Review of Industrial Engineering Letters
2014 Vol. 1, No. 1, pp. 25-35
ISSN(e): 2408-9427
ISSN(p): 2409-2169
DOI: 10.18488/journal.71/2014.1.1/71.1.25.35

RANKING IRANIAN ACCREDITED LABORATORIES WITH PROFICIENCY TESTS USING PROMETHEE METHOD

Mousa Amini[1] --- Alireza Alinezhad[2] --- Hamid Najafabadiha[3]

[1]*MSc graduate of industrial engineering (System management and productivity), Alghadir University, Tabriz, Iran*

[2,3]*Faculty of Industrial and Mechanical Engineering, Qazvin Branch, Islamic Azad University, Qazvin, Iran*

ABSTRACT

The rapid pace of changing technology is leading to high rate of import and export between different countries. In outsourcing governmental organizations duties to private sectors, it is a need to control sectors and they should be under assessment policy. This research has been developed to show how the accredited laboratories of Iranian standard (ISIRI) can be assessed for their technical servicing using the Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) in combination with proficiency testing inter- laboratories comparison, in order to rank them for an urgent or crucial need of testing any kind of goods or products under compulsory regulation or national standard for their quality or safety aspect. The proposed approach, therefore, allows a decision to be made with confidence that the alternative (laboratory) chosen has best performance for conformity assessment.

Keywords: MADM, Proficiency testing, PROMETHEE, Preference function, Ranking, Criteria.

Contribution/ Originality

The paper's primary contribution is finding that implementation of a hybrid integration of PROMETHEE I, II with Proficiency Testing inter-groups comparison, provide a successful tool for ranking of those candidates.

1. INTRODUCTION

Nowadays, the key issue for managers is decision making. They are always faced with choosing, selecting and ranking between different choices. In the past four decades the comparison of the laboratories effectiveness and competencies were mostly justified by argument that the experts of Reference laboratory (ISIRI) had done by their experiences and knowledge. The issue about the choice and ranking alternatives is not easy to solve. In particular, there is no

optimal solution-neither alternative is the best for every criterion. The choice is subjected to test quality of the individual's accredited laboratories compared with reference ones. In recent years, several Multi Criteria Decision Analysis (MCDA) methods have been proposed to help in selecting the best compromised alternatives. The development of MCDA methods has been motivated not only by a variety of real-life problems requiring the consideration of multiple criteria, but also by practitioners' desire to propose enhanced decision making techniques, using recent advancements in mathematical optimization, scientific computing, and computer technology [1]. PROMETHEE is also a quite simple ranking method in conception and application compared with the other methods for multi-criteria analysis [2]. In the context of outsourcing, we employed a hybrid integration of PROMETHEE I, II and Proficiency Testing inter-laboratories comparison, to provide a tool for ranking candidates for accepting the outsourcing duties of conformity assessment with International or National Standards. The broad purpose of this paper is to introduce, how MADM method can be used in ranking the accredited laboratories of ISIRI due to the outsourcing duties of this organization, by taking account the result of testing performance based on six criteria. In order to evaluate the competency of these laboratories in offering crucial and important services as conformity assessment of vital goods and products that directly affect the human life which in case of wrong performance of quality and safety aspects. In the past four decades the comparison of the laboratories effectiveness and competencies were mostly justified by argument that the experts of Reference laboratory (ISIRI) had done by their experiences and knowledge.

For our approach, it was necessary to prepare a uniform paint sample and to send that to the accredited laboratories for testing as regulation of Proficiency Testing inter- laboratories comparison in order to make the initial data decision matrix through real experimental results. The same testing for reference evaluation was done by the reference laboratory of ISIRI as key point. Alternatives are evaluated according to different criteria (given by related National Standard), by pair wise comparison of alternatives along each recognized criterion. To have better rank ones we had to make minimum deviation from reference value.

This paper is organized as follows: the history and the method of PROMETHEE are described in section 2. In section 3, an example of the application of the PROMETHEE method in ISIR will be solved and section 4 contains conclusions.

2. THE PROMETHEE METHOD

The PROMETHEE includes the PROMETHEE I for partial ranking of the alternatives and the PROMETHEE II for complete ranking of the alternatives, is one of the MCDA methods that was developed by Brans [3] and further extended by Vincke and Brans [4].

