UTILIZATION OF PROMETHEE METHODS IN A METALLURGICAL SALES CENTER ESTABLISHMENT

LENORT Radim, ZAPLETAL František, WICHER Pavel

VSB - Technical University of Ostrava, Czech Republic, EU,
radim.lenort@vsb.cz, frantisek.zapletal@vsb.cz, pavel.wicher@vsb.cz

Abstract

Currently, there are several ways for a metallurgical company to distribute its own products to end customers. A typical example is the construction of steel sales and service centres. One of the strategic decisions related to the creation of those centres is the selection of appropriate locations. The paper presents possibilities of using the PROMETHEE multi-criteria decision making methods in the selection of the most appropriate place for a metallurgical sales center establishment. The aim was to select one of ten possible locations according to seventeen criteria.

Keywords: Metallurgical sales center, multi-criteria decision making method, PROMETHEE

1. INTRODUCTION

A significant trend in recent years is the active involvement of metallurgical enterprises in the distribution of their products in the form of steel sales and service centres. Metallurgical enterprises have to implement a number of strategic decisions in this context. One such decision is the selection of suitable sites for the building of those centres. Essentially, this is a typical example of multi-criteria decision making. A group of PROMETHEE methods enables the assessing of the ranking of alternatives when considering a given set of criteria and corresponding preference functions. The paper presents possibilities of using the PROMETHEE multi-criteria decision making methods in the selection of the most appropriate place for a metallurgical sales center establishment. The aim was to select one of ten possible locations according to seventeen criteria.

2. STEEL DISTRIBUTION

Currently, there is a relatively wide range of options for a metallurgical company to build its own distribution network. Starting with the establishment of corporate stores, its own distribution warehouses and specialized trading companies to service centres created in places optimally situated in terms of customers. [1]

Setting up a distribution network can also take many forms. Metallurgical enterprises build a distribution network as their exclusive investment activity or in collaboration with other manufacturers or trading companies as e.g. joint ventures. Another option is a capital interconnection with existing trade companies, i.e. sales through companies with the capital participation of steel producers.

A metallurgical company uses its own distribution network mainly to satisfy large quantities of small and medium size customers requiring a small amount of a common assortment of goods, for which it is not efficient to purchase directly from manufacturers. A high level of customer service is expected - the completion of several types of metallurgical materials, including those which the respective company does not produce (also including non-metallic materials), immediate consumption and ensuring just-in-time deliveries, or the modification of the material (cutting or bending according to the request of the customer is of course commonplace).

Current trends are leading to the expansion of activities towards complex, often manufacturing and capital-intensive operations such as pickling, plating and the like. It turns out that steel service centres are able to perform these activities more efficiently than manufacturing companies. Increased finalization reduces the storage range only to a number of fundamental dimensions of the rolled material. Other savings in the costs associated with maintaining a wide assortment is the effective application of information and forecasting systems that enable the effective risk reduction of having unsalable and obsolete inventory.

3. METHODOLOGICAL BASIS

3.1. Multi-criteria decision making methods

As part of the strategic decision-making of the metallurgical enterprise, managers often get themselves in a situation where finding the optimal solution is not possible based just on one or a small number of criteria. In such a case, for a good decision it is necessary to use any of the multi-criteria decision-making methods that allow finding the preferential order of possible solutions of the problematic situation with regard to the larger number of decision criteria. The methods can be divided into four base categories. Methods based on multi-criteria utility function, compromise criterion, fuzzy preferential relation and decomposition. A summary of the individual methods is in **Table 1**. [2, 3, 4, 5]

Table 1 Categories of multi-criteria decision making

Utility function		Compromise criterion	Fuzzy preferential relation	Decomposition
WSA	PDA	TOPSIS	ORESTE	AHP
WPA	UTADIS	VIKOR	PROMETHE	ANP
UTA	MHDIS	GRA	ELECTRE	
MAUT	SMART	PEG-theorem	GAIA	
MACBETH	UTASTAR			

The practical application of each of the above methods in business practice has its advantages, disadvantages and limitations. There are two main reasons why we have decided to use PROMETHEE. Firstly, it allows us to express both preferences among criteria and ambiguity in preference strength. Secondly, PROMETHEE results can be very easily denoted graphically (e.g. by a preference tree). Moreover, the software Visual PROMETHEE is available for free for academic use.

