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Developing the Green Supplier Selection Procedure Based on Analytical Hierarchy Process and Outranking Methods

Che-Wei Tsui and Ue-Pyng Wen
Department of Industrial Engineering and Engineering Management
National Tsing Hua University
Kuang-Fu Road, Hsinchu, 300, Taiwan

Abstract

With increasing concern toward environmental protection, enterprises have become more and more responsible for their products reducing pollution and damage. Green supply chain management (GSCM) considers a systematic and integrated approach for companies to maintain their sustainability and competitiveness in the market. Among issues of GSCM, green supplier selection is an important issue in improving environmental performance. This because a good supplier helps supply materials that comply with the regulations and further assists in green design, affecting the performance of the entire supplier chain. This study attempts to develop the green supplier selection procedure for the optoelectronics industry. The highest output value of the optoelectronics industry in Taiwan is the TFT-LCD industry. This study proposes an integrated method which combine analytical hierarchy process (AHP), Preference Ranking Organization METHod for Enrichment Evaluations (PROMETHEE) I and II methods to solve the green supplier selection problem for the TFT-LCD case. We first obtain the weight of each criterion from AHP, and then adopt PROMETHEE I and II methods to evaluate the green supplier selection problem. An illustrative example shows the proposed evaluation procedure is applicable and valuable.

Keywords
Green supply chain management, Green supplier selection, Analytical hierarchy process, PROMETHEE I, PROMETHEE II

1. Introduction

Green supply chain management (GSCM) considers a systematic and integrated approach for companies to maintain their sustainability and competitiveness in the market. Among issues of GSCM, green supplier selection is a crucial problem in improving environmental performance. his because a good supplier helps supply materials that comply with the regulations and further assists in green design, affecting the performance of the entire supplier chain.
The optoelectronics industry is the core industry in Taiwan promoting economic growth and is greatly influenced by international regulations, especially in Europe. The Photonics Industry and Technology Development Association (PIDA), an organization established by entrepreneurs and academics in Taiwan, reported the highest output value of optoelectronics industry was the TFT-LCD industry. The output value of TFT-LCD industry was about US$50 billion in 2010 (Global Sources 2011). Hung (2006) pointed out, except for the well-known competitors from Japan and Korea, TFT-LCD industries from China have arisen because of government support, cheap labor, and an extensive market. Therefore, Taiwan manufacturers have faced challenges worldwide, requiring them make all efforts to provide green products that conform to environmental regulations and meet the customers' request. Consequently, green supplier selection emerges as an important issue for companies to sustain their market.

Within the extensive literature on traditional supplier evaluation and selection (Ho et al. 2010), comparatively little research has focused on green supplier selection. Bai and Sarkis (2010) applied rough set theory to examine the relationships between organization attributes, supplier development program involvement attributes, and performance outcomes. Zhu and Dou (2010) integrated the analytic network process (ANP) into a green supplier management process model based on portfolio analysis. Kuo et al. (2010) showed a green supplier selection model integrating an artificial neural network and two multi-criteria decision analysis (MCDA) methods: data envelopment analysis and ANP. Tuzkaya et al. (2009) proposed a hybrid fuzzy MCDA approach to evaluate the environmental performance of suppliers which integrated the Fuzzy ANP and Fuzzy Preference Ranking Organization METHod for Enrichment Evaluations (PROMETHEE). The ANP is a generalization of the analytic hierarchy process (AHP) (Saaty 2004). However, Macharis et al. (2004) indicated AHP has the disadvantage that the number of pairwise comparisons to be made may become very large.

The issue of green supplier selection is a typical MCDA problem (Bhutta and Hug 2002). Little literature has been published on green supplier selection using the MCDA method, especially the outranking method. The PROMETHEE method is the one of the most well-known approach in MCDA (Figueira et al. 2005). The PROMETHEE method allows quantitative data to be evaluated with qualitative data. In this study, PROMETHEE I and PROMETHEE II methods are employed to develop the green supplier selection procedure for the TFT-LCD industry. In addition, the PROMETHEE methods assume the DMs can decide the weights of the criteria. The AHP method is a useful method to explore subjective weights from DMs. Thus, this study combines the AHP method and the PROMETHEE I and II methods to evaluate the green supplier selection problem with the TFT-LCD case.

