530	0.6946	0.5538
C_2	0.7580	0.6410	0.7847	0.3400	0.8224	0.8495	0.7576	0.7809	0.8137	0.6464
C_3	0.7480	0.7294	0.6898	0.3315	0.8443	0.8712	0.7666	0.8036	0.8296	0.6729
C_4	0.4262	0.4511	0.4366	0.1668	0.4773	0.4959	0.4293	0.4706	0.4817	0.4084
C_5	0.7560	0.7440	0.7981	0.3295	0.7374	0.8636	0.7865	0.8244	0.8561	0.6862
C_6	0.7593	0.7407	0.7954	0.3025	0.8504	0.7556	0.7841	0.8270	0.8414	0.6830
C_7	0.6122	0.6402	0.6836	0.2723	0.7218	0.7397	0.5713	0.6959	0.7186	0.5695
C_8	0.6580	0.6622	0.7047	0.2848	0.7321	0.7627	0.6612	0.6186	0.7231	0.5889
C_9	0.7544	0.7472	0.8129	0.3287	0.8453	0.8668	0.7666	0.8158	0.7315	0.6841
C_{10}	0.6252	0.6371	0.6845	0.3219	0.7238	0.7424	0.6524	0.7167	0.7209	0.5093

Table 7. Weighted supermatrix based on DANP.

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
C_1	0.0895	0.1054	0.1027	0.1004	0.1024	0.1035	0.0983	0.1029	0.1026	0.0987
C_2	0.1085	0.0891	0.1001	0.1063	0.1008	0.1009	0.1028	0.1035	0.1016	0.1006
C_3	0.1084	0.1091	0.0947	0.1029	0.1081	0.1084	0.1098	0.1102	0.1105	0.1081
C_4	0.0407	0.0473	0.0455	0.0393	0.0446	0.0412	0.0437	0.0445	0.0447	0.0508
C_5	0.1135	0.1143	0.1159	0.1125	0.0999	0.1159	0.1160	0.1145	0.1150	0.1143
C_6	0.1184	0.1181	0.1196	0.1169	0.1170	0.1030	0.1188	0.1192	0.1179	0.1172
C_7	0.1063	0.1053	0.1052	0.1012	0.1066	0.1068	0.0918	0.1034	0.1043	0.1030
C_8	0.1081	0.1085	0.1103	0.1109	0.1117	0.1127	0.1118	0.0967	0.1109	0.1131
C_9	0.1150	0.1131	0.1138	0.1135	0.1160	0.1146	0.1154	0.1130	0.0995	0.1138
C_{10}	0.0917	0.0898	0.0923	0.0962	0.0930	0.0931	0.0915	0.0921	0.0930	0.0804

Table 8. Influential weights of stable matrix of DANP.

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
C_1	0.1008	0.1008	0.1008	0.1008	0.1008	0.1008	0.1008	0.1008	0.1008	0.1008
C_2	0.1012	0.1012	0.1012	0.1012	0.1012	0.1012	0.1012	0.1012	0.1012	0.1012
C_3	0.1073	0.1073	0.1073	0.1073	0.1073	0.1073	0.1073	0.1073	0.1073	0.1073
C_4	0.0444	0.0444	0.0444	0.0444	0.0444	0.0444	0.0444	0.0444	0.0444	0.0444
C_5	0.1131	0.1131	0.1131	0.1131	0.1131	0.1131	0.1131	0.1131	0.1131	0.1131
C_6	0.1164	0.1164	0.1164	0.1164	0.1164	0.1164	0.1164	0.1164	0.1164	0.1164
C_7	0.1036	0.1036	0.1036	0.1036	0.1036	0.1036	0.1036	0.1036	0.1036	0.1036
C_8	0.1094	0.1094	0.1094	0.1094	0.1094	0.1094	0.1094	0.1094	0.1094	0.1094
C_9	0.1127	0.1127	0.1127	0.1127	0.1127	0.1127	0.1127	0.1127	0.1127	0.1127
C_{10}	0.0912	0.0912	0.0912	0.0912	0.0912	0.0912	0.0912	0.0912	0.0912	0.0912

