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A Novel Evaluation Approach for Power Distribution System Planning based on Linear Programming Model and ELECTRE III

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***Abstract*—To evaluate solutions of power distribution system planning (PDSP) is an essential task in smart grid and requires multi-criteria decision making (MCDM). However, the vagueness of attribute values and the fuzziness of weights of criteria need integrate fuzzy techniques with MCDM. In order to incorporate the issues with uncertainty in PDSP evaluation, this paper proposes a novel PDSP approach based on linear programming model and ELECTRE III. The incomplete weight preference information of decision-maker is elicited and expressed by a group of weight constraint functions, combined these functions with the simple multi-attribute rating technique, a linear programming model is set up to obtain the weights for each solution. Then with the weights and a PDSP model based on ELECTRE III model, the outranking score of each solution compared with other solutions can be calculated, and a net present score for each solution will be obtained for ranking these solutions, DM can choose one desired. A case is demonstrated to show the evaluation process using this approach and the results indicate that this approach incorporating the issues with uncertainty is robust for PDSP evaluation. The results are acceptable to DM.**

Keywords*—Multi-criteria Decision-making; Power distribution system; linear programming Model; ELECTRE III; Uncertainty; Fuzziness

I. INTRODUCTION

The evaluation of solutions is an important phase in power distribution system planning (PDSP) which allows issues such as quality of supply, cost and environmental implications to be considered [1]. The distribution planning optimal model include many issues under uncertainty is difficult to be set up and difficult to be applied [2, 3]. The planning problem is thus suitable for the multi-criteria decision-making (MCDM) method. MCDM method can help decision-makers (DMs) choose the desirable solution based on a set of criteria and attributes among the solutions. In many MCDM applications, because of inaccurate attribute values or inconsistent judgments from experts, available information for DM is usually imprecise, so using determined values to express that information, the results are unsatisfactory [4]. Obviously, considering the vague of the information in the decision process is necessary for strengthening the confidence of the decision-making results. On the other hand, the preference information also should be included in MCDM process and such information is often incomplete, which requires MCDM model can cope with incomplete preference information.

Overall, there are four issues usually to be considered when a PDSP evaluation is processed by MCDM method.

The first issue is to incorporate the vagueness of attribute values and the fuzziness of weights of criteria. Previous PDSP applications using MCDM methods in literatures [5]-[8] used the probability and fuzzy interval data to express uncertainty and used constant or interval numbers to express DMs' preference information. Due to their limited capability in interacting with DMs, more or less affect their use.

From the point of view of DM, uncertainty of the data also can be dealt with in an easy and practical way by applying so-called pseudo-criteria [10]. A typical and sophisticated method using pseudo-criteria is ELECTRE III [11], which takes a risk to a certain extent to establish outranking relations, which can incorporate both criterion error/uncertainty and DM's risk attitudes or sensitivity, also can be used as an interactive tool to aid decision. It simulates human thinking in decision process, is sensible and straightforward, easy to be achieved. It is a popular and proven MCDM method in Europe [12]-[14]. The work in reference [15, 16] shows its advantage in PDSP evaluation.

The second issue is how to avoid the flaw that the capital cost effectively masks the technical benefits in PDSP evaluation and consider the non-compensated part among criteria. Most MCDM methods are based on the linear additive utility theory, assuming the utilities between criteria can be compensated each other completely, as a result, it is benefit to the solution with low cost, there is a flaw that the capital cost effectively masks the technical benefits in the resulting desirability order. Reference [9] suggests that the technical benefits and capital cost for each solution are calculated respectively to ensure the technical benefits are not obscured, but not incorporating data uncertainty.

