http://ansinet.com/itj

ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 9 (2): 325-330, 2010
ISSN 1812-5638

A Complete Ranking Model for MCDA Based on Multi-Graded Dominance Relations

[1,2]Rong Zhang, [1]Sifeng Liu and [2]Bin Liu
[1]College of Economics and Management, Nanjing University of Aeronautics and Astronautics, Nanjing, 210016, Peoples Republic of China
[2]College of Information and Management Science, Henan Agriculture University, Zhengzhou, 450002, Peoples Republic of China

Abstract: Based on multi-grade dominance relations, this study develops a new multi-criterion decision model, which can avoid losing information when decision table is changed into PCT and obtain complete ranking of alternatives. The model introduces PROMETHEE II into dominance-based rough set theory and with different preference grades for different criterions, describes binary preference relations of two objects. Meanwhile, the model resolves the problem of some alternatives having the same net flow value, which is a common problem when rough set method is applied to MCDA. Finally, an example illustrates the model is scientific and validity.

Key words: Dominance-based rough sets, PROMETHEE II model, synergic model, multi-criterion decision-making

INTRODUCTION

PCT (Pairwise Comparison Table) introduced by Greco has made rough set method be able to deal with choice and ranking problems, which extends the application range of rough set method (Greco *et al*., 2001, 2002a, b; Zaras, 2001). When studying the multi-criterion ranking problems with rough sets method from the point of view of ordinal relation, we need first describe the problem as PCT or change the traditional decision table into PCT and then derive rules. So, it becomes the focus paid more attention by the decision maker to change decision table possessing ordinal relation into PCT. But information loss in the changing process may bring new inconsistencies and finally influences on the validity of order rules; unfortunately the excessively simple changing method inevitably produces a certain information loss (Jiang *et al*., 2007; Wang *et al*., 2006a; Hua and Liu, 2004). Another question is that, when with the derived rules we rank some new instances, different alternatives have the same net flow values, which makes decision maker not be able to get the complete ranking. So, it is particularly important to change the traditional decision table into PCT meanwhile to avoid information loss and finally get the complete ranking.

PROMETHEE II is a valid one of multi-criterion decision analysis methods. It has such excellence as agility, adaptability to environment and stabilization of ranking result. And its ranking is based on pair comparison of alternatives and graded dominance relations so that the method need not standardize criterion values. Just for these good qualities, the method now is widely used in many fields such as selecting supplier, urban industrialization evaluation and optimal configuration of naval gun weapon systems (Sun and Qiu, 2007; Albadvi, 2004; Dulmin and Mininno, 2003; Wang and Yang, 2006; Wang *et al*., 2006b). Aiming at the localization that PROMETHEE II method do not deal with uncertain information and weight coefficients unknown, many scholars either properly change it or hybridize it with other methods such as AHP, fuzzy mathematic method, non-linear programming etc., to get an more effective decision analysis method which is more coincident with real environment (Goumas and Lygerou, 2000; Fernández-Castro and Jiménez, 2005; Macharis *et al*., 2004; Rekiek *et al*., 2002; Duvivier *et al*., 2007; Wang, 2005). Based on references, though PROMETHEE II is a valid analysis method for multi-criterion decision, we know still there are some certain problems. One is to get weights for criterions from exterior; the other is that the method cannot deal with the lingual criterion and uncertainty information.

Due to both PROMETHEE II and dominance-based theory based on preference dominance relation, so both they root the same theory base and have inherent contact. Therefore, this study hybrids the two methods and develops a new decision model that is more similar to natural reasoning process. The new model is designed to eal with ranking and choice in multi-criterion decision making problems.