After the weights of the criteria were determined by DANP, the VIKOR method was used to evaluate the carbon performance of supplier selection (Table 9). In this study, five suppliers (S1, S2, S3, S4, and S5) of the hotel company in the case study were shown to assess carbon performance according to the 10 criteria identified. Three managers in the case company conducting the assessment were responsible for the fields of supplier management, procurement management, and energy management. Managers used a five-point scale (*i.e.*, 0 = bad, 1 = low, 2 = moderate, 3 = good, and 4 = excellent performance) to evaluate the suppliers. Then, the authors evaluated these merchants by using the hybrid MCDM model, which combines DANP with VIKOR. The average performance scores of each merchant through the VIKOR method were used to obtain the performance and the ideal level gaps among the suppliers, as shown in Table 9. Given the ease of use of the proposed model in the case company, in this research, *v* value of VIKOR was set to 0.5 based on both maximum group utility and individual regret in the expert opinions. As R_i represents the gap between the alternative and the ideal solution, S_3 contains the smallest gap in terms of the value of VIKOR, followed by S_1, S_2, S_5, and S_4. The sum of these values for each alternative is provided in Table 9, which shows that S_3 is the best supplier.

Table 9. VIKOR results.

Supplier	S_i	Q_i	R_i	Ranking
S_1	0.536	0.087	0.312	2
S_2	0.635	0.113	0.374	3
S_3	0.474	0.085	0.279	1
S_4	0.785	0.116	0.450	5
S_5	0.641	0.116	0.379	4

5. Results and Discussion

We present the following results of our proposed MCDM model that can facilitate low carbon supplier selection in the hotel industry. First, the FDM method was used to identify the consistency of the selection criteria for low carbon suppliers through expert opinions. The threshold value was set to 6.0; the agreed proportion of experts was more than 80%. With this principle, the two criteria, namely, "carbon governance" and "carbon management systems" were excluded, as shown in Table 1. These criteria were used as the basis for selecting the 10 criteria for the selection of low carbon suppliers in the hotel industry, as shown in Figure 3.

Second, the NRM of the criteria was recognized by DEMATEL. The influential relationship within the 10 criteria was revealed. Considering the significance of carbon management in supplier selection, as presented in Table 5, the importance is identified as $C_6 > C_5 > C_9 > C_3 > C_2 > C_8 > C_7 > C_1 > C_{10} > C_4$ according to the degree of importance ($r_i + c_i$). Contrary to the importance of criteria, energy reduction of food processing (C_4), eco-labeling of products (C_2), food mile management (C_{10}), and carbon accounting and inventory (C_3) are net causers in accordance with the value of difference ($r_i - c_i$). As indicated in the causal relationships in Figure 4 and Table 5, C_2 affects criteria C_1, C_3, C_5, C_6, C_7, C_8, and C_9; C_3 affects criteria C_5, C_6, C_7, C_8, and C_9. Although C_4 and C_{10} are net causers, they have no influence on other criteria in terms of the threshold value, which is less than 0.756. All relationships that met or exceeded the threshold were rendered in boldface, as shown in Table 4, matrix ***T***.

By following this principle, Figure 4 depicts the influence map of the 10 mutually interdependent criteria. One-way relationships are represented by dashed lines, while two-way relationships are represented by solid lines. By understanding these influential relationships, managers can focus on the two criteria of eco-labeling of products (C_2) and carbon accounting and inventory (C_3) to determine how green suppliers are exposed to carbon risk. By following the causal relationship of DEMATEL, managers can clearly understand the criterion to improve the management of low carbon suppliers.

Third, the influential weights of criteria were determined by DANP. In terms of the relative weights of criteria for evaluating carbon performance of suppliers, "carbon reduction targets (C_6)" (0.1164), "carbon policy (C_5)" (0.1131), and "measures of carbon reduction and energy conservation (C_9)" (0.1127) are the top three significant evaluation criteria. To improve the low carbon supply chain, setting the targets of carbon emission reduction is important so suppliers can monitor authentic and measurable progress in addressing climate change. To achieve the targets of carbon reduction, suppliers should launch various climate strategies that include quantitative emission reduction targets for their scopes 1 and 2, and occasionally even scope 3, GHG emissions [34]. Subsequent results show that "measures of carbon reduction (C_9)" is the third important criterion. The criterion of carbon policy (C_5) is the second most important. While the supplier launches the carbon policy, the company can facilitate carbon management practices by establishing a carbon policy to show its position on carbon emission disclosure, reduction targets, and emission certification, among others [12]. Considering the significant weights of the criteria, managers should select the best and appropriate suppliers through the VIKOR method of the proposed MCDM model. Finally, S_3 is selected as best carbon performance of five suppliers.