The third issue is how to get the “right” weights of criteria. Many technologies and theories [17] can be resorted to get the “right” weights. Analytical hierarchy process (AHP) [18] may be the most popular method used to allocate the weight values to criteria. The interval AHP [7] is a good mathematical tool for quantitative description, but it is difficult to deal with incomplete preference information. Sometimes DMs can provide some qualitative information about the weights such as criterion A has half of the total weight, criterion A is more important than that of B, C is two times the average weight, etc. DMs may give the weight range for some criteria such as the highest weight, the lowest weight or weight interval in some situations. All these weight allocation can be expressed by a set of constraint functions, but such weight information is not suitable for the interval AHP.

The forth issue is how to gather opinions from many DMs. This often involves group decision theory, which can concentrate the information from many DMs, several methods [19]-[21] can be used in this process. After all, many actors (customers, managers, owners, regulators) involved in power distribution planning is a very common thing, their opinions on importance of the criteria and their sensitivities to the criteria should be taken into account. Related tool is available in [22] and its use in PDSP evaluation reported in [23].

In this paper, a novel PDSP evaluation approach including the former three issues is proposed, which is based linear programming model and a PDSP evaluation model based on ELECTRE III model. The incomplete weight preference information of DM is elicited and expressed by a set of weight constraint functions, with the simple multi-attribute rating technique (SMART), an optimum model is set up to maximize the weighted score and obtain the optimum weights for each solution, these weights will be used in PDSP evaluation model based on ELECTRE III. The outranking score of each solution compared with other solutions can be calculated, and a net present score for each solution will be calculated for ranking these solutions, then DM can choose one desired.

The main contributions of this paper are: 1) a linear programming model is proposed to obtain the weights for incomplete preference information processing; 2) a PDSP evaluation model based on ELECTREIII is presented; 3) a novel PDSP evaluation approach using these two models is proposed.

This paper is organized as follows. Section II introduces a linear programming model to get the weights of criteria. Section III presents a PDSP evaluation model based on ELECTRE III. Section IV demonstrates the application of the approach to PDSP evaluation by a case. Section V presents some discussions. Section VI gives some conclusions.

II. The Linear Programming Model

A MCDM problem is usually formulated by a set of solutions $a_i, i=1,2,\ldots,n$ and a set of criteria $g_j, j=1,2,\ldots,r$. The performance values of solutions are $a_{ij}, i=1,2,\ldots,n; \ j=1,2,\ldots,r$. Without loss of generality, given that all the criteria values are to be maximized.

A. To express the weight preference of DM

The attentions to the criteria are usually different for DMs and there are subjective and fuzzy, this weight information can be expressed by the values in a range. The expression of the preference information is a process that DM puts his (her) weight attitudes by mathematic formula.

For all solutions, we use w_{ij} to represent the relative weight importance of the *i*th solution under criterion g_j, without loss of generality, we let $\sum w_{ij} = 1$ (in fact, the weight of each criterion values must not be limited to 0-1 range, but a total weight value should be given. Usually the importance of a criterion is based on its comparison with the average weight, and thus the total weight value may be set to an integer multiple of the number of criteria). w_{ij} should meet the universal weight constraint functions for all solutions. For example, assuming that there are three criteria, DM can express the weight constraint functions as the follows.

$$w_{i1} \ge w_{i2} \ge w_{i3}, w_{i2} \ge 0.2, w_{i3} \ge 0.1$$

These constraint functions have equal effects on all solutions. A general form of the weight can be expressed by

$$g(w_1, w_2, \cdots, w_r) = 0$$

or

$$h(w_1, w_2, \cdots, w_r) \le 0$$

Where the equation or inequality may include many expressions and all functions are the linear function of the weights. If the number of criteria is large, the weight constraint functions can be expressed in layers by adding variables.

B. The SMART method

The procedure of SMART [5] is as follows.

1) Normalization. The attribute data are scaled so as to fall within a small specified range, here is 0.0 to 1.0, the new attribute data $z_{ij}, i = 1, 2, \cdots, n; j = 1, 2, \cdots, r$.