Corresponding Author: Bin Liu, College of Information and Management Science, Henan Agriculture University, Zhengzhou, 450002, Peoples Republic of China

P2DRS DECISION MODEL

For short, the hybrid model developed from PROMETHEE II method and Dominance-based Rough Sets theory is shortened as P2DRS. The system flow figure of P2DRS is as Fig. 1. The process is that: first to change the decision table into PCT by criterion with multi-grade; then based on both the synthetic preference information of alternatives and the criterions' preference information, to assign weights of criterions with goal programming method and regarding the known ranking result of examples as the goal; finally, to derive decision rules from PCT and to rank the new objects with decision rules. Furthermore, the objects that have the same scores are compared with net flow value got with PROMETHEE II method. The new hybrid model can be used to deal with choice and ranking problems in multi-criterion decision fields, which inherits the virtue that PROMETHEE II method produces steady ranking result, meanwhile carry forward the characteristic that dominance-based rough sets method is good at dealing with uncertain problems.

Multi-grade dominance function: With respect to criterion α, the multi-grade dominance by pairwise comparison for alternatives are as follow:

When criterion is a numeric type, the preference grades produced by pairwise comparison for alternatives are as (Eq. 1):

$$P_a^H(x, y) = \mathrm{sgn}(x_a - y_a)\begin{cases} 0 & 0 < |x_a - y_a| \le \delta_{a1} \\ 1 & \delta_{a1} < |x_a - y_a| \le \delta_{a2} \\ \vdots & \vdots \\ h-1 & \delta_{a(h-1)} < |x_a - y_a| \le \delta_{ah} \\ h & |x_a - y_a| > \delta_{ah} \end{cases} \quad (1)$$

where, δ_{ah} is grade threshold, $k \in H_a$ and $H_a = \{1, 2,..., h\text{-}1, h\}$ is the set of dominance grades produced by pairwise comparison of two alternative with regard to criterion a, namely, it is actual range of dominance function P_a^H (x, y) and when P_a^H (x, y) = k, it can be simply noted as P_a^k (x, y) or P_a^k (x, y)≥0; when P_a^k (x, y)<0, it shows that with respect to criterion α alternative x is at least as good as alternative y and the degree is k; when P_a^k (x, y)<0, it shows that with respect to criterion α alternative x is worse than alternative y and the degree is k.

When criterion is a linguistic type, it can be considered as two instances.

The first is that: assume that α a linguistic criterion and its evaluation set of natural language is