6. Conclusions and Future Research

To promote low carbon operations in the hotel industry, the selection of suppliers in the field of carbon and energy management is important in achieving the target of the low carbon supply chain. We presented a supply chain-based conceptual framework and an operational model to incorporate carbon management into supplier selection in the hotel industry. By identifying the related criteria of carbon management activities for the proposed framework, which is a hybrid MCDM model, an integration of FDM, DANP, and VIKOR methods was applied in the empirical analysis on a hotel company for selecting low carbon suppliers.

The proposed framework brings several contributes to the evaluation and selection of low carbon suppliers in the hotel industry. First, a new hybrid MCDM model for evaluating suppliers, with emphasis on carbon and energy management, was developed using the FDM method. Such framework with 10 criteria is rare in the previous literature. Second, the DEMATEL method was applied in selecting suppliers in terms of carbon management. DEMATEL proved to be an appropriate method to delineate the structure of a completely interdependent supplier selection problem model and to obtain the problem's solution. Third, DANP was used to acquire considerable weights of the 10 criteria. The three important criteria, namely, carbon reduction targets, carbon policy, and measures of carbon reduction, were derived. Finally, an empirical study was conducted to demonstrate the application of hybrid MCDM model that combines DANP with VIKOR. The hybrid model also considers both maximum group utility and individual regret to measure the gaps between alternative and ideal solutions, which can enhance the assessment of carbon and energy management of suppliers when quantitative information is lacking. Based on the example, this model has potential advantage in selecting appropriate suppliers for carbon and energy management. A company in the hotel industry intending to facilitate a low carbon supply chain can adopt the presented model or align the suppliers' carbon management to its needs.

After the findings are discussed with three managers of the case company, carbon and energy management for supplier selection, regarded as an emerging parameter to facilitate low-carbon hotels, is also discussed. Initially, a low-carbon supplier scorecard can be adopted, and this can further integrate supplier evaluation in terms of the 10 criteria within the proposed framework. By incorporating the carbon issue into procurement policies, suppliers will be required to perform a preliminary self-assessment throughout the carbon management questionnaire. The case company can then obtain information on the carbon management capability of its suppliers, and this information would in turn help the suppliers identify and prioritize specific carbon risks. Meanwhile, firms can pay attention to the three criteria on carbon reduction targets (C_6), carbon policy (C_5), and measures of carbon reduction and energy conservation (C_9) to identify how their low-carbon supply chain suppliers are exposed to carbon risk. Finally, firms can launch collaborative training and capability building programs within their suppliers to mitigate carbon risk.

Although the results obtained from this research are satisfactory, there still a room for improvement. The outcome of the carbon performance model with the MCDM method conducted in this study was exclusively determined by eight experts. Increasing the number of participating experts from the hotel industry can give a more generalized model of suppliers' carbon management, thus paving the way for the mastery of carbon risk. The proposed framework and criteria on low-carbon supplier selection are applicable to the Taiwanese hotel industry; they can also serve as bases for further research on developing carbon management criteria in hotels in different regions or countries. In response to the preference of decision makers in assigning precise numerical values, fuzzy DANP and fuzzy VIKOR can be used in future studies.