0-1 normalization performs a linear transformation on the original data. Suppose that $y_j^{\max}$ and $y_j^{\min}$ are the maximum and minimum values of the ith attribute, 0-1 normalization map a value v, of A to v0 in the range [0;1], by computing

$$z_{ij} = \frac{y_{ij} - y_j^{\min}}{y_j^{\max} - y_j^{\min}} \tag{1}$$

2) The weight determination. The weights are given as $w_{ij}, j = 1, 2, \cdots, r$.

3) Optimization goals.

The sum of weighted attribute values for each solution will be the object to be maximized.

$$C_i = \sum_{j=1}^{r} w_{ij} z_{ij}$$

C. Set up the linear programming model

Each solution is a decision making unit (DMU), the object function is defined by

$$S(i) = \max \sum_{j=1}^{r} w_{ij} z_{ij} \tag{2a}$$

The constraint functions show the weight information as in 'the weight preference of DM'.

$$g(w_{i1}, w_{i2}, ..., w_{ir}) = 0$$

or
$$h(w_{i1}, w_{i2}, ..., w_{ir}) \le 0 \tag{2b}$$

Thus, a linear programming model is set up, which can be used to optimize each DMU in the allowed weight value range.

With the same weight constraint functions, each solution optimizes its own weights to maximize the object. For the solutions, their weights may be different from each other under the same criterion. So, the optimization can enable DM to avoid the subjectivity to a great extent and the weight constraint functions can fully express the real part of opinions of DM, and embody DMs' dominant status in the decision making process.

III. PDSP EVALUATION MODEL

This section will describe a PDSP evaluation model based on ELECTRE III. In this model, the weight may be different under the same criterion for each solution, which is different from the traditional ELECTRE III [15] and a ranking way is given.

A. Thresholds

For any ordered pair (a_l, a_k) of solutions, the three thresholds are as follows:

The indifference threshold, q_j : For the *j*th criterion, a_l and a_k are indifferent if $a_{lj} + q_j \ge a_{kj}$ and $a_{kj} + q_j \ge a_{lj}$.

The strict preference threshold, p_j : For the *j*th criterion, a_l is strictly preferred to a_k if $a_{lj} > a_{kj} + p_j$ and a_l is weakly preferred to a_k if $a_{kj} + q_j < a_{lj} \le a_{kj} + p_j$.

The veto threshold, v_j : For the *j*th criterion, reject the hypothesis of outranking of a_l over a_k if $a_{kj} \ge v_j + a_{lj}$.

It implies that: $v_j > p_j > q_j > 0$.

B. The index of concordance and discordance

A concordance index is computed for each ordered pair (a_l, a_k) of solutions and defined by

$$c(l,k) = \frac{\sum_{j=1}^{r} w_{lj} c_j(l,k)}{\sum_{j=1}^{r} w_{lj}} \tag{3}$$

Where w_{ij} is the weight determining the relative importance of *j*th criterion for the *i*th solution and $c_j(l,k)$ is defined by

$$c_j(l,k) = \begin{cases} 1 & if \quad a_{lj} + q_j \ge a_{kj} \\ 0 & if \quad a_{lj} + q_j \le a_{kj} \\ \dfrac{p_j + a_{lj} - a_{kj}}{p_j - q_j} & otherwise \end{cases}$$

$c_j(l,k)$ shows the degree of concordance with the judgmental statement that a_l outranks a_k under the *j*th criterion, the index of global concordance $c(l,k)$ represents the amount of evidence to support the concordance among all the criteria, under the hypothesis that a_l outranks a_k.

The index of discordance of solution a_l vs. a_k under the *j*th criterion, is defined by

$$d_j(l,k) = \begin{cases} 0 & if \quad a_{kj} \le a_{lj} + p_j \\ 1 & if \quad a_{kj} \ge a_{lj} + v_j \\ \dfrac{a_{kj} - a_{lj} - p_j}{v_j - p_j} & otherwise \end{cases} \tag{4}$$

$d_j(l,k)$ shows the degree of discordance with the judgmental statement that a_l outranks a_k.