2. Literature Review

2.1 Green Supply Selection

The term “GSCM” can be defined as integrating environmental thinking in to supply chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers, and end-of-life management of the product after its useful life (Srivastava 2007). Among issues in GSCM, green procurement is one of the most important activities. Nikbakhsh (2009) stated procurement activities include inventory management, identifying requirements, determining requirement specifications, finding appropriate suppliers, contract negotiation and management (price, amount, quality, schedules, etc.), receiving, quality inspection, storage, and inbound distribution. Green procurement tries to manage these activities while minimizing the environmental impacts of them. It is the initial stage where an organization and its suppliers encounter. Thus, it is a starting point in greening the supply chain.

Supplier selection is a deterministic element to successful green procurement. In the past, manufacturers were inclined to keep many suppliers so they could negotiate lower costs, higher quality, reasonable delivery times, and special exigencies. Due to global competition, manufacturers tend to keep a long-term relationship with suppliers to efficiently integrate the material and information flow along the supply chain and respond to fast-moving markets. The competition is now supply chain versus supply chain rather than business versus business. In addition, midstream companies require good relationships with only a few suppliers to obtain a stable supply of materials, assist them in developing new products, share technology/information/risk, and achieve mutual success. If the selected supplier does not meet the requirements, the partnership may become a disaster. Therefore, selecting appropriate suppliers and forming a partnership with them becomes a crucial issue in green procurement.

2.2 Criteria for Evaluating Suppliers

This section forms a complete criteria set for evaluating green suppliers. According to the different stages of supply chain management methodology development, a complete criteria set is divided into three parts: traditional criteria, partnership criteria and green criteria.

For traditional criteria, Dickson (1966) listed 23 criteria for vendor selection analyzing the relative importance of them by distribution questionnaires to purchasing agents in USA and Canada. The author also stated: (1) quality, delivery, performance history, warranties & claims policies and production facilities & capacity are the top five important criteria; (2) when it comes to a highly complex product, price is of minor importance relative to the above mentioned criteria; (3) though the relative importance among the 23 criteria may differ from case by case, it would be a complete criteria set to include them into the decision process. Further, Weber et al. (1991) reconfirmed the correctness of the 23 criteria listed by Dickson through a thorough literature review that appeared in 1966 and focused on vendor selection for industries. Their study showed the 23 criteria are still of interest and important when evaluating suppliers, and the completeness of the criteria is indisputable.

For partnership criteria, Ellram (1990) stressed the importance of newly-emerged criteria as a reply to the need of selecting a long-term partner to support the business. His study explored the criteria by combining a literature review and an empirical case study. The results were classified into four categories: (1) financial issues; (2) organizational culture and strategy; (3) technology; and (4) a group of miscellaneous factors. Wu et al. (2009)

conducted recent research on the criteria of partnership selection by reviewing literatures. Three of five criteria (characteristics of the partner, intangible assets, degree of fitness) were already included in Ellram's paper; while the other two criteria (marketing knowledge capability and complimentary capabilities) were not completely covered. Among the subcriteria of the uncovered ones, some were too detailed to consider and appear to be redundant in the evaluation process; some are similar to the existing ones and thus are omitted or combined in the structure modified from Ellram's results.

For green criteria, Noci (1997) rated the suppliers from an environmental point of view. The author suggested an effective model should possess three characteristics: (1) it should allow the purchasing team to consider both quantitative and qualitative data; (2) it should be able to consider as many environmental-related dimensions as possible; and (3) the assessment procedure should be objective. Further, Handfield et al. (2002) assembled a Delphi group of supply chain managers from different companies to rank all the criteria according to their preferences. The categories of those criteria are: (1) product attributes; (2) waste management; (3) labeling/certification; (4) packaging/reverse logistics; (5) compliance with government regulations and (6) environmental programs at the supplier's facilities.