PROMETHEE is an outranking method for a finite set of alternative actions to be ranked and selected among criteria, which are often conflicting. PROMETHEE is also a quite simple ranking method in conception and application compared with other methods for multi-criteria

analysis [2]. Therefore, the numbers of researchers who are applying the PROMETHEE method to practical multiple criteria decision problems increases year by year.

Several versions of the PROMETHEE methods were developed to help in more complicated decision-making situations [5] such as the PROMETHEE III for ranking based on interval, the PROMETHEE IV for complete or partial ranking of the alternatives when the set of viable solutions is continuous, the PROMETHEE V for problems with segmentation constraints [6], the PROMETHEE VI for the human brain representation [7], the PROMETHEE GDSS for group decision-making [8], and the visual interactive module; Geometrical Analysis for Interactive Aid (GAIA) for graphical representation [8], [9]. Figueira, et al. [10] has recently proposed two extended approaches on PROMETHEE, called as the PROMETHEE TRI for dealing with sorting problems and the PROMETHEE CLUSTER for nominal classification [11].

The methods of PROMETHEE have successfully been applied in many fields and a number of researchers have used them in decision-making problems. The PROMETHEE methods have some requisites of an appropriate multi-criteria method and their success is basically due to their mathematical properties and their particular friendliness of use [5].

The more a method is used, the more credit and the less doubts it gets. Nevertheless, every method has its restrictions, mostly due to model assumptions, which should always be considered when the method is used. PROMETHEE methods may be applied when the following considerations are taken into account [12]:

- The decision maker can express his preferences between two actions on all the criteria on ratio scales.
- The decision maker can express the importance he attaches to the criteria on a ratio scale.
- The decision maker wants to take all criteria into account and is aware of the fact that the weights are representing trade-offs.
- For all criteria the difference between evaluations must be meaningful.
- None of the possible differences on any of the criteria can give rise to discordance.
- The decision maker knows exactly what can happen if one or more actions are added or deleted and is fully aware of the influences on the final decision.

PROMETHEE II stepwise procedure this part of the paper briefly describes PROMETHEE II, which is intended to provide a complete ranking of a finite set of feasible alternatives from the best to the worst. This method is fundamental to implement the other PROMETHEE methods and the majority of researchers have referred to this version of the PROMETHEE methods. The basic principle of PROMETHEE II is based on a pair wise comparison of alternatives along each recognized criterion Alternatives are evaluated according to different criteria, which have to be maximized or minimized. The implementation of the PROMETHEE II requires two additional types of information:

The weight Determination of the weights is an important step in most multi-criteria methods. PROMETHEE II assumes that the decision-makers able to weigh the criteria

appropriately, at least when the number of criteria is not too large [10]. The preference function for each criterion translates the difference between the evaluations obtained by two alternatives into a preference degree ranging from zero to one. In order to facilitate the selection of a specific preference function, Vincke and Brans [4] proposed six basic types: (1) usual criterion, (2) U-shape criterion, (3) V-shape criterion, (4) level criterion, (5) V-shape with indifference criterion and (6) Gaussian criterion (see Table1) [4]. These six types are particularly easy to define. For each criterion, the value of indifference threshold, q; the value of a strict preference threshold; and the value of an intermediate value between p and q, s, have to be fixed [6]. In each case, these parameters have a clear significance for the decision-maker. Fig. 1 presents stepwise procedure for implementing PROMETHEEII. The procedure is started to determine deviations based on pair-wise comparisons. It is followed by using a relevant preference function for each criterion in Step 2, calculating global preference index in Step 3, and calculating positive and negative outranking flows for each alternative and partial ranking in step 4.The procedure is come to an end with the calculation of net outranking flow for each alternative and complete ranking.

2.1. The PROMETHEE Preference Modeling Information

The PROMETHEE methods were designed to treat multi criteria problems of table (1) and their associated evaluation figure (l).