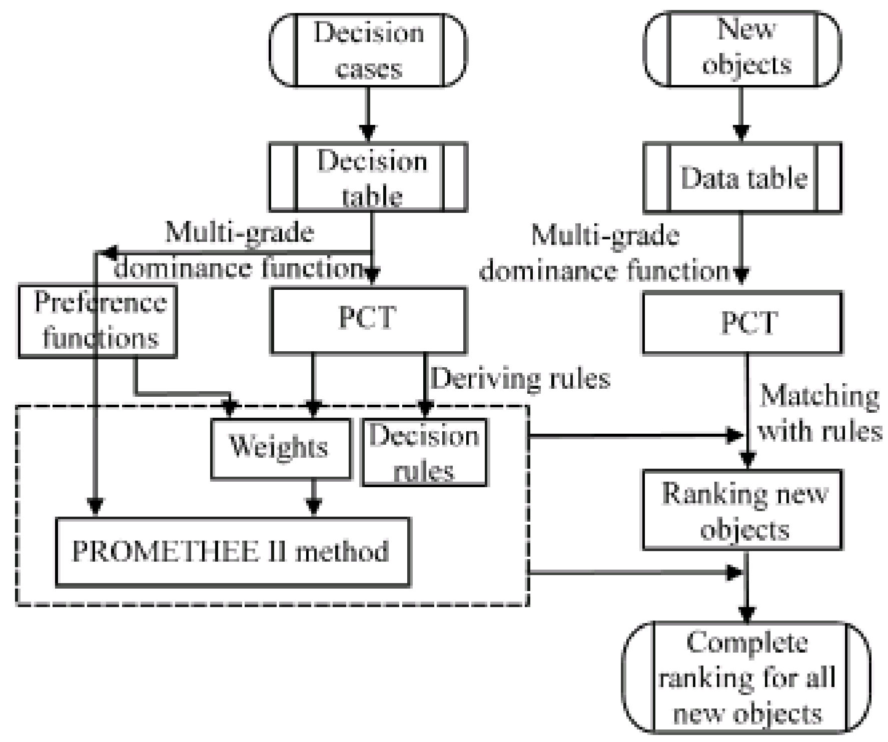

Fig. 1: System flow figure of P2DRS method

Vα = {v_1, v_2,..., v_l}, where, V_α satisfies order, namely if i≥j, then $n_i \ge n_j$, meanwhile the neighbour grades are equal at interval. Now change the set of qualitative descriptive language into ordinal scales set VN = {1,2,...,*l*}.

Example 1: An evaluation set of natural language is Va = {v_1: Worse, v_2: Bad, v_3: Medium, v_4: Good, v_5: Better} and can be changed into the ordinal scales set as Va = {1, 2, 3, 4, 5}, where the size of element shows the grades of criterions and 1 shows that the value of criterion gets from the worst grade, 3 shows that the value of criterion gets from the third grade. In fact the ordinal scales set shows the same meaning as the evaluation set of natural language, which is just changed into numerical expression. Namely, ordinal grades of criterions are expressed by discrete numbers between which have equal interval. Then criterion with multi-grade still can be use.

The second instance for linguistic criterion is that: the decision makers have given preference information of pairwise comparison of alternatives with regard to that criterion, namely linguistic judgement matrix with regard to criterion is known. Assume that the evaluation set of natural language phrase is L = {l_i|i∈ {1, 2,..., T}}, where, T is odd and satisfies:

- Ordinal, when i≥j, there is $l_i \ge l_j$;
- Converse operation in existence, neg (l_i) = l_j, j = T+1-i
- Maximizing operation, Max (l_i) = l_j, where, $l_i \ge l_j$
- Minimizing operation, min (l_i) = l_j, where, $l_i \ge l_j$

Then change the set into quantitative set:

$$L = \{ l_1 = \text{Worse}, l_2 = \text{Bad}, l_3 = \text{Equal}, l_4 = \text{Good}, l_5 = \text{Better} \}$$

Example 2: When T = 5, there is an evaluation set of natural linguistic phrase L = {l_1 = Worse, l_2 = Bad, l_3 = Equal, l_4 = Good, l_5 = Better} satisfies the above conditions, change it into the preference grade set showed as quantity set $H_\alpha = \{-2, -1, 0, 1, 2\}$. If alternative x compares with alternative y very bad, then there is P_α^H (x, y), or P_α^{-2} (x, y).

To make PCT: Information system S = (U, A, V, f), need change it into pairwise comparison table D_{PCT} = (U×U, A⋃{D}, $T_A \bigcup T_{\{d\}}$, g), where, U×U is binary comparison objects set, criterion set is divided into conditions criterion set A and decision criterion set {d} and A⋂{d} = Φ; $T_A = \bigcup_{a\in A} T_\alpha, T_\alpha = \{P_a^h, h\in H_\alpha\}$, P_a^h is graded preference produced when pairs of alternatives compare about criterion α, H_a is a particular subset that shows the preference grades of criterion α. T_d is the decision value of comprehensive pairwise comparison; g is information function, which shows for ∀ (x, y)∈ U×U, ∀α∈A, there is g[(x×y), α⋃d]∈$T_a \bigcup T_d$. Then there are three instances as follow.

To change the condition criterion. The multi-grade dominance function in Eq. 1 can be used.