In this study, the criteria set is adopted from Dickson (1966), Ellram (1990) and Noci (1997) because their collections of criteria are the most representative of the field of traditional, partner and green considerations for evaluating suppliers. Consequently, the proposed decision framework is shown in Figure 1. Further, the criteria for evaluating suppliers can be divided into two categories based on their characteristics; one is qualitative criteria and the other is quantitative criteria. All the checkpoints are yes/no questions, and the suppliers get one point for each checkpoint they receive a "yes". The relative importance among the checkpoints under the same criterion is assumed to be equal. All the qualitative criteria are benefit attributes. For quantitative criteria, water emission, air emission, energy consumption and net price are cost attributes, and the others are benefit attributes. The benefit attributes preserve the larger-the-better characteristic, and the cost attributes are the smaller-the better.

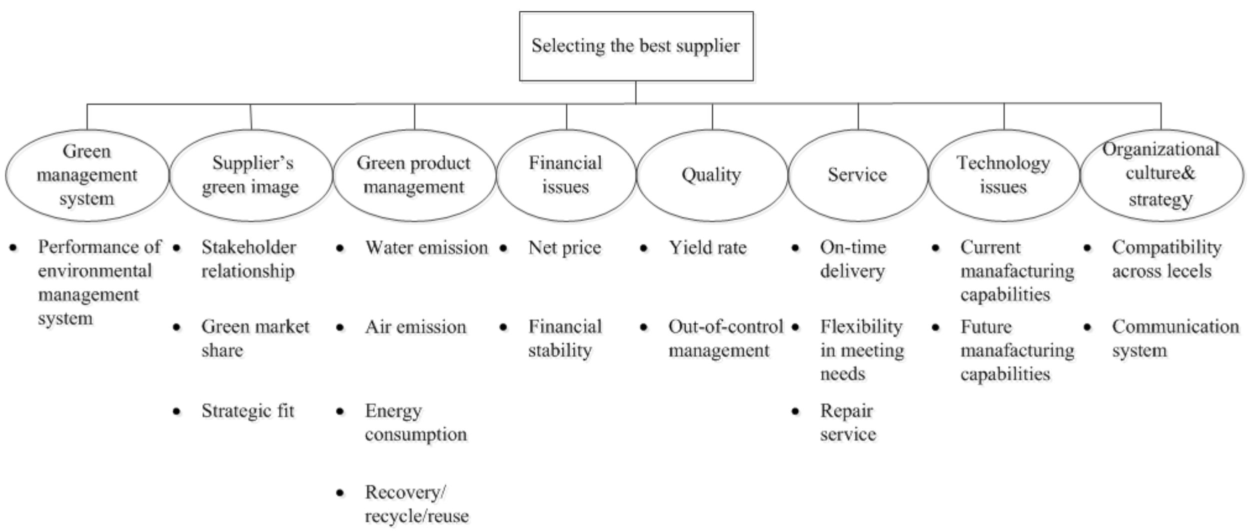

Figure 1: The proposed decision framework in this study

3. Methods

3.1 AHP method

Saaty (2008) offers a brief introduction on how AHP could be used in decision-making. First, structure the decision hierarchy from the top with goal, then through the intermediate level with criteria and subcriteria (the subsequent elements of criteria), to the bottom with alternatives. Then, construct a set of pairwise comparison matrices with one to nine preference scale and then calculate their eigenvector. Each element in the upper level is used to compare the elements in the level immediately below with respect to it. After that, for each comparison matrix, check the consistency ratio. If the consistency ratio value is smaller than 0.1, then go back to adjust the comparison matrix; otherwise continue to go on. After finding out all the eigenvectors as priorities for each hierarchy, the lower level's priority is weighed by each element of the upper level's priority and summed up. Continue the process of weighing and adding until the top hierarchy is reached and the overall/global priority for each alternative is obtained.

3.2 PROMETHEE I and II Methods

The PROMETHEE I and PROMETHEE II method were developed by Brans and presented for the first time in 1982 (Figueira et al. 2005) and the original journal papers are published by Brans and Vincke (1985) and Brans et al (1986). PROMETHEE I can provide partial ranking of alternatives, and complete ranking can be derived from PROMETHEE II. The implementation of the PROMETHEE method requires two types of information, which are the criteria weight and preference function. The PROMETHEE method assumes the DMs can decide the weights of the criteria. For each criterion, the preference function translates the difference between the evaluations that are obtained by the two alternatives into a preference degree ranging from 0 to 1. Brans and Vincke (1985) proposed six types of generalized criteria preference function.