Figure-1. Types of generalized criteria [5]

Generalised criterion	Definition	Parameters to fix
Type 1: Usual Criterion	$P(d) = \begin{cases} 0 & d \le 0 \\ 1 & d > 0 \end{cases}$	–
Type 2: U-shape Criterion	$P(d) = \begin{cases} 0 & d \le q \\ 1 & d > q \end{cases}$	q
Type 3: V-shape Criterion	$P(d) = \begin{cases} 0 & d \le 0 \\ \frac{d}{p} & 0 \le d \le p \\ 1 & d > p \end{cases}$	p
Type 4: Level Criterion	$P(d) = \begin{cases} 0 & d \le q \\ \frac{1}{2} & q < d \le p \\ 1 & d > p \end{cases}$	p, q
Type 5: V-shape with Indifference Criterion	$P(d) = \begin{cases} 0 & d \le q \\ \frac{d-q}{p-q} & q < d \le p \\ 1 & d > p \end{cases}$	p, q
Type 6: Gaussian Criterion	$P(d) = \begin{cases} 0 & d \le 0 \\ 1 - e^{-\frac{d^2}{2s^2}} & d > 0 \end{cases}$	s

Table-1. Evaluation table

a	$g_1(.)$	$g_2(.)$	. . .	$g_j(.)$	. . .	$g_k(.)$
a_1	$g_1(a_1)$	$g_2(a_1)$	. . .	$g_j(a_1)$	. . .	$g_k(a_1)$
a_2	$g_1(a_2)$	$g_1(a_2)$	. . .	$g_j(a_2)$	. . .	$g_k(a_2)$
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
a_i	$g_1(a_i)$		. . .	$g_j(a_i)$	. . .	$g_k(a_i)$
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
a_n	$g_1(a_n)$	$g_2(a_n)$	. . .	$g_j(a_n)$	. . .	$g_k(a_n)$

The additional information requested to run PROMETHEE is particularly clear and understandable by both the analysts and the decision-makers and consists of:

- Information between the criteria;
- Information within each criterion

2.2. Information between the Criteria (Weights)

The weights can be determined according to various methods (see Nijkamp, et al. [13]; Eckenrode [14] for an overview of these methods). PROMETHEE does not provide specific guidelines for determining these weights, but assumes that the decision-maker is able to weigh the criteria appropriately, at least when the number of criteria is not too large.

Table (2) should be completed with the understanding that the set $\{w_j, j=1,2,...,k\}$ represents weights of relative importance of the different criteria. These weights are non-negative numbers and independent from the measurement Units of the criteria and the sum of them is equal to 1 as Formula 1.

$$\sum_{j=1}^{k} w_j = 1 \qquad (1)$$

Table-2. Weights of relative importance

$g_1(.)$	$g_2(.)$	. . .	$g_j(.)$	. . .	$g_k(.)$
w_1	w_2	. . .	w_j	. . .	w_k

2.3. Information within the Criteria

PROMETHEE doesn't allocate an intrinsic absolute utility to each alternative, neither globally and nor on each criterion. We strongly believe that the decision makers not to proceed that way. The preference structure of PROMETHEE is based on pair wise comparisons. In this case the deviation between the evaluations of two alternatives on a particular criterion is considered. For small deviations, the decision-maker will allocate a small preference to the best alternative and even possibly no preference if he considers that this deviation be negligible. The preference is based on the easy rule of; the larger the deviation, the larger the preference. It is considered that the preferences are real numbers varying between 0 and 1. This means that for each criterion the decision-maker has in mind a function as:

$$P_j(a,b) = F_j\left\lfloor d_j(a,b)\right\rfloor \qquad \forall a,b \ni A \tag{2}$$

Where:

$$d_j(a,b) = g_j(a) - g_j(b) \tag{3}$$

And for which:

$$0 \le p_j(a,b) \le 1$$

In case of a criterion to be 1, this function is giving the maximum preference for observed deviations between their evaluations on criterion and the preferences equals 0 when the deviations are negative.