C. The degree of outranking

The degree of outranking is defined by

$$S(l,k) = \begin{cases} c(l,k) & if \quad J(l,k) = \phi \\ c(l,k) \prod_{j \in J(l,k)} \frac{1 - d_j(l,k)}{1 - c(l,k)} & otherwise \end{cases} \tag{5}$$

Where $J(l,k)$ is defined as the set of criteria for which $d_j(l,k) > c(l,k)$. If $J(l,k) = \phi$, we have $d_j(l,k) \le c(l,k)$ for all criteria, then, $S(l,k)$ is the same as $c(l,k)$.

$S(l,k)$ shows the degree of credibility of outranking with the judgmental statement that a_l outranks a_k.

D. The ranking of the solutions

After getting the matrix of the outranking degree, the ranking of the solutions can be carried out by the values computed by

$$\delta_l = \sum_{k=l}^{n} S(l,k) - \sum_{k=l}^{n} S(k,l), l = 1,2,...,n \tag{6}$$

The solutions are ranked based on the score δ_l of each solution a_l. The solution having the highest score will be ranked as the first, and so on.

IV. CASE STUDY

Using the proposed linear programming model in Section II and PDSP evaluation model in Section III, we propose a novel PDSP evaluation approach including the above two stages, the steps are basically described in each stage.

In this section, a case based on a planning problem in [9] will be used to demonstrate the application of the proposed approach. For briefness, the first five planning solutions under 2.7% annual load growth are selected for the example.

The criteria are as follows.

- g_1 Annual energy losses (MWh);
- g_2 System security: number of customers interrupted per 100 connected customers;
- g_3 Supply availability: average customer minutes lost per connected customer;
- g_4 Capacity constraints: load unsupplied (MWh);
- g_5 Environmental impact: the total circuit length of new or modified network circuits (kM);
- g_6 Capital cost (£'000).

Since they are all to be minimized, their negatives are maximized. The performances of solutions are in Table I.

TABLE I. THE PERFORMANCES OF SOLUTIONS

	g_1	g_2	g_3	g_4	g_5	g_6
a_1	17420.24	-6.64	-150.12	-23.40	-0.27	-2580
a_2	-17470.41	-6.37	-134.00	-23.40	-1.04	-2053
a_3	-17401.69	-6.34	-128.47	-110.18	-1.19	-2040
a_4	-17496.41	-6.07	-112.24	-110.18	-1.95	-1513
a_5	-17410.24	-6.58	-150.00	-23.40	-0.27	-2930

Defining the thresholds and weights is the key of using the proposed approach to aid decision in PDSP evaluation. These values have relation with the importance of the criteria and the preferences of DM. So the position of every criterion according to its impact on the planning problems has to be realized.

When using the proposed PDSP evaluation approach, the first stage is using the linear programming model to obtain the weights of criteria; the second stage is using the PDSP model based on ELECTRE III to evaluate the solutions with the weights obtained in the first stage.

The steps of the approach are described as follows.

A. Express the weight preference information of DM

In the criteria, annual energy losses is an important criterion in power distribution planning in any country, it impacts the operation cost [24]. System security is a key criterion in any country within any planning methodology, it is one aspect of distribution network reliability which is an issue of particular importance to large industrial connected customers as even short supply interruptions may result in significant downtime and associated cost penalties in some countries. Supply availability is a same important key criterion as system security and is the other aspect of network reliability. Capacity constraints is a very important criterion, in the long term, it will affect the total cost in the planning period. Environmental impact is an important issue that must be considered by all distribution companies when carrying out any engineering work is the likely environmental impact. The importance of environmental impact depends on the planning area. In urban area or park, environmental impact will be paid more importance than in rural area, so the weight value may depend on the specific situation. Capital cost is a key criterion in any electricity utilities. Especially in electricity market, the aim of investment is to get the profit or a high return with the limited capital.

As the criteria are conflictive, willing or unwilling, DM must make trade-off among these objectives. In this example, given the planning is in rural area.