The stepwise green supplier selection procedure of implementing the PROMETHEE I method can be described as follows.

Step 1: Calculate the preference index, which can be described as

We first calculate the deviations of pairwise comparisons using the following equation:

$$x_j(a_i, a_k) = g_j(a_i) - g_j(a_k), \quad j = 1, 2, ..., n, \tag{1}$$

Where x_j (a_i, a_k) is the difference between the evaluations of a_i and a_k on each criterion j. We calculate the qualitative criteria by the following equation:

$$H_j[x_j(a_i, a_k)] = \begin{cases} 0, \text{ if } x_j(a_i, a_k) = 0 \\ 1, \text{ if } x_j(a_i, a_k) \neq 0 \end{cases}, \quad j = 1, 2, ..., n_1, \tag{2}$$

Then, we can calculate the preference function, which can be written as

$$P_j(a_i, a_k) = H_j\left[x_j(a_i, a_k)\right], \; j = 1, 2, ..., n, \tag{3}$$

where $P_j(a_i, a_k)$ denotes the preference of alternative a_i with regard to alternative a_k on each criterion j.

Again, we also calculate the deviations in pairwise comparisons and the preference function by equations (7) and (9). In addition, we set the linear preference and indifference area for quantitative criteria by the following equation:

$$H_j[x_j(a_i, a_k)] = \begin{cases} 0, \text{ if } \left|x_j(a_i, a_k)\right| \leq q \\ \dfrac{\left|x_j(a_i, a_k)\right| - q}{p - q}, \; \text{ if } q < \left|x_j(a_i, a_k)\right| \leq p \\ 1, \text{ if } p < \left|x_j(a_i, a_k)\right| \end{cases}, \quad j = n_1 + 1, n_2 + 1, ..., n. \tag{4}$$

Then, we can calculate the preference index, which can be described as

$$\pi(a_i, a_k) = \sum_{j=1}^{n} P_j(a_i, a_k) w_j. \tag{5}$$

The preference index is defined for a_i with regard to a_k over all the criteria, and w_j is the weight of j^{th} criterion.

Step 2: Calculate the leaving flows and entering flows by the following equations:

$$\phi^+(a_i) = \sum_{k=1}^{m} \pi(a_i, a_k), \; i \neq k \text{ and} \tag{6}$$

$$\phi^-(a_i) = \sum_{k=1}^{m} \pi(a_k, a_i), \; i \neq k; \tag{7}$$

where ϕ^+ and ϕ^- denote the leaving flow and entering flow for each alternative, respectively.

Step 3: Rank the alternatives by the leaving flow and entering flow

Alternative a_i outranks alternative a_k (a_iPa_k), if two conditions hold. One is alternative a_i has a greater leaving flow than that of alternative a_k, and another condition is alternative a_i has a smaller entering flow than that of alternative a_k. We can describe the relation as follows:

$$a_iPa_k \;\text{ iff }\; \begin{cases} \phi^+(a_i) > \phi^+(a_k) \text{ and } \phi^-(a_i) < \phi^-(a_k), \\ \phi^+(a_i) > \phi^+(a_k) \text{ and } \phi^-(a_i) = \phi^-(a_k), \\ \phi^+(a_i) = \phi^+(a_k) \text{ and } \phi^-(a_i) < \phi^-(a_k). \end{cases} \tag{8}$$

Further, alternative a_i and alternative a_k are in an indifference situation (a_iIa_k), if alternative a_i and a_k has the same leaving flow and entering flow. The relation can be expressed as

$$a_iIa_k \quad \text{iff} \quad \phi^+(a_i) = \phi^+(a_k) \text{ and } \phi^-(a_i) = \phi^-(a_k). \tag{9}$$

Except for the above outranking and indifferent relations, the PROMETHEE I method also considers an incomparable relation. This means alternative a_i and alternative a_k are incomparable (a_iRa_k), which can be described as

$$a_iRa_k \quad \text{iff} \quad \begin{cases} \phi^+(a_i) > \phi^+(a_k) \text{ and } \phi^-(a_i) > \phi^-(a_k), \\ \phi^+(a_i) < \phi^+(a_k) \text{ and } \phi^-(a_i) < \phi^-(a_k). \end{cases} \tag{10}$$

Therefore, PROMETHEE I partial relation can be developed. However, if the complete relation without an incomparable situation is requested by DMs, we can adopt the PROMETHEE II method and consider the complete preorder of alternatives by step 3'.