To change the decision criterion. For decision cases, their decision criterion is already known. So their decision criterion can be pairedly compared. The value of decision criterion can be got as: for ∀(x,y)∈U×U,

$$T_d = \begin{cases} S & x \succ y \\ S^C & \text{else} \end{cases}$$

where, ≻ means that object x is at least as good as object y. When value of decision criterion is continuous type, we can determine threshold δ_d. If $x_d - y_d \geq \delta_d$, judge that object x is at least as good as object y; if $x_d - y_d < \delta_d$, judge that object x is not better than object y.

To expand PROMETHEE II: First, to expand preference function in PROMETHEE II method and to extend its range of preference function from [0,1] to [-1,1]. Denote the previous preference function as q_a (Wang, 2005), then there is:

$$q_a(x, y) = \begin{cases} 0, & \text{if } x_a \leq y_a \\ q(x_a - y_a), & \text{if } x_a > y_a \end{cases} \quad (2)$$

Denote:

$$P_a(x, y) = \begin{cases} q_a(x, y), & \text{if } x_a > y_a \\ 0, & \text{if } x_a = y_a \\ -q_a(x, y), & \text{if } x_a < y_a \end{cases} \quad (3)$$

then its range is [-1,1]. So the extended preference function can be denoted as $P_a(x,y)$ and simply denoted as P_a. Where the minus value of preference function shows that with respect to criterion a alternative x is worse than y.

Meanwhile, based on the extended preference function, the calculating formula for net flow value is (Eq. 4).

$$\phi(x) = \sum_{j=1}^{n} w_j \sum_{k=1}^{m} P_j(x, x_k) \quad (4)$$

And obviously both net flow values from the two preference functions are completely equal. The reason is (Eq. 5).

$$\begin{aligned} \phi(x) &= \phi^+(x) - \phi^-(x) = \sum_{k=1}^{m}\sum_{j=1}^{n} w_j q_j(x, x_k) - \\ &\sum_{k=1}^{m}\sum_{j=1}^{n} w_j q_j(x_k, x) = \sum_{k=1}^{m}\sum_{j=1}^{n} w_j (q_j(x, x_k) - q_j(x_k, x)) \\ &= \sum_{k=1}^{m}\sum_{j=1}^{n} w_j P_j(x, x_k) = \sum_{j=1}^{n} w_j \sum_{k=1}^{m} P_j(x, x_k) \end{aligned} \quad (5)$$

After extending the range of preference function, it can be determined from the multi-grade dominance criterion in section 1 as:

$$P_a(x, y) = \frac{1}{h} P_a^h(x, y)$$

It can be seen that the preference function of each criterion in PROMETHEE II method can be obtained, when the traditional decision table is changed into PCT. Namely, for the same decision problem, the PCT information in dominance-based rough set method is completely same as paired comparison information of alternatives with regard to certain criterion.

Calculate weight of criterion: In the decision cases, the pairwise comparison information of alternatives with regard to each criterion is known and the comprehensive comparison information of alternative is also known. So a method can be developed for mining the relatively important information of each criterion in decision cases.

Assume that in PCT set A of condition criterions has card(A) and set E(E⊂U) of alternatives has card(E). Then the comprehensive preference information of alternative set E has been known and the ranking of alternatives is considered as $x_1^* \succ x_2^* \succ \cdots \succ x_{m-1}^* \succ x_m^*$. In PROMETHEE method, if $x_i \succ x_j$, then net flow values hold $\phi(x_i) > \phi(x_j)$, where:

$$\phi(x) = \sum_{j=1}^{n} w_j \sum_{k=1}^{m} P_j(x, x_k)$$

and the weights of criterions, w_j, j = 1,2,...,n, are unknown.