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Author Contributions

Chia-Wei Hsu is responsible for conducting this research and wrote the paper. Tasi-Chi Kuo contributed to MCDM method and the identification of criteria in the area of carbon management. Guey-Shin Shyu contributed to the revisions and results analysis of manuscript. Pi-Shen Chen contributed to questionnaire development and data analysis.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. Chan, W.W.; Mak, L.M.; Chen, Y.M.; Wang, Y.H.; Xie, H.R.; Hou, G.Q.; Li, D. Energy saving and tourism sustainability: Solar control window film in hotel rooms. *J. Sustain. Tour* **2008**, *16*, 563–574.
2. Filimonau, V.; Dickinson, J.; Robbins, D.; Huijbregts, M.A. Reviewing the carbon footprint analysis of hotels: Life Cycle Energy Analysis (LCEA) as a holistic method for carbon impact appraisal of tourist accommodation. *J. Cleaner Prod.* **2011**, *19*, 1917–1930.
3. Su, Y.P.; Hall, C.M.; Ozanne, L. Hospitality industry responses to climate change: A benchmark study of Taiwanese tourist hotels. *Asia Pac. J. Tour Res.* **2013**, *18*, 92–107.
4. Wu, X.; Rajagopalan, P.; Lee, S.E. Benchmarking energy use and greenhouse gas emissions in Singapore's hotel industry. *Energy Policy* **2010**, *38*, 4520–4527.
5. Teng, C.C.; Horng, J.S.; Hu, M.L.M.; Chien, L.H.; Shen, Y.C. Developing energy conservation and carbon reduction indicators for the hotel industry in Taiwan. *Int. J. Hosp. Manag.* **2012**, *31*, 199–208.
6. Stohl, A. The travel-related carbon dioxide emissions of atmospheric researchers. *Atmos. Chem. Phys.* **2008**, *8*, 6499–6504.
7. Chan, W. Energy benchmarking in support of low carbon hotels: Developments, challenges, and approaches in China. *Int. J. Hosp. Manag.* **2012**, *31*, 1130–1142.
8. Taiwan Green Productivity Foundation. (Taipei, Taiwan) The list of high-energy users in Taiwanese hospitality industry. Personal communication, 2010.
9. The Greenhouse Gas Protocol Initiative—Scope 3 Accounting and Reporting Standard. Available online: http://www.ghgprotocol.org/files/ghgp/public/ghg-protocol-scope-3-standard-draft-for-stakeholder-review-november-2009.pdf (accessed on 29 January 2014).
10. Sundarakani, B.; de Souza, R.; Goh, M.; Wagner, S.M.; Manikandan, S. Modeling carbon footprints across the supply chain. *Inter. J. Prod. Econo.* **2010**, *128*, 43–50.
11. Wittneben, B.F.; Kiyar, D. Climate change basics for managers. *Manag. Decis.* **2009***, 47*, 1122–1132.
12. Carbon Disclosure Project (CDP). Supply Chain Report 2010. Available online: https://www.cdp.net/CDPResults/CDP-Supply-Chain-Report_2010.pdf (accessed on 29 January 2014).
13. Choi, T.M. Local sourcing and fashion quick response system: The impacts of carbon footprint tax. *Transp. Res. Part E-Logist. Transp. Rev.* **2013**, *55*, 43–54.
14. Choi, T.M. Carbon footprint tax on fashion supply chain systems. *Int. J. Adv. Manuf. Technol.* **2013**, *68*, 835–847.
15. Hua, G.; Cheng, T.C.E.; Wang, S. Managing carbon footprints in inventory management. *Int. J. Prod. Econ.* **2011**, *132*, 178–185.
16. Gemechu, E.D.; Butnar, I.; Llop, M.; Castells, F. Environmental tax on products and services based on their carbon footprint: A case study of the pulp and paper sector. *Energy Policy* **2012**, *50*, 336–344.
17. Bonilla-Priego, M.; Najera, J.J.; Font, X. Environmental management decision-making in certified hotels. *J. Sustain. Tour.* **2011**, *19*, 361–381.