Step 3': Calculate the net flow of each alternative by the following equation:

$$\phi(a_i) = \phi^+(a_i) - \phi^-(a_i); \tag{11}$$

We then rank all alternatives by the following relations:

$$\begin{cases} a_iPa_k \quad \text{iff} \quad \phi(a_i) > \phi(a_k), \\ a_iIa_k \quad \text{iff} \quad \phi(a_i) = \phi(a_k). \end{cases} \tag{12}$$

4. Case Study

The proposed outranking methods to the green supplier selection problem of the optoelectronics industry are applied to a TFT-LCD case in this study. The TFT-LCD industry is the most important optoelectronics industry in Taiwan because of the highest output value (Global Sources 2011). The illustrative example is under a real-world situation, and is based on our communications and discussions with employees who are working in the optoelectronics industry and electric component industry in Hsinchu Science Park in Taiwan. Here, we consider 10 suppliers and 30 criteria including qualitative and quantitative criteria. The data of the green supplier selection problem is shown in Table 1.

Table 1: The data of the green supplier selection problem

Crit.	Min/ Max	Actions									
		a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	a_9	a_{10}
g_1	MAX	3	1	2	4	6	3	4	5	4	4
g_2	MAX	1	1	1	1	1	0	1	0	0	1
g_3	MAX	1	1	1	1	1	0	1	0	2	0
g_4	MAX	2	2	1	2	1	1	2	0	1	2
g_5	MAX	1	1	0	1	0	0	0	0	1	2
g_6	MAX	1	1	2	1	0	1	1	1	1	1
g_7	MAX	0	1	1	0	1	0	0	1	1	1
g_8	MAX	0	0	1	1	0	1	0	0	0	0
g_9	MAX	1	1	0	1	1	0	0	0	1	0
g_{10}	MAX	0	1	0	1	0	1	1	1	0	0
g_{11}	MAX	0.08	0.06	0.07	0.04	0.1	0.02	0.05	0.08	0.06	0.03
g_{12}	MAX	6.74	7.85	6.46	6.88	6.83	6	6.88	7.27	7.17	6.71
g_{13}	MIN	83.26	91.73	92.81	107.15	67.98	78.56	98.3	75.5	100.21	85.4
g_{14}	MIN	31.62	29.25	30.47	45.53	44.59	42	42.05	25.27	50	28.09
g_{15}	MIN	37.67	25.49	29.76	39.36	30.72	39.74	38.62	42.37	33.23	23.37
g_{16}	MIN	2.5	2.12	1.98	2.84	1.21	2.17	1.51	1.69	2.3	1.93
g_{17}	MIN	0.6	0.92	0.65	0.46	0.95	0.94	0.79	0.82	0.79	0.44
g_{18}	MIN	145.33	232.57	171.84	314	252.75	286.29	213.94	243.93	242.49	313
g_{19}	MIN	170.55	291.99	261.43	283.99	285.77	261.56	376.03	368.4	221.46	277.8
g_{20}	MIN	119.82	99.1	189.44	72.16	144.32	105.16	166.39	166.1	97.67	161.3
g_{21}	MIN	137.71	216.28	168.62	163.51	112.56	138.12	46.4	192.44	150.96	183.97
g_{22}	MIN	57.9	24.85	70.23	45.13	69.74	50.45	52.36	55.47	46.77	68.7
g_{23}	MIN	1.61	1.64	1.18	1.32	1.5	1.69	1.93	1.13	1.33	1.61
g_{24}	MIN	9.29	9.16	12.38	12.33	14.6	12.54	6.24	9.67	11.72	11.3
g_{25}	MAX	82.29	91.65	89.97	85.96	78.07	82.7	82.64	76.62	73.78	82.49
g_{26}	MAX	72.49	72.6	76.07	74.3	68.94	75.79	78.38	76.5	73.95	76.8
g_{27}	MIN	138.91	140.57	135.14	142.82	145.72	139.66	136.86	134.02	133.47	136.96