For the six criteria, with the constrain $\sum w_{ij} = 1$, DM thinks that the weight of "capital cost" is between 0.2 and 0.25, also the weight of "system security" is the same as that of "supply availability" and so on. Finally, a set of constraint functions is as follows.

$$
\begin{aligned}
& w_{i2} = w_{i3} \\
& w_{i4} \ge w_{i3} \ge w_{i5} \ge w_{i1} \\
& 0.25 \ge w_{i6} \ge 0.2 \\
& 0.1 \ge w_{i1} \ge 0.05 \\
& 0.2 \ge w_{i2} \ge 0.15 \\
& 0.15 \ge w_{i5} \ge 0.1 \\
& w_{i4} \le 0.25
\end{aligned}
$$

B. 0-1 Normalization

For the performances of solutions in Table I, normalized by (1), the matrix is shown in Table II.

TABLE II. THE NORMALIZED MATRIX

	g_1	g_2	g_3	g_4	g_5	g_6
a_1	0.8042	0	0	1	1	0.2470
a_2	0.2745	0.4737	0.4256	1	0.5417	0.6189
a_3	1	0.5263	0.5715	0	0.4524	0.6281
a_4	0	1	1	0	0	1
a_5	0.9097	0.1053	0.0032	1	1	0

C. Set up integrated optimum programming model

A linear programming model set up is as follows.

$$
S(l) = \max \sum_{j=1}^{r} w_{lj} c_j(l)
$$

$$
\begin{cases}
w_{l2} = w_{l3} \\
w_{l4} \ge w_{l3} \ge w_{l5} \ge w_{l1} \\
0.25 \ge w_{l6} \ge 0.2 \\
0.1 \ge w_{l1} \ge 0.05 \\
0.2 \ge w_{l2} \ge 0.15 \\
0.15 \ge w_{l5} \ge 0.1 \\
w_{l4} \le 0.25 \\
\sum w_{lj} = 1
\end{cases} \tag{7}
$$

D. Optimize the DMUs

With the data as normalized matrix in Table II and the linear programming model in (7), the weights of each solution can be obtained through optimizing DMUs and the result is shown in Table III.

TABLE III. THE WEIGHTS OF SOLUTIONS

	w_1	w_2	w_3	w_4	w_5	w_6
a_1	0.05	0.15	0.15	0.25	0.15	0.25
a_2	0.05	0.15	0.15	0.25	0.15	0.25
a_3	0.1	0.1667	0.1667	0.1667	0.15	0.25
a_4	0.05	0.20	0.20	0.20	0.1	0.25
a_5	0.10	0.15	0.15	0.25	0.15	0.20

E. Define the thresholds

For the thresholds, the threshold value depends on error/uncertainty and DM's sensitivity to the criterion.

The thresholds may be constants, linear or affine functions of the performance of the solution a_l [10].

In the daily decision-making, people often connect their risk attitudes to the attribute values' range under special criterion, so that when the number of solution is increasing, with the value range changing, people's attitudes towards risk also change accordingly.

Therefore, we suggest: for the relative concentration values of some criteria, we can take the measure that indifferent threshold and preference threshold are set by a certain percentage of the value scale, for a criterion, indifferent threshold = (maximum value - minimum values) * a percentage. If the number of solutions is more, the percentage of which can be taken as follows: 1 / the number of solutions. In most cases, desirable percentage may be 5%-10%, depending on the risk attitudes of DMs.

Then based on the research in literature [14], we can take three-times rule, that is, preference threshold is three times indifferent threshold. For these non-concentration values, we can assign a constant value to the threshold, which also depends on the risk attitudes of DMs, and that indifferent threshold at least makes one solution indifferent to another solution is appropriate.

For some criteria, DM is very sensitive to their values' change. In this case, indifferent threshold may not exceed the error range, other threshold still follow three times rule to be defined.