The general methodology for the application of the multi-criteria decision-making methods includes the following steps:

- Setting solution goals and limits.
- Creation of alternative solutions.
- Determination of criteria for evaluating alternatives.
- Determination of criteria materiality.
- Determination of criteria values for the considered alternatives.
- Evaluation and selection of the best variant.

3.2. PROMETHEE methods

The PROMETHEE family consists of methods of multi-criteria decision-making. Regarding a given set of criteria, a decision-maker is able to rank a set of alternatives. The core of these methods is a pair wise comparison using so called preference functions, see [6]. A preference function p_i is a function which assigns a preference degree when comparing (by difference in values) two alternatives according to the i-th criterion. The preference degree $p_i(a,b)$ (i.e. the preference degree expressing a level of preference a over b, let a and b be the alternatives) can reach values from 0 to 1 where the value of 0 stands for either non-preference or indifference a over b, the value of one expresses the absolute preference a over b. When a preference degree is assigned to each ordered pair of alternatives, a positive flow of the j-th criterion ϕ_j^+ (i.e. a weighted average of degrees at which other criteria are preferred j-th criterion is preferred over the others) and a negative flow ϕ_j^- (i.e. a weighted average of degrees at which other criteria are preferred over the j-th one), see the equations (1). A net flow aggregates positive and negative flows together, see (2). Two basic PROMETHEE methods for evaluation can be used: PROMETHEE I (based on partial, positive and negative, flows) and PROMETHEE II (based on net flows). An advantage of the former is that detailed information about the alternative is preserved. On the other hand, a situation when two alternatives are incomparable may occur. When the equation (3) holds, a is preferred over b. The equation (4) defines the situation when a and b are comparable but indifferent. For all other cases, the alternatives a and b are mutually incomparable.

$$\phi^+(a) = \frac{1}{n-1}\sum_{b\neq a}\sum_{j=1}^{k} w_j \cdot P_j(a,b), \qquad \phi^-(a) = \frac{1}{n-1}\sum_{b\neq a}\sum_{j=1}^{k} w_j \cdot P_j(b,a) \tag{1}$$

$$\phi(a) = \phi^+(a) - \phi^-(a) \tag{2}$$

$a \succ b \Leftrightarrow \phi^+(a) \geq \phi^+(b) \wedge \phi^-(a) \leq \phi^-(b)$, at least one of these inequalities has to be strict. (3)

$$a = b \Leftrightarrow \phi^+(a) = \phi^+(b) \wedge \phi^-(a) = \phi^-(b) \tag{4}$$

A ranking by PROMETHEE I gives the decision-maker valuable information. Unfortunately, sometimes, incomparability is not acceptable and a complete ranking of alternatives has to be done. That can be done using PROMETHEE II. It can be seen that it admits only two possibilities: preference (5) and indifference (6).

$$a \succ b \Leftrightarrow \phi(a) > \phi(b); \; a = b \Leftrightarrow \phi(a) = \phi(b) \qquad (5), (6)$$

4. CASE STUDY - METALLURGICAL SALES CENTER ESTABLISHMENT

The case study has been based on the methodology shown in Chapter 3.1.

4.1. Setting solution goals and limits

The main objective of the realization of the sales center has been formulated as the support and development of interest of small customers from companies and individual citizens through the administratively simple, time-inexpensive, immediate and convenient sale of metallurgical products. The sales center was supposed to replace the existing highly complicated system of retail product sale, when ordering, distribution and payment took place at different workplaces of the enterprise. The ultimate goal therefore was an increase in the sales of steel products to the segment of small customers. The evaluated center should also offer products from other companies for sale and obsolete inventory and assets, company waste and other unneeded materials should also be offered. From the organizational aspect, the preferred option was to build the center outside the company premises. The essential problem was then finding such a location that would fulfil most of the set targets.

4.2. Creation of alternative solutions

To identify suitable sites, the estimated parameters of the future sales center have been determined; especially total sales, stocks and the area required for the storage, treatment, handling and sale of products. The postulated requirements have been met by a total of ten possible variants (V1 to V10) of sales center locations. At this stage of the assessment of the investment plan it was necessary to make a pre-selection, which would provide the range of variants for a subsequent detailed assessment through a technical-economic study.

4.3. Determination of criteria for evaluating alternatives and determination of their materiality

A total of seventeen criteria have been identified.