g_{28}	MAX	20.76	18.54	24.71	12.52	24.14	32.83	24.27	15.69	19.52	23.53
g_{29}	MAX	99.36	99.25	99.17	99.32	99.65	99.48	99.17	99.28	99.4	99.3
g_{30}	MAX	99.4	99.09	99.27	99.29	99.5	99.26	99.36	99.32	99.52	99.32

After that, we have to determine the thresholds including the preference threshold (p), indifference threshold (q) and veto threshold (v). Maystre et al. (1994) proposed the relations among these thresholds that is, $q < p < v$. In this study, we simulate the threshold values through the following process. For every criterion, we simulate 21 suppliers' performance values, and calculate the absolute difference for every pair of data. Therefore, there will be 210 values. We sort these values from the smallest to the largest, and take the value located around one-third (the 70th data) as the value of q, and the value located around two-thirds (the 140th data) as the value of p. After that, we set the veto threshold v to be twice the value of p, and for the rest of the criteria we adjust the value according to its significance. Table 2 indicates the simulation data of p, q and v for each criterion.

Table 2: Simulation data of preference, indifference and veto thresholds

Criteria	Parameters				Criteria	Parameters		
	q	p	v			q	p	v
g_1	1	3	4		g_{16}	0.3	0.5	1
g_2	0	1	1		g_{17}	0.12	0.2	0.4
g_3	0	1	2		g_{18}	30	70	150
g_4	1	2	2		g_{19}	30	80	160
g_5	0	1	2		g_{20}	20	45	150
g_6	0	1	2		g_{21}	25	50	100
g_7	0	1	1		g_{22}	7	18	40
g_8	0	1	2		g_{23}	0.2	0.4	0.8
g_9	0	1	2		g_{24}	1	2.5	5
g_{10}	0	1	1		g_{25}	2.8	6	15
g_{11}	0.012	0.025	0.048		g_{26}	2	4.5	9
g_{12}	0.4	0.7	1		g_{27}	3	7	14.5
g_{13}	9	19	40		g_{28}	4	8	13
g_{14}	6	11	25		g_{29}	0.08	0.18	0.35
g_{15}	4	8	20		g_{30}	0.07	0.16	0.25

4.1 Application of AHP and PROMETHEE Methods for TFT-LCD Case

First, we calculate the weights of criteria based on AHP method, as shown in Table 3.

Table 3: The weights of criteria from AHP method

Criteria	Weights		Criteria	Weights
g_1	0.073		g_{16}	0.003
g_2	0.04		g_{17}	0.04
g_3	0.028		g_{18}	0.023
g_4	0.039		g_{19}	0.023
g_5	0.004		g_{20}	0.084
g_6	0.004		g_{21}	0.054
g_7	0.004		g_{22}	0.069
g_8	0.004		g_{23}	0.058
g_9	0.004		g_{24}	0.066
g_{10}	0.004		g_{25}	0.032
g_{11}	0.003		g_{26}	0.019
g_{12}	0.003		g_{27}	0.115
g_{13}	0.003		g_{28}	0.102
g_{14}	0.003		g_{29}	0.042
g_{15}	0.003		g_{30}	0.05

After we obtain the weights of criteria, the implementations of the PROMETHEE methods are as follows:

Step 1: Calculate the preference index

Now, the preference indexes are aggregated using equations (1)-(5), as shown in Table 4.
Step 2: Calculate the leaving flows and entering flows
We obtain the leaving and entering flows using equations (6) and (7), respectively, as shown in Table 5.