For special criterion, usually have a veto threshold, when one solution is compared with other solution, if the difference reaches or exceeds this veto threshold, we cannot accept the argument overall that the former is better than the latter, this also means that the criterion cannot be compensated by other criteria.

In the case, according to the above discussions and DM's attentions, for g_1, g_2 and g_6, their attribute values are relative concentrated, thus indifferent threshold can be defined as: 10%*(maximum value - minimum values) and preference threshold =3* indifferent threshold. For g_3 and g_4 , the attribute values are not concentrated, so indifferent threshold can be defined to ensure that the value makes two solutions with the smallest difference indifferent and also let preference threshold is three times indifferent threshold.

For the capital cost, at the planning stage of a project, the budget error compared with the final budget for the capital cost is at least about ±5% in real world. Thus, in the example, according to the capital cost criterion, the indifferent threshold may be defined by $q_{lj} = 5\% * a_{l6}$ and preference threshold may be defined by $p_{lj} = 15\% * a_{l6}$. With veto power, in order that the solutions with high capital cost in accord with the capital budget will not be eliminated, the veto threshold should be given large enough, here we let $v_{l6} = 600$. For g_5, DM thinks it includes the non-compensated part, so let $v_{l5} = 1$.

The thresholds are defined for the example, as in Table IV.

TABLE IV. THRESHOLDS UNDER DIFFERENT CRITERIA

	g_1	g_2	g_3	g_4	g_5	g_6
q_j	9.472	0.057	3.788	20	0.15	$5\%*a_{l6}$
p_j	28.42	0.171	11.364	60	0.45	$15\%*a_{l6}$
v_j	189.4	1.140	75.760	173	1	600

F. Calculate the index of concordance and discordance

The concordance index for every pair of solutions is calculated by (3), as in Table V.

According to the criteria, the list of discordance matrix is calculated by (4), as in Table VI.

TABLE V. CONCORDANCE MATRIX

	a_1	a_2	a_3	a_4	a_5
a_1	1	0.45	0.43	0.45	1
a_2	0.80	1	0.92	0.45	0.80
a_3	0.69	0.84	1	0.42	0.69
a_4	0.66	0.66	0.86	1	0.66
a_5	0.88	0.50	0.5	0.5	1

TABLE V I (a). DISCORDANCE MATRIX FOR g_1

g_1	a_1	a_2	a_3	a_4	a_5
a_1	0	0	0	0	0
a_2	0.1351	0	0.2503	0	0.1972
a_3	0	0	0	0	0
a_4	0.2966	0	0.4118	0	0.3587
a_5	0	0	0	0	0

TABLE V I (b). DISCORDANCE MATRIX FOR g_2

g_2	a_1	a_2	a_3	a_4	a_5
a_1	0	0.1022	0.1331	0.4118	0
a_2	0	0	0	0.1331	0
a_3	0	0	0	0.1022	0
a_4	0	0	0	0	0
a_5	0	0.0402	0.0712	0.3498	0

TABLE V I (C). DISCORDANCE MATRIX FOR g_3

g_3	a_1	a_2	a_3	a_4	a_5
a_1	0	0.0739	0.1597	0.4118	0
a_2	0	0	0	0.1614	0
a_3	0	0	0	0.0756	0
a_4	0	0	0	0	0
a_5	0	0.0720	0.1579	0.4099	0

TABLE V I (d). DISCORDANCE MATRIX FOR g_4

g_4	a_1	a_2	a_3	a_4	a_5
a_1	0	0	0	0	0
a_2	0	0	0	0	0
a_3	0.2358	0.2358	0	0	0.2358
a_4	0.2358	0.2358	0	0	0.2358
a_5	0	0	0	0	0

TABLE V I (e). DISCORDANCE MATRIX FOR g_5

g_5	a_1	a_2	a_3	a_4	a_5
a_1	0	0	0	0	0
a_2	0.5818	0	0	0	0.5818
a_3	0.8545	0	0	0	0.8545
a_4	1	0.8364	0.5636	0	1
a_5	0	0	0	0	0

TABLE V I (f). DISCORDANCE MATRIX FOR g_6

g_6	a_1	a_2	a_3	a_4	a_5
a_1	0	0.6573	0.7183	1	0
a_2	0	0	0	0.7946	0
a_3	0	0	0	0.7517	0
a_4	0	0	0	0	0
a_5	0	1	1	1	0

G. Calculate the degree of outranking

Table VII shows outranking matrix calculated by (5).