18. Accor Procurement Charter 21. Available online: http://www.accor.com/fileadmin/user_upload/Contenus_Accor/Developpement_Durable/img/PLANET_21/docs/EN/procurement_charter_21.pdf (accessed on 29 January 2014).
19. Dou, Y.; Sarkis, J. A joint location and outsourcing sustainability analysis for a strategic offshoring decision. *Int. J. Prod. Res.* **2010**, *48*, 567–592.
20. Hsu, C.W.; Kuo, T.C.; Chen, S.H.; Hu, A.H. Using DEMATEL to develop a carbon management model of supplier selection in green supply chain management. *J. Cleaner Prod.* **2013**, *56*, 164–172.
21. Le, T.P.N.; Lee, T.R. Model selection with considering the CO_2 emission alone the global supply chain. *J. Intell. Manuf.* **2013**, *24*, 653–672.
22. Lee, K.H. Integrating carbon footprint into supply chain management: The case of Hyundai Motor Company (HMC) in the automobile industry. *J. Cleaner Prod.* **2011**, *19*, 1216–1223.
23. Schoenherr, T.; Modi, S.B.; Benton, W.C.; Carter, C.R.; Choi, T.Y.; Larson, P.D.; Leenders, M.R.; Mabert, V.A.; Narasimhan, R.; Wagner, S.M. Research opportunities in purchasing and supply management. *Int. J. Prod. Res.* **2012**, *50*, 4556–4579.
24. Shaw, K.; Shankar, R.; Yadav, S.S.; Thakur, L.S. Supplier selection using fuzzy AHP and fuzzy multi-objective linear programming for developing low carbon supply chain. *Expert Syst. Appl.* **2012**, *39*, 8182–8192.
25. Lee, A.M.I.; Kang, H.Y.; Lin, C.Y.; Wu, H.W. An evaluation model for green and low-carbon suppliers. In Proceedings of the 9th International Conference on Informatics in Control, Automation and Robotics (ICINCO 2012), Rome, Italy, 28–31 July 2012; SciTePress: Odense, Denmark; pp. 604–608.
26. Peng, J. Research on the optimization of green suppliers based on AHP and GRA. *J. Inf. Comput. Sci.* **2012**, *9*, 173–182.
27. Choi, T.M. Optimal apparel supplier selection with forecast updates under carbon emission taxation scheme. *Comput. Oper. Res.* **2013**, *40*, 2646–2655.
28. Huang, S.; Keskar, H. Comprehensive and configurable metrics for supplier selection. *Int. J. Prod. Econ.* **2007**, *105*, 510–523.
29. Liaoa, Z.; Rittscherb, J. A multi-objective supplier selection model under stochastic demand conditions. *Int. J. Prod. Econ.* **2007**, *105*, 150–159.
30. ISO 50001:2011—Energy Management Systems—Requirements with Guidance for Use. Available online: http://www.iso.org/iso/catalogue_detail?csnumber=51297 (accessed on 29 January 2014).
31. Butler, J. The compelling "hard case" for "green" hotel development. *Cornell Hosp. Q.* **2008**, *49*, 234–244.
32. Sanchez, M.C.; Brown, R.E.; Webber, C.; Homan, G.K. Savings estimates for the United States Environmental Protection Agency's ENERGY STAR voluntary product labeling program. *Energy Policy* **2008**, *36*, 2098–2108.
33. Kolk, A.; Pinkse, J. Market strategies for climate change. *Eur. Manag. J.* **2004**, *22*, 304–314.
34. Cogan, D.; Good, M.; Kantor, G.; McAteer, E. *Corporate Governance and Climate Change: Consumer and Technology Companies*; Ceres: Boston, MA, USA, 2008.
35. Lee, W.; Okos, M.R. Sustainable food processing systems—Path to a zero discharge: Reduction of water, waste and energy. *Procedia Food Sci.* **2011**, *1*, 1768–1777.

