A Formulation of DM's Risk Attitude in ELECTRE III

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Abstract

This study aims to formulate a decision maker's (DM's) risk attitude to modify ELECTRE (ELimination Et Choix Traduisant la REalité, or ELimination and Choice Expressing REality) III model. We apply both the traditional and modified models to evaluate WEEE (Waste Electrical and Electronic Equipment) recycling plants in Taiwan for the purpose of improving their operation quality in the future. The results show that both models are stable and suitable for the applications of environment evaluation.

The evaluation criteria include environmental, managerial, social, financial, and technological aspects on 15 recycling plants. Taiwan's Environmental Protection Administration (EPA) looks to provide higher differentiated subsidies as a bonus to those plants with better performances and offers some directives to the underachieving plants for further improvement. We employ concave and convex utility functions to modify the concordance and discordance indices in order to represent the DM's risk attitude, mimicking the gain and the loss in the DM's mind. We also execute sensitivity analyses on different weights and thresholds so as to demonstrate the stability of our proposed model.

Keywords: ELECTRE III, Utility function, Concordance, Discordance, Sensitivity analysis.

1. Introduction

The resource recovery rate of the WEEE (Waste Electrical and Electronic Equipment) recycling plants is reaching 80% in Taiwan, and is higher than the EU's standard. The capacity of the plants not only can process the current domestic wastes but also deal with the demand for the future growth. At the next stage Taiwan's Environmental Protection Administration (EPA) aims to enhance the quality of recycling process so that there is less damage to the environment. Hence, EPA attempts to evaluate these recycling plants and looks to provide higher differentiated subsidies as a bonus to those plants with better performances and offers some directives to the underachieving plants for further improvement.

Performance evaluation is one of the important managerial works, and many multi-criteria decision making (MCDM) techniques have been developed, such as ELECTRE, TOPSIS, AHP/ANP and others, and these techniques have been applied to many evaluation problems in practice. ELECTRE (ELimination Et Choix Traduisant la REalité - ELimination and Choice Expressing the REality) was introduced by Benayoun, Roy and Sussmann (1966) as a main stream of French School (Lootsma, 1990). The technique models decision maker's (DM's) preference by an outranking relation on a set of actions (Figueira et al., 2013), and its preference modeling has an edge over other MCDM techniques. The ELECTRE has been demonstrated in various environmental applications, e.g., water resources planning, alternative energy, and waste management (Hokkanen & Salminen, 1997; Norese, 2006).

ELECTRE III (Roy, 1978) is an extension in dealing with fuzziness and uncertainty in making a decision. It can provide a relative ranking on alternatives, and is popular around the world. However, it seems that no work involves DM's risk attitude in ELECTREs. Inspiring by the work of Almeida (2007) on the performance evaluation by utility functions, this study employs concave and convex utility functions to modify the concordance and discordance indices in order to represent the DM's risk attitude, mimicking the gain and the loss in DM's mind. In the following sections, we will propose a modified procedure of ELECTRE III, illustrate the evaluation of Taiwan's recycling plants, execute sensitivity analyses, and provide discussions and conclusions.

2. Proposed model

To tackle DM's risk attitude, we use utility functions to modify the core of the concordance and discordance indices in ELECTRE III. The original linear shape of the function is replaced by the concave and convex shapes of the utility functions to represent the DM's risk attitude, i.e., risk aversion or risk seeking (Hillier and Lieberman, 2010). Both shapes can mimic the gain and the loss in DM's mind which proposed by prospect theory (Kahneman & Tversky, 1979). Based on the concept, we illustrate the concordance and discordance indices as follows.

The formula of partial concordance matrices can be defined as:

$$c_j(aSb) = \begin{cases} 1 & , \ g_j(\mathrm{a}) \geq g_j(b) - (q_j(g_j(a)) \\ 0 & , \ g_j(\mathrm{a}) < g_j(b) - (p_j(g_j(a)) \\ \mathrm{R}\left(1 - e^{-\frac{\frac{g_j(a) - g_j(b) - p_j(g_j(a))}{v_j(g_j(a)) - p_j(g_j(a))}}{R}}\right) & , \ else \end{cases} \quad (1)$$

The formula of partial discordance matrices can be defined as:

$$d_j(aSb) = \begin{cases} 1 & , \ g_j(\mathrm{b}) > g_j(a) + (v_j(g_j(a)) \\ 0 & , \ g_j(\mathrm{b}) \leq g_j(a) - (p_j(g_j(a)) \\ \mathrm{R}\left(1 - e^{-\frac{\frac{g_j(b) - g_j(a) - p_j(g_j(a))}{v_j(g_j(a)) - p_j(g_j(a))}}{R}}\right) & , \ else \end{cases} \quad (2)$$

We can see that the third part of the above two equations are utility functions.

3. Analysis results

There are 15 recycling plants to be evaluated in Taiwan. The performance values of the plants are illustrated by five aspects: environment protection, management system, financial performance, technology achievement, and social responsibility. Table 1 presents the detailed data of the plants which are marked by the letters A to O.