TABLE VII. OUTRANKING MATRIX

	a_1	a_2	a_3	a_4	a_5
a_1	1	0.28	0.21	0	1
a_2	0.80	1	0.92	0.17	0.80
a_3	0.32	0.84	1	0.18	0.32
a_4	0	0.2	0.86	1	0
a_5	0.88	0	0	0	1

H. *Obtain the final ranking of the solutions*

The scores $\delta_l, l = 1, 2, \ldots, n$ show the degree of preferences of the solutions and are calculated by (6), as in Table VIII.

TABLE VIII. THE SCORES OF THE SOLUTIONS

	a_1	a_2	a_3	a_4	a_5
δ_l	-0.51	0.69	-0.34	-0.94	-1.12

Thus, the final ranking of the solutions in the example is:

$$a_2 \succ a_3 \succ a_1 \succ a_4 \succ a_5$$

Here that the difference in the score between the best solution and the second best solution is 0.1 taken as the criterion to carry through a sensitivity analysis. Since the difference in the case is 1.03, so no sensitivity analysis is carried.

V. DISCUSSIONS

Since the performances are objective, it only requires the DM to make the effort and ensure that the performance data is both accurate and defensible. The thresholds and weights, however, are subjective. The consideration of evaluation criterion weight values and threshold values is perhaps the most contentious issue associated with the application of ELECTRE III as the chosen weight values and threshold values will have direct impact on the resulting solution. What are the 'right' values for the weights and thresholds? They are really key issues in the proposed PDSP evaluation approach. To ensure that the planning solution(s) recommended by the analysis are suitably robust, some tasks discussed as above should be carried to elicit threshold values and weight values from DM by an iterative process.

In the PDSP evaluation process, the weight constrain functions from DM may cause the formula (2) no solution. This may need an iteration to check to determine the weights like using AHP.

To learn more about the stability of ranking list, sensitivity analysis should be carried and another threshold will be used to decide the start of this task.

VI. CONCLUSION AND FURTHER STUDY

Considering three issues including the vague of attribute values, incomplete weight preference information from DM and the flaw that the capital cost effectively masks the technical benefits in PDSP evaluation, we propose a novel PDSP approach including two stages using two models.

The two models have two advantages as follows.

First, the linear programming model uses the traditional optimum technique to obtain the weights of criteria, which utilizes the incomplete preference information effectively. The weight information from DM is expressed by a set of constraint functions, object function is to maximize the sum of weighted attribute values, with the linear programming model, each solution will has its weights from their own views, the objectivity of obtaining the weights is ensured by 'non-uniform assessment', and the vagueness of DMs' opinion is considered fully.

Second, the PDSP evaluation model based on ELECTRE III is based on outranking relation. The uncertainty of the data is incorporated by the thresholds reflecting DM's risk attitudes by pair comparison of the solutions, the information such as experience, judgment, sensitivity from DM is incorporated with the decision-aid process, and the evaluation model isn't based on the linear additive utility theory, including the idea that the utilities between criteria can't be compensated each other completely. So, the flaw that the capital cost effectively masks the technical benefit will be overcome to a great extent.

In summary, the proposed approach is a novel PDSP evaluation approach, whose interactive characteristic may increase the robustness of decision and enhance the confidence of DM in PDSP evaluation. The case study shows this approach can consider the former three issues in PDSP evaluation.

The approach also provides a novel way to deal with the MCDM problem in many fields.

Our further study is to develop a tool for implementing this approach and develop a method incorporating those four issues.

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