Now obtain weights of criterions with the following goal programming model (Eq. 6).

$$\text{Min}Z = P_1 d_1^- + P_2 d_2^- + \cdots + P_{m-1} d_{m-1}^-$$

$$\text{s.t.} \begin{cases} \sum_{j=1}^{n} w_j = 1 \\ \phi(x_1^*) - \phi(x_2^*) + d_1^- - d_1^+ = 0 \\ \phi(x_2^*) - \phi(x_3^*) + d_2^- - d_2^+ = 0 \\ \vdots \\ \phi(x_{m-1}^*) - \phi(x_m^*) + d_{m-1}^- - d_{m-1}^+ = 0 \\ w_j > 0,\ j = 1,2,\ldots,n;\ d_j^-, d_j^+ \geq 0,\ j = 1,2,\ldots,m-1 \end{cases} \tag{6}$$

Weights of criterions are satisfactory solution obtained by solving the above goal-programming model. And weights obtained from PCT can reflect the comprehensive preference information of alternatives in PCT.

To derive decision rules: Assume that the comprehensive preference information of a part set of alternatives denoted as E($E \subset B$) are known, then pairwise comparison table is a decision table that has complete information, namely $D_{PCT} = (E \times E,\ C \cup \{d\},\ T_c \cup T_{(d)}, g)$, where, E is the exemplary objects set that their comprehensive preference relation or multicriteria evaluations are unknown and E×E is pair comparison set.

For $\forall (x,y), (w,z) \in E \times E$, with respect to criterion $a \in A$, $(x,y)D_a(w,z)$ mean that (x,y) dominates (w,z), or x is preferred to y at least as strongly as w is preferred to z. Then the following holds: for $\forall (x,y), (w,z) \in E \times E$, $a \in A$, h_a, $k_a \in H_a$, $xP^h_a y$ and $(x,y)D_a(w,z) \leftrightarrow h_a \geq k_a$.

Using the dominance relation D_a, let us introduce the positive dominance $D^+_A(x,y)$ and the negative dominance $D^-_A(x,y)$.

$$D_A^+(x, y) = \{(w, z) \in E \times E \mid (w, z) D_A (x, y)\}$$

$$D_A^-(x, y) = \{(w, z) \in E \times E \mid (x, y) D_A (w, z)\}$$

Considering the binary relation S and S^C confined to the decision criterion {d}, we can respectively define lower and upper approximations of S with respect to condition criterion set C as follow:

$$\underline{C}(S) = \{(x, y) \in E \times E \mid D_A^+(x, y) \subseteq S\}$$

$$\overline{C}(S) = \{(x, y) \in E \times E \mid D_A^-(x, y) \cap S \neq \Phi\} = \bigcup_{(x, y) \in S} D_A^+(x, y)$$

Analogously we can defined the approximations of S^C:

$$\underline{C}(S^C) = \{(x, y) \in E \times E \mid D_A^-(x, y) \subseteq S^C\}$$

$$\overline{C}(S^C) = \{(x, y) \in E \times E \mid D_A^+(x, y) \cap S^C \neq \Phi\} = \bigcup_{(x, y) \in S^C} D_A^-(x, y)$$

Exact definitions of the concept of upward cumulated preferences and downward cumulated preferences are the following: $\forall (x,y) \in E \times E$, $a \in A$, h, $k \in H_a$, where, $k \geq h$, if $xP^k_a y$, then $xP^{\geq h}_a y$; where $k \leq h$, if $xP^k_a y$, then $xP^{\geq h}_a y$.

Using the above concepts, from the given PCT, three types of decision rules can be obtained:

$$P = \{a_1, a_2, \ldots, a_p\} \subseteq A$$
$$(h_{a1}, h_{a2}, \ldots, h_{ap}) \in H_{a1} \times H_{a2} \times \ldots \times H_{ap},$$

$D_{\leq}$ decision rules: If $xP_{a1}^{\leq h_{a1}} y$ and $xP_{a2}^{\leq h_{a2}} y$, …… and $xP_{a2}^{\leq h_{ap}} y$, then xSy and these rules are supported by pairs of objects from $\underline{C}(S)$.

$D_{\#}$ decision rules: If $xP_{a1}^{\leq h_{a1}} y$ and $xP_{a1}^{\leq h_{a2}} y$, …… and $xP_{a1}^{\leq h_{ap}} y$, then $xS^C y$ and these rules are supported by pairs of objects from $\underline{C}(S^C)$.