2.4. Ranking by PROMETHEE I

The PROMETHEE **I** procedure is based on pair wise comparisons. First aggregated preference indices and outranking flows are defined. Let *a* and *b* ∋ *A*:

$$\left.\begin{aligned}\pi(a,b) &= \sum_{j=1}^{k} P_j(a,b) * \omega_j,\\ \pi(b,a) &= \sum_{j=1}^{k} P_j(b,a) * \omega_j,\end{aligned}\right\} \tag{4}$$

Formula 4 is expressing that which degree is preferred to over all the criteria and how it is preferred. Generally, the criteria for which a is better than b and criteria for which b is better than a and consequently $\pi(a,b)$ and $\pi(b,a)$ are usually positive. The following properties hold for all $(a,b) \ni A$.

$$\begin{aligned}&\pi(a,a) = 0,\\ &0 \le \pi(a,b) \le 1,\\ &0 \le \pi(b,a) \le 1,\\ &0 \le \pi(a,b) + \pi(b,a) \le 1.\end{aligned} \tag{5}$$

Each alternative is facing other alternatives in A. Two outranking flows as negative and positive are defined as follows:

$$\begin{aligned}\phi^{+}(a)&=\frac{1}{n-1}\sum_{\chi\in A}\pi(a,\chi)\\ \phi^{-}(a)&=\frac{1}{n-1}\sum_{\chi\in A}\pi(\chi,a)\end{aligned} \tag{6}$$

2.5. Complete Ranking by PROMETHEE II

PROMETHEE II consists of the complete ranking. It is often the case that the decision-maker requests a complete ranking. The *net outranking flow* can then be considered.

$$\phi(a)=\phi^{+}(a)-\phi^{-}(a) \tag{7}$$

There is a balance between the positive and the negative outranking flows. The higher the net flow, the better the alternative, so that:

$$\begin{cases} aP^{II}b & iff \quad \phi(a)\rangle\phi(b), \\ aI^{II}b & iff \quad \phi(a)\rangle\phi(b), \end{cases} \tag{8}$$

When PROMETHEE II is considered, all the alternatives are comparable. Not in comparability's remain, but the resulting information can be more disputable because more information gets lost by considering the difference based on the Formula (7). The following properties hold:

$$\begin{cases} -1\le\phi(a)\le 1 \\ \sum_{\chi\in A}\phi(a)=0 \end{cases} \tag{9}$$

When $\phi(a)\rangle 0, a$ is outranking all the alternatives on all the criteria, $\phi(a)\langle 0$ it is outranked.

3. ISIR APPLICATION

3.1. Criteria and Laboratories Selection

The main objective of this article is to choose laboratories and determine the criteria to perform a multidimensional comparison of the test results. Seven accredited laboratories of ISIRI (Iranian Standard organization) i.e. Ira, Baj, Ran, Sah, Tei, Met, Haw and six quantitative criteria related to paint National Standard No. 2225, named: Viscosity, Non-volatile mass, fineness of grind, Hiding power, Gloss at 60^0 angle and Density were selected and compared amongst seven laboratories.

3.2. Sampling Based on Criteria

In order to make the initial data decision matrix through real experimental results, a uniform paint sample for testing as regulation of Proficiency Testing inter-laboratories comparison was

experimented. The sampling was done by a group of ISIR experts in the laboratories and the laboratories were informed in advance that they will be examined and ranked based on their competency and proficiencies. After the sampling was done by a glance to individual value of criteria, differences in results of these laboratories with reference laboratory were obvious and showed that, for the aim of this research, determining the performance of the accredited laboratories is a need. In Table (3) the result of reference and accredited laboratories is considered.

Table-3. Test result of reference and accredited laboratories

	Viscosity (ku)	**Non-volatile mass Weight solid%**	**fineness of grind µm**	**Hiding power** m^2/lit	**Gloss at** 60^0 **angle**	**Density** g/cm^3
IRa	110	75	25	10	3	1.5
Baj	118.5	77.72	20	11.4	8	1.552
Ran	110	76.5	25	8.7	3.5	1.55
Sah	117	78	20	11	4	1.55
Tei	115	78	20	10	2.8	1.56
Met	119.3	77.19	20	12.5	2.4	1.54
Haw	116	77	22	8.5	3.4	1.53
Reference	120	77.25	20	10.8	3	1.556

3.3. Constructing Deviation Table

As far as the above table can't be used as PROMETHEE input matrix for pair wise comparison of alternatives along each recognized criterion. For this purpose the deviations table of these results from the reference result should be considered as input matrix for PROMETHEE.