36. Okos, M.; Rao, N.; Drecher, S.; Rode, M.; Kozak, J. Energy usage in the food industry. Available online: http://www.aceee.org/research-report/ie981 (accessed on 29 January 2014).
37. Fritzson, A.; Berntsson, T. Energy efficiency in the slaughter and meat processing industry-opportunities for improvements in future energy markets. *J. Food Eng.* **2006**, *77*, 792–802.
38. Ates, S.A.; Durakbasa, N.M. Evaluation of corporate energy management practices of energy intensive industries in Turkey. *Energy* **2012**, *45*, 81–91.
39. Weinhofer, G.; Hoffmann, V.H. Mitigating climate change—How do corporate strategies differ? *Bus. Strateg. Env.* **2008**, *19*, 77–89.
40. Kannan, R.; Boie, W. Energy management practices in SMEs case study of a bakery in Germany. *Energy Conv. Manag.* **2003**, *44*, 945–959.
41. International Tourism Partnership. *Going Green: Minimum Standards towards a Sustainable Hotel*; International Tourism Partnership: London, UK, 2008.
42. Scott, D.; Becken, S. Adapting to climate change and climate policy: Progress, problems and potentials. *J. Sustain. Tour.* **2010**, *18*, 283–295.
43. Okereke, C. An exploration of motivations, drivers and barriers to carbon management: The UK FTSE 100. *Eur. Manag. J.* **2007**, *25*, 475–486.
44. Boiral, O. Global warming: Should companies adopt a proactive strategy? *Long Range Plan.* **2006**, *39*, 315–330.
45. Jeswani, H.K.; Wehrmeyer, W.; Mulugetta, Y. How warm is the corporate response to climate change? Evidence from Pakistan and the UK. *Bus. Strateg. Environ.* **2008**, *1*, 46–60.
46. Department for Environment, Food and Rural Affairs. The validity of food miles as an indicator of sustainable development. Available online: http://archive.defra.gov.uk/evidence/economics/foodfarm/reports/documents/foodmile.pdf (accessed on 29 January 2014).
47. Gössling, S.; Garrod, B.; Aall, C.; Hille, J.; Peeters, P. Food management in tourism: Reducing tourism's carbon "footprint". *Tour. Manag.* **2011**, *32*, 534–543.
48. Pratt, S. Minimising food miles: Issues and outcomes in an ecotourism venture in Fiji. *J. Sustain. Tour.* **2013**, *21*, 1148–1165.
49. Landeta, J. Current validity of the Delphi method in social sciences. *Technol. Forecast. Soc.* **2006**, *73*, 467–482.
50. Dalkey, N.; Helmer, O. An experimental application of the Delphi method to the use of experts. *Manag. Sci*. **1963**, *9*, 458–467.
51. Hwang, C.L.; Lin, M.J. *Group Decision Making under Multiple Criteria: Methods and Applications*; Springer-Verlag: Berlin/Heidelberg, Germany, 1987.
52. Ishikawa, A.; Amagasa, M.; Shiga, T.; Tomizawa, G.; Tatsuta, R.; Mieno, H. The max-min Delphi method and fuzzy Delphi method via fuzzy integration. *Fuzzy. Set Syst.* **1993**, *55*, 241–253.
53. Shen, Y.C.; Chang, S.H.; Lin, G.T.R.; Yu, H.C. A hybrid selection model for emerging technology. *Technol. Forecast. Soc.* **2010**, *77*, 151–166.
54. Chang, P.T.; Huang, L.C.; Lin, H.J. The fuzzy Delphi method via fuzzy statistics and membership function fitting and an application to the human resources. *Fuzzy Set Syst.* **2000**, *112*, 511–520.
55. Murray, T.J.; Pipino, L.L.; van Gigch, J.P. A pilot study of fuzzy set modification of Delphi. *Human Sys. Manag.* **1985**, *5*, 76–80.