$D_{\leq\#}$ decision rules: If $xP_{a1}^{\leq h_{a1}} y$ and $xP_{a2}^{\leq h_{a2}} y$, …… and $xP_{ak}^{\geq h_{ak}} y$ and $xP_{a(k+1)}^{\leq h_{a(k+1)}} y$ and $xP_{a(k+2)}^{\leq h_{a(k+2)}} y$, …… and $xP_{ap}^{\leq h_{ap}} y$, then xSy or $xS^C y$ and these rules are supported by pairs of objects from $bn_C(S)$ (Greco *et al*., 2001).

To handle ranking problem with decision rules and PROMETHEE II method: After the application of the decision rules obtained on E to the whole object set U finally for each object $x \in U$, to calculate Net Flow Score S(x), for handling ranking and choice, where:

$$S(x) = S^{++}(x) - S^{+-}(x) + S^{-+}(x) - S^{--}(x)$$

and

$$S^{++}(x) = \text{Card}\left(\left\{y \in U \,\middle|\, \begin{array}{l}\text{There is at least one decision} \\ \text{rule which affirms xSy}\end{array}\right\}\right);$$

$$S^{+-}(x) = \text{Card}\left(\left\{y \in U \,\middle|\, \begin{array}{l}\text{There is at least one decision} \\ \text{rule which affirms yS}\end{array} x\right\}\right);$$

$$S^{-+}(x) = \text{Card}\left(\left\{y \in U \,\middle|\, \begin{array}{l}\text{There is at least one decision} \\ \text{rule which affirms yS}^C\text{x}\end{array}\right\}\right);$$

$$S^{--}(x) = \text{Card}\left(\left\{y \in U \,\middle|\, \begin{array}{l}\text{There is at least one decision} \\ \text{rule which affirms xS}^C\text{y}\end{array}\right\}\right)$$

The alternative $x^*(x^* \in U)$, which satisfies $S(x^*)$, is optimal (Greco *et al*., 2001).

In the ranking problems, when S(x), namely both object x and object y have the same Net Flow Score, we cannot distinguish the two objects with their Score. So we cannot completely rank all alternatives. Furthermore, we can calculate net flow $\phi(x)$ by PROMETHEE method and then compare $\phi(x)$ with $\phi(y)$, if $\phi(x)>\phi(y)$, then $x \succ y$.

THE PROCESS OF P2DRS

The process of P2DRS decision model is as following:

- **Step 1:** According to criterion with multi-grade, change decision table of exemplary objects into Pairwise Comparison Table (PCT) and meanwhile get the preference function in PROMETHEE II method
- **Step 2:** With goal programming method, calculate weights for criterions, based on the known ranking information in the decision table and preference information obtained by preference functions with respect to condition criterions
- **Step 3:** Derive decision rules from PCT
- **Step 4:** Use the decision rules to deal with alternative ranking and choice. To the alternatives that still cannot be distinguished, we can judge them with PROMETHEE II to get the completely ranking for all objects

AN APPLICATION OF P2DRS DECISION MODEL IN SELECTING SUPPLIERS

A selecting suppliers problem: there are 6 successful purchasing cases and now need rank 5 new suppliers (Table 1). Condition criterion set is:

A = {Price, Delivery Date, Ability of R and D}

and decision criterion set is {d} = {Ranking Number}. First change range {good, medium, poor} of linguistic criterion Ability of R and D into {3, 2, 1}; then with the model in this study, change the decision table into PCT.