Table-4. Result Deviations of accredited laboratories from reference value

	Viscosity (ku)	**Non-volatile mass Weight solid%**	**fineness of grind µm**	**Hiding power** m^2/lit	**Gloss at** 60^0 **angle**	**Density** g/cm^3
IRA	10	2.25	5	0.8	0.3	0.056
Baj	1.5	0.47	0	0.6	4.7	0.004
Ran	10	0.75	5	2.1	0.2	0.006
Sah	3	0.75	0	0.2	.07	0.006
Teip	5	0.75	0	0.8	0.5	0.004
Met	0.7	0.06	0	1.7	0.9	0.016
Haw	4	0.25	2	2.3	0.1	0.026

3.4. Preference Function

As far as here all the criteria are the V-shape Preference function, that is type (3) according to Figure (1), parameter P is a threshold of strict preference that is the smallest deviation which

considers sufficient to generate a full preference. The evaluation of this parameter is dragged out from laboratories experts view's Table (5). Also in our case, as far as the same importance of criteria due to the National Standard with code number of 2225 decision makers gave appropriate weights 1/6 to all the criteria.

Table-5. Values of P for V- shape prefernce function

	Viscosity (ku)	**Non-volatile mass Weight solid%**	**finene ss of grind µm**	**Hiding power** m^2/lit	**Gloss at** 60^0 **angle**	**Density** g/cm^3
P(m)	± 3	± 0.5	± 3	± 2	± 2	± 0.01

3.5. Pair wise Comparison and Ranking

Calculations will be continued by pair wise comparison of alternatives along each recognized criterion: From (2) and (3)

$d_j(a,b) = g_j(a) - g_j(b)$ for d>0 P=0

$$P_j(a,b) = F_j\left\lfloor d_j(a,b)\right\rfloor$$

for which :

$$0 \le p_j(a,b) \le 1$$

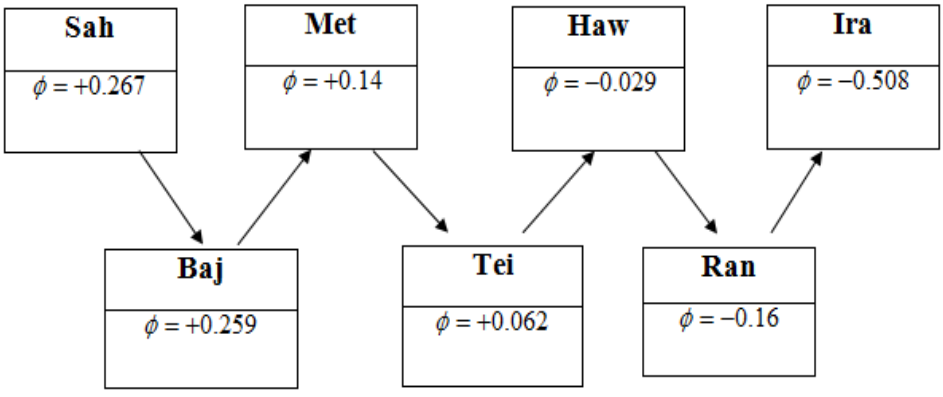
And according to the formulas' number (4), (5), (6), (7) and (8) the table of positive and negative and net outranking flows has been determined as follows:

Table-6. Positive and negative and net outranking flows

$\pi(a,b)$	**IRa**	**Baj**	**Ran**	**Sah**	**Tei**	**Met**	**Haw**	ϕ^+
IRa	0	0.17	0.11	0.003	0.02	0.125	0.125	0.092
Baj	0.68	0.	0.59	0.21	0.28	0.395	0.56	0.45
Ran	0.18	0.17	0	0.04	0.16	0.35	0.18	0.18
Sah	0.72	0.2	0.49	0	0.18	0.31	0.5	0.4
Tei	0.67	0.17	0.05	0.03	0	0.275	0.4	0.266
Met	0.67	0.21	0.31	0.295	0.333	0	0.56	0.39
Haw	0.68	0.24	0.51	0.22	0.25	0.07	0	0.33
ϕ^-	0.6	0.19	0.34	0.13	0.204	0.25	0.39	
$\phi^+ - \phi^-$	-0.508	+0.259	-0.16	+0.267	+0.062	+0.14	-0.059	

From the table, positive, negative and net outranking flows can make the base of outranking so that by using PROMETHEE (I) we obtain partial ranking and by using the net value of ϕ to get the complete ranking of laboratories.