56. Kaufmann, A.; Gupta, M. *Fuzzy Mathematical Models in Engineering and Management Science*; Elsevier: New York, NY, USA, 1988.
57. Lee, A.H.I.; Wang, W.M.; Lin, T.Y. An evaluation framework for technology transfer of new equipment in high technology industry. *Technol. Forecast. Soc.* **2010**, *77*, 135–150.
58. Kuo, Y.F.; Chen, P.C. Constructing performance appraisal indicators for mobility of the service industries using Fuzzy Delphi Method. *Expert Syst. Appl.* **2008**, *35*, 1930–1939.
59. Hu, A.H.; Chen, L.T.; Hus, C.W.; Ao, J.G. An evaluation framework for scoring corporate sustainability reports in Taiwan. *Environ. Eng. Sci.* **2011**, *28*, 843–858.
60. Wei, W.L.; Chang, W.C. Analytic network process based model for selecting an optimal product design solution with zero-one goal programming. *J. Eng. Design* **2008**, *19*, 15–44.
61. Wu, W.W.; Lee, Y.T. Developing global managers' competencies using the fuzzy DEMATEL method. *Expert Syst. Appl.* **2007**, *32*, 499–507.
62. Chiu, Y.J.; Chen, H.C.; Tzeng, G.H.; Shyu, J.Z. Marketing strategy based on customer behaviour for the LCD-TV. *Int. J. Manag. Decis. Making* **2006**, *7*, 143–165.
63. Hori, S.; Shimizu, Y. Designing methods of human interface for supervisory control systems. *Control Eng. Pract.* **1999**, *7*, 1413–1419.
64. Rahman, S.; Subramanian, N. Factors for implementing end-of-life computer recycling operations in reverse supply chains. *Int. J. Prod. Econ.* **2012**, *140*, 239–248.
65. Wu, W.W.; Lan, W.L.; Lee, Y.T. Exploring decisive factors affecting an organization's SaaS adoption: A case study. *Int. J. Inform. Manag.* **2011**, *31*, 556–563.
66. Hsu, Y.L.; Li, W.C.; Chen, K.W. Structuring critical success factors of airline safety management system using a hybrid model. *Transp. Res. Part E-Logist. Transp. Rev.* **2010**, *46*, 222–235.
67. Chen, F.H.; Hsu, T.S.; Tzeng, G.H. A balanced scorecard approach to establish a performance evaluation and relationship model for hot spring hotels based on a hybrid MCDM model combining DEMATEL and ANP. *Int. J. Hosp. Manag.* **2011**, *30*, 908–932.
68. Gabus, A.; Fontela, E. *World Problems, an Invitation to Further Thought within the Framework of DEMATEL*; Batelle Geneva Research Center: Geneva, Switzerland, 1972.
69. Liou, J.H.; Tzeng, G.H.; Chang, H.C. Airline safety measurement using a novel hybrid model. *J. Air Transp. Manag.* **2007**, *13*, 243–249.
70. Tzeng, G.H.; Chiang, C.H.; Li, C.W. Evaluating intertwined effects in elearning programs: A novel hybrid MCDM model based on factor analysis and DEMATEL. *Expert Syst. Appl.* **2007**, *32*, 1028–1044.
71. Yang, J.L.; Tzeng, G.H. An integrated MCDM technique combined with DEMATEL for a novel cluster-weighted with ANP method. *Expert Syst. Appl.* **2011**, *38*, 1417–1424.
72. Huang, J.J.; Tzeng, G.H.; Ong, C.S. Multidimensional data in multidimensional scaling using the analytic network process. *Pattern Recognit. Lett.* **2005**, *26*, 755–767.
73. Hung, Y.H.; Huang, T.L.; Hsieh, J.C.; Tsuei, H.J.; Cheng, C.C.; Tzeng, G.H. Online reputation management for improving marketing by using a hybrid MCDM model. *Knowl.-Based Syst.* **2012**, *35*, 87–93.
74. Chiu, W.Y.; Tzeng, G.H.; Li, H.L. A new hybrid MCDM model combining DANP with VIKOR to improve e-store business. *Knowl.-Based Syst.* **2013**, *37*, 48–61.

75. Hsu, C.H.; Wang, F.K.; Tzeng, G.H. The best vendor selection for conducting the recycled material based on a hybrid MCDM model combining DANP with VIKOR. *Resour. Conserv. Recycl.* **2012**, *66*, 95–111.
76. Ou Yang, Y.P.; Shieh, H.M.; Leu, J.D.; Tzeng, G.H. A novel hybrid MCDM model combined with DEMATEL and ANP with applications. *Int. J. Oper. Res.* **2008**, *5*, 160–168.
77. Liu, C.H.; Tzeng, G.H.; Lee, M.H. Improving tourism policy implementation—The use of hybrid MCDM models. *Tour. Manag.* **2012**, *33*, 413–426.
78. Tsai, W.H.; Chou, W.C.; Lai, C.W. An effective evaluation model and improvement analysis for national park websites: A case study of Taiwan. *Tour. Manag.* **2010**, *31*, 936–952.
79. Opricovic, S. *Multicriteria Optimization of Civil Engineering Systems*; Faculty of Civil Engineering, Belgrade: Belgrade, Serbia, 1998; pp. 5–21.
80. Opricovic, S.; Tzeng, G.H. Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. *Eur. J. Oper. Res.* **2004**, *156*, 445–455.
81. Opricovic, S.; Tzeng, G.H. Extended VIKOR method in comparison with outranking methods. *Eur. J. Oper. Res.* **2007**, *178*, 514–529.
82. Liou, J.J.; Chuang, Y.T. Developing a hybrid multi-criteria model for selection of outsourcing providers. *Expert Syst. Appl.* **2010**, *37*, 3755–3761.
83. Tzeng, G.H.; Teng, M.H.; Chen, J.J.; Opricovic, S. Multicriteria selection for a restaurant location in Taipei. *Int. J. Hosp. Manag.* **2002**, *21*, 171–187.