Confirm the criterion with multi-grade and preference functions for 3 condition criterions as following:

Table 1: The decision table of suppliers

Suppliers	Price (\$) a_1	Delivery date (Month) a_2	Ability of R and D a_3	Ranking No.
S1	180	4	Good	1
S2	160	5	Medium	4
S3	165	6	Good	2
S4	145	7	Medium	3
S5	145	7	Medium	5
S6	135	8	Poor	6

$$P^h_{a_1}(x, y) = \mathrm{sgn}(x_{a_1} - y_{z_1}) \cdot \begin{cases} 0 & 0 < |x_{a_1} - y_{a_1}| \le 5 \\ 1 & 5 < |x_{a_1} - y_{a_1}| \le 15 \\ 2 & 15 < |x_{a_1} - y_{a_1}| \le 35 \\ 3 & |x_{a_1} - y_{a_1}| > 35 \end{cases}$$

$$P_{a_1}(x, y) = \frac{1}{3} P^h_{a_1}(x, y)$$

$$P_{a_2}(x, y) = \mathrm{sgn}(x_{a_2} - y_{z_2}) \cdot \begin{cases} 0 & 0 < |x_{a_2} - y_{a_2}| \le 0.5 \\ 1 & 5 < |x_{a2} - y_{a2}| \le 1.5 \\ 2 & 15 < |x_{a_2} - y_{a_2}| \le 3 \\ 3 & |x_{a_2} - y_{a_2}| > 3 \end{cases}$$

$$P_{a_2}(x, y) = \frac{1}{3} P^h_{a_2}(x, y)$$

$$P_{a_3}(x, y) = \mathrm{sgn}(x_{a3} - y_{z3}) \cdot \begin{cases} 0 & |x_{a_3} - y_{a3}| = 0 \\ 1 & 0 < |x_{a3} - y_{a3}| \le 1 \\ 2 & 1 < |x_{a_3} - y_{a_3}| \le 2 \end{cases}$$

$$P_{a_3}(x, y) = \frac{1}{2} P^h_{a_3}(x, y)$$

With goal programming method weights can be got as $w_1 = 0.43$, $w_2 = 0.25$, $w_3 = 0.32$.

From PCT, three types of decision rules are induced and applied to new objects in order to obtain a recommendation for the decision makers. For each object the Net Flow Score is in Table 2 and the ranking is $(S7, S9, S10) \succ S8 \succ S11$. Furthermore, with PROMETHEE II method, for alternatives S7, S9 and S10, calculate net flow value as $\phi(S7) = 0.22$, $\phi(S9) = 0.4733$, $\phi(S10) = 0.4967$, so the complete ranking for all alternatives is $S7 \succ S10 \succ S9 \succ S8 \succ S11$, where supplier S7 is the optimal.

To get more abundant conclusion, just with PROMETHEE II method, we evaluation all new objects and can get their net flow values, respectively as $\phi(S7) = 0.22$, $\phi(S8) = -0.1367$, $\phi(S9) = 0.4733$, $\phi(S10) = 4967$ and $\phi(S11) = 1.0533$. The result is consistent with the ranking result obtained with decision rules derived with dominance-based rough set method. To some degree, it is feasible to hybrid the two methods of PROMETHEE II and dominance-based rough set both based on binary dominance relation.

Table 2: The decision table of new suppliers

Suppliers	a_1	a_2	a_3	S(x)	$\phi(x)$	Ranking
S7	165	4.0	3	4	0.2200	1
S8	150	5.0	2	-4	-0.1367	4
S9	145	6.0	3	4	0.4733	3
S10	135	5.5	2	4	0.4967	2
S11	135	7.5	1	-8	-1.0533	5

CONCLUSION

By hybridizing the two methods of PROMETHEE II and dominance-based both based on binary dominance relation, this study builds a new P2DRS model to deal with ranking problem in multi-criterion decision field. On one side, due to the excellence of PROMETHEE II having steady ranking result, this model can easily deals with the problems of translating PCT and equal scores of different objects. On the other side, the model can not only derive decision rules from PCT, but also obtain weights of criterions with goal programming method based on PCT. In short, the model built in this study, which not only inherits the virtue of PROMETHEE II having steady ranking result, but also develops the characteristic of dominance-based rough set being good at dealing with uncertain problems, provides a new effective method for dealing with choice and ranking problem in multi-criterion decision field.