Figure-2. Net Outranking flow for Accredited Laboratories



4. CONCLUSIONS

As far as the main goal of our research is ranking the accredited laboratories the ranking will be as follows:

$$Sah \rangle Baj \rangle Met \rangle Tei \rangle Haw \rangle RAn \rangle Ira$$

But the result of ranking is not only an ordinal one but also the cardinal as well and it can be concluded that implementation of a hybrid integration of PROMETHEE I, II with Proficiency Testing inter-laboratories comparison, provided a successful tool for ranking of those candidates. By essence of reference laboratory or any other reference value two Pair wise comparisons of alternatives are necessary, one with reference value and the other with alternatives for making decision matrix or input matrix for PROMETHEE.

Some extensions of this research might be of interest. While in this paper, we only considered the paint and varnish accredited laboratories process can be applied to other sections of the ISIRI which consist of about 600 accredit laboratories. The other extension of this research could be combined with TOPSIS and PROMETHEE for solving such a ranking problems.

REFERENCES

[1] M. M. Wiecek, M. Ehrgott, G. Fadel, and J. R. Figueira, "Editorial: Multiplecriteria decision making for engineering," *Omega*, vol. 36, pp. 337–339, 2008.

[2] J. P. Brans, P. Vincke, and B. Mareschal, "How to select and how to rank projects:The promethee method," *European Journal of Operational Research*, vol. 24, pp. 228–238, 1986.

[3] J. P. Brans, *Lingenierie de la decision. Elaboration dinstruments daide a la decision, methode promethee. In: laide a la decision: Nature, instrumentset perspectives davenir*. Quebec, Canada: Pressesde Universite Laval, 1982.

[4] J. P. Vincke and P. Brans, "A preference ranking organization method. the promethee method for mcdm," *Management Science*, vol. 31, pp. 641–656, 1985.

[5] J. P. Brans and B. Mareschal, "Promethee methods. Multiple criteria decision analysis, State of the art surveys," pp. 163-186, 2005.

[6] J. P. Brans and B. Mareschal, "Promethee v–mcdm problems with segmentation constraints," *INFOR*, vol. 30, pp. 85–96, 1992.

[7] J. P. Brans and B. Mareschal, "The promethee VI procedure. How to differentiate hard from soft multicriteria problems," *Journal of Decision Systems*, vol. 4, pp. 213–223, 1995.

[8] C. Macharis, J. P. Brans, and B. Mareschal, "The gdss promethee procedure–a promethee–gaia based procedure for group decision support," *Journal of Decision Systems*, vol. 7, pp. 283–307, 1998.

[9] J. P. Brans and B. Mareschal, "The promethee gaia decision support system for multicriteria investigations," *Investigation Operative*, vol. 4, pp. 107–117, 1994.

[10] J. Figueira, Y. Desmet, and J. P. Brans, *MCDA methods for sorting and clustering problems: Promethee TRI and Promethee CLUSTER*. Université Librede Bruxelles. Service de Mathématiques dela Gestion, Working Paper 2004/02, 2004.

[11] M. R. B. Behzadian, A. Kazemzadeh, M. Albadvi, and M. Aghdasi, "Promethee: A comprehensive literature review on methodologies and applications," *European Journal of Operational Research*, vol. 200, pp. 198–215, 2010.

[12] W. D. Keyser and P. Peeters, "A note on the use of promethee multicriteria methods," *European Journal of Operational Research*, vol. 89, pp. 457-461, 1996.

[13] P. Nijkamp, P. Rietveld, and H. Voogd, *Multicriteria evaluation in physical planning*. Amsterdam: Elsevier Science Publishers, 1990.

[14] R. Eckenrode, "Weighting multiple criteria," *Management Science*, vol. 12, pp. 180-192, 1965.