Table 4: Values of preference index

	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	a_9	a_{10}
a_1	0	0.195	0.368	0.185	0.270	0.344	0.192	0.273	0.191	0.157
a_2	0.197	0	0.229	0.240	0.294	0.430	0.232	0.248	0.221	0.222
a_3	0.301	0.37	0	0.325	0.296	0.315	0.293	0.351	0.213	0.218
a_4	0.239	0.255	0.314	0	0.351	0.313	0.242	0.348	0.277	0.246
a_5	0.306	0.272	0.293	0.423	0	0.474	0.394	0.473	0.239	0.33
a_6	0.249	0.383	0.256	0.124	0.362	0	0.24	0.319	0.237	0.288
a_7	0.193	0.251	0.249	0.185	0.295	0.317	0	0.257	0.251	0.158
a_8	0.304	0.259	0.190	0.357	0.225	0.323	0.248	0	0.184	0.177
a_9	0.319	0.323	0.330	0.373	0.249	0.471	0.384	0.279	0	0.214
a_{10}	0.251	0.226	0.207	0.282	0.278	0.336	0.201	0.216	0.176	0

Table 5: Results for leaving flow, entering flow and net flow

	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	a_9	a_{10}
$\phi^+(\alpha)$	2.175	2.313	2.682	2.585	3.203	2.459	2.157	2.267	2.942	2.173
$\phi^-(\alpha)$	2.359	2.535	2.435	2.493	2.62	3.325	2.426	2.765	1.989	2.011
$\phi(\alpha)$	-0.184	-0.222	0.247	0.092	0.583	-0.866	-0.269	-0.498	0.954	0.163

Step 3: Rank alternatives by the leaving flow and entering flow
The partial relations are established using equations (8)-(10), and given as shown in Figure 2.

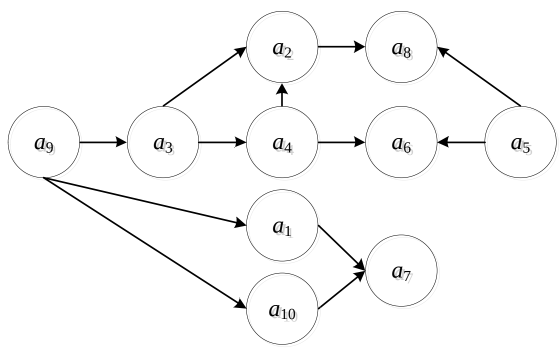

Figure 2: The PROMETHEE II method partial preorder

Figure 2 shows supplier 9 is the best alternative, followed by Supplier 3 and the worse alternatives are 6, 7 and 8.
Step 3': Calculate the net flow of each alternative
The complete preorder is provided using equations (11) and (12), as shown in Figure 3.

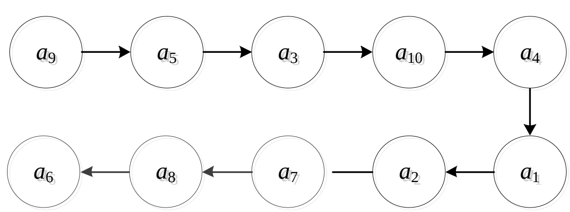

Figure 3: The PROMETHEE II method complete preorder

In this study, we combined AHP and PROMETHEE I and II methods to solve a green supplier selection problem for the TFT-LCD case, considering across the field of green, traditional, and partnership aspects being able to make real world applications. The proposed outranking methods can deal with qualitative and quantitative data to evaluate the green supply selection problem. Further, we consider 30 criteria of the green management system and green product management in the evaluation procedure. The proposed evaluation procedure is practical and competitive for the optoelectronics industry in the global market. From the ranking results, we obtained the supplier 9 is the best alternative, and the suppliers 6 and 8 are the worst.

5. Conclusion

This paper studied the selection procedure for the green supplier selection problem of the TFT-LCD industry in Taiwan. For sustaining the competitiveness of Taiwan's optoelectronics industry in the global market, we combined AHP and PROMETHEE I and II methods to solve a green supplier selection problem by integrating the field of green, traditional, and partnership aspects within the evaluation criteria. From the case study, we obtained partial and complete ranking results using the PROMETHEE methods. In sum, we suggest DMs use AHP and PROMETHEE methods to deal with the green supplier selection problem. Further, the proposed decision procedure is applicable and valuable.

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