ACKNOWLEDGMENTS

The authors thank the editor and anonymous referees for their helpful comments and suggestions, which have improved the exposition of this study. Additionally, this study was supported in part by Natural Science Foundation of China under Grant No. 70871035 and the Program for Science and Technology Innovation Talents in Universities of Henan Province under Grant No. 2010HASTIT030.

REFERENCES

Albadvi, A., 2004. Formulating national information technology strategies: A preference ranking model using PROMETHEE method. Eur. J. Operat. Res., 2: 290-296.

Dulmin, R. and V. Mininno, 2003. Supplier selection using a multi-criteria decision aid method. J. Purchase Supp. Manage., 9: 177-187.

Duvivier, D., O . Roux, V. Dhaevers, N. Meskens and A. Artiba, 2007. Multi-criteria optimization and simulation: An industrial application. Ann. Operat. Res., 6: 45-60.

Fernández-Castro, A.S. and M. Jiménez, 2005. PROMETHEE: An extension through fuzzy mathematical programming. J. Operat. Res. Soc., 1: 119-122.

Goumas, M. and V. Lygerou, 2000. An extension of the PROMETHEE method for decision making in fuzzy environment: Ranking of alternative energy exploitation. Eur. J. Operat. Res., 3: 606-613.

Greco, S., B. Matarazzo and R. Slowinski, 2001. Rough sets theory for multi-criteria decision analysis. Eur. J. Operat. Res., 1: 1-47.

Greco, S., B. Matarazzo and R. Slowinski, 2002a. Rough approximation by dominance relations. Int. J. Intel. Syst., 17: 153-171.

Greco, S., B. Matarazzo and R. Slowinski, 2002b. Rough sets methodology for sorting problems in presence of multiple attributes and criteria. Eur. J. Operat. Res., 8: 247-259.

Hua, W.J. and Z.L. Liu, 2004. A method of measuring preference and deriving rules in MCDM based on rough sets theory. J. Air Force Eng. Univ., 3: 60-64.

Jiang, Y.Y., H.X. Zhang, K. Meng and J. Jie, 2007. Research and application of multi-criteria decision making method based on order relation and rough set. Syst. Eng. Theory Practice, 6: 161-165.

Macharis, C., J. Springael, K.D. Brucker and A. Verbeke, 2004. PROMETHEE and AHP: The design of operational synergies in multi-criteria Analysis-strengthening promethee with ideas of AHP. Eur. J. Operat. Res., 2: 307-317.

Rekiek, B., P.D. Lit and A. Delchambre, 2002. Hybrid assembly line design and user's preferences. Int. J. Prod. Res., 5: 1095-1111.

Sun, S.Y. and Z.M. Qiu, 2007. A comparison study on optimal configuration methods of naval gun weapon systems. Acta Armamentarii, 7: 778-781.

Wang, J.Q., 2005. PROMETHEE method with incomplete certain information and its application. Syst. Eng. Electr., 11: 1909-1913.

Wang, J.J. and D.L. Yang, 2006. An AHP/PROMETHEE based method of selecting supplier. Manage. Rev., 7: 57-61.

Wang, J.J., C.M. Wei and D.L. Yang, 2006a. A decision method for vendor selection based on AHP/PROMETHEE/GAIA. J. Dalian Univ. Technol., 6: 926-931.

Wang, Y., S.Y. Liu and J. Zhang, 2006b. Rough set approach to group decision making based on linguistic information processing. J. Syst. Eng., 1: 18-23.

Zaras, K., 2001. Rough approximation of a preference relation by a multi-criterion stochastic dominance for determinist and stochastic evaluation problems. Eur. J. Operat. Res., 3: 305-314.