3.1 Selections of weights and parameters

Before the analysis, we need to setup the weights and the parameters for ELECTRE III. This study considers equal and Rank Order Centroid (ROC) weights in the evaluation. Equals

weights are used to represent these five aspects being equally important in DM's mind, and ROC weights are utilized while the importance of the aspects can be ordered. Both are common in the evaluation. In addition, ELECTRE III needs three types of parameters for the analysis, i.e., indifference, preference, and veto thresholds. In general, ELECTRE III sets the preference threshold is larger than the indifference threshold, while the veto threshold is the largest, and these parameters depend on the preference of DM (Hedel & Vance, 2005). In our evaluation, the preference thresholds of all aspects are set by the DM. Indifference and veto thresholds are considered as the same value, which means the DM feels the cases of the indifference and the rejection are the same. Table 2 lists the values of the weights and the parameters on each aspect.

Table 1

The performance of 15 recycling plants in Taiwan

Plant	Aspect				
	Environment Protection	**Management System**	**Financial Performances**	**Technology Achievement**	**Social Responsibility**
A	3.75	5.5	7.5	6.3	2
B	3.75	5.1	7.5	6.3	3
C	4.25	4.75	8.5	7.6	3.5
D	3.25	5	5.25	2.2	1
E	3.25	5.5	6	4.6	1
F	4.25	5.1	7	6.1	2.8
G	2.75	1.3	6.6	3.9	1.3
H	3.95	3.8	7.35	2.6	1.5
I	2.8	4.55	7.1	4.1	2.5
J	3.85	6.75	7	5.3	4.3
K	4.1	4	5.6	8.6	2
L	3.25	2.75	6.8	4.1	1
M	4.25	5.5	5.05	5.9	2
N	3.25	4.75	6.6	3.6	4
O	2.8	3.5	6.6	4.6	3

Table 2

The chosen values of weights and parameters in this study

		Environment Protection	**Management System**	**Financial Performances**	**Technology Achievement**	**Social Responsibility**
Criteria Weight	**Equal Weights**	0.2	0.2	0.2	0.2	0.2
	ROC Weights	0.4567	0.2567	0.1567	0.09	0.04
Indifference threshold *q*		0.0949	0.0949	0.0949	0.0949	0.0949
Preference threshold *p*		0.5	0.45	0.4	0.3	0.3
Veto threshold *v*		0.8	0.8	0.8	0.8	0.8

3.2 Comparison results

Table 3 shows the ranks of 15 plants by score sum, traditional and modified ELECTRE III. Score sum is to sum up the performance values on all five aspects of any plant, which is taken by the EPA original evaluation. However, EPA worried about the ranks because a simple method might not be suitable for the purpose. Thus, we adopt ELECTRE III and modified ELECTRE III to make the evaluation. Table 3 illustrates the comparison results of three methods. The second, the third, and the fourth columns of Table 3 are the ranks of the 15 plants by score sum, ELECTRE III, and modify ELECTRE III, respectively. We can see that the upper half ranks of the group have no significant difference. EPA should have a confident on the decision for subsidy and supervision.

Table 3

The final ranks of 15 plants by three methods

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Score sum	5	3	1	14	11	4	15	12	9	2	6	13	7	8	10
ELECTRE III	5	3	1	14	11	3	15	9	10	2	6	11	7	7	11
Modified ELECTRE III	5	2	1	14	9	4	15	12	8	3	7	13	9	6	11

3.3 Sensitivity analysis

Sensitivity analysis is to investigate the effect on the solution if the parameters take other possible values (Hillier & Lieberman, 2010). WE can think about the model being stable if the effect is minor. Here we conduct a sensitivity analysis on the weights of the evaluation aspects in which the weight of environment protection is chosen due to its big value. We change its values to the plus and the minus 30% of its original value. The analyses on equal and ROC weights are executed, and find that there is no significant difference on the ranks of the plants. Figure 1 shows the results of the sensitivity analysis on equal weights.

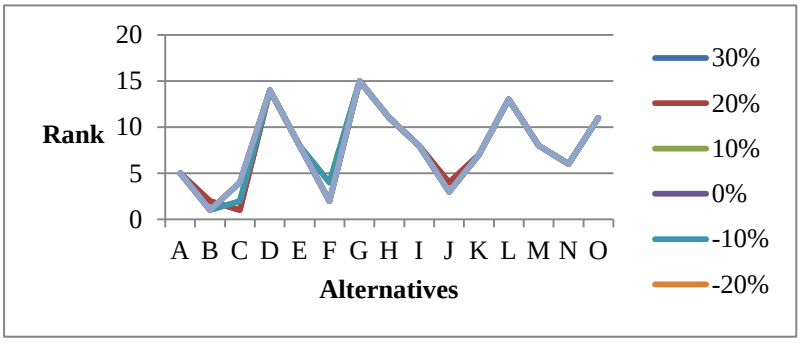

Figure 1 A sensitivity analysis on the weight of environment protection, equal weights

4. Conclusions and remarks

We propose the modified ELECTRE III to model DM's risk attitude in evaluating 15 recycling plants in Taiwan. Compared to the traditional ELECTRE III, the upper half of the group in the analysis is almost the same. Through the sensitivity analysis, we ensure that these two models are stable, and think both models are suitable for the environment applications.

The thresholds are the important parameters for decision making in using ELECTRE III. We will check the effect of the changes of the values of three thresholds on the final ranks. In addition, ranking tests and the simulation on the range of performance values of the plants will be executed in order to verify the difference between the two models of ELECTRE III.

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