The significance of individual criteria was expressed by assigning points from a point scale ranging from 1 to 100, on the basis of which it was possible to calculate the weights:

- C1 - attractive location, accessibility for clients, $w_1 = 0.120$.
- C2 - possibility of site expansion, $w_2 = 0.117$.
- C3 - location outside company premises, $w_3 = 0.114$.
- C4 - suitable truck access, $w_4 = 0.111$.
- C5 - suitable parking space, $w_5 = 0.072$,
- C6 - city center not burdened by traffic, $w_6 = 0.078$.
- C7 - Simplicity in entering into agreements with other firms, or group companies, $w_7 = 0.072$.
- C8 - expedient and trouble-free property proceedings, $w_8 = 0.057$.
- C9 - maintaining the current shop, $w_9 = 0.054$.
- C10 - area size, $w_{10} = 0.045$.
- C11 - presence of a reinforced area, $w_{11} = 0.042$.
- C12 - presence of other usable equipment within the area, $w_{12} = 0.039$.
- C13 - access by railroad, $w_{13} = 0.036$.
- C14 - possibility of supplies exceeding 10 tons, use of trailer, tow, $w_{14} = 0.016$.
- C15 - possibility of separate dispensation of purchased metallurgical products and materials to the company departments, $w_{15} = 0.012$.
- C16 - non-aggressive environment for outside storage, $w_{16} = 0.010$.
- C17 - subsoil carrying capacity, $w_{17} = 0.005$.

4.4. Determination of criteria values for considered alternatives

For the partial evaluation of variants by individual criteria a subjective point scale from 0 to 5 was used, wherein the individual point values express:

- 0 - invalid.
- 1 - minimum validity.
- 2 - average validity.
- 3 - above-average validity.
- 4 - high validity.
- 5 - full validity.

The determined criteria values for the considered alternatives are shown in **Table 2**.

Table 2 Criteria values for the considered alternatives of sales center locations

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17
V1	2	3	0	4	3	4	3	0	0	4	5	4	5	5	0	2	5
V2	3	1	5	4	1	4	3	0	0	1	5	3	5	2	0	2	5
V3	5	4	4	5	3	4	2	1	0	3	5	5	2	4	3	4	5
V4	5	0	4	5	3	4	3	0	0	1	5	5	2	4	3	2	5
V5	3	0	5	5	4	5	5	0	5	3	0	0	2	4	0	4	2
V6	3	4	5	5	5	5	5	0	5	5	0	0	2	4	0	4	3
V7	3	0	5	5	4	5	5	0	5	2	0	0	2	4	0	4	2
V8	3	5	5	5	5	5	2	5	0	5	5	5	5	4	5	4	5
V9	1	1	5	1	2	5	3	5	5	3	0	0	5	0	0	4	4
V10	1	4	5	5	5	5	5	4	5	5	0	0	2	4	3	4	1

4.5. Evaluation and selection of the best variant.

For the evaluation and selection of the best variant, the PROMETHEE I and PROMETHEE II methods have been selected, which together provide a complex view of the solved problem. At the same time, 4 different modifications of the solution have also been used. The first modification uses the preferential function of type “Usual”, that for the given pair comparison gives a preferential grade 1 for any difference between the assessed variants. The second modification then used the preferential function of type “V-shape”, where the preference grade increases with the amount of difference between the assessed variants. Both types of preferential functions are suitable for criteria scoring. Modifications 3 and 4 are then created based on the same preferential functions, but with neglecting the individual criteria weights, which facilitates their solution in business practice.

The PROMETHEE I and PROMETHEE II methods also provide a wide range of graphical outputs that facilitate the interpretation of results on top of the final ranking. Due to limited scope, only the most significant outputs will be selected, those for modification with weights and the preferential function of the type „V-shape“. The comparison of results from all the modifications is summarized at the end of the chapter. The multi-criteria assessment of alternatives has been conducted using the Visual PROMETHEE software.

The basic output of the PROMETHEE I method is shown in **Figure 1**, where the left axis captures the positive flows and the right axis captures the negative flows of the individual variants. Variants, which cross each other, are incomparable using the PROMETHEE I method. In **figure 2** you can analyze the PROMETHEE II method output, where the positive and negative flows of the individual alternatives are merged and thus their final order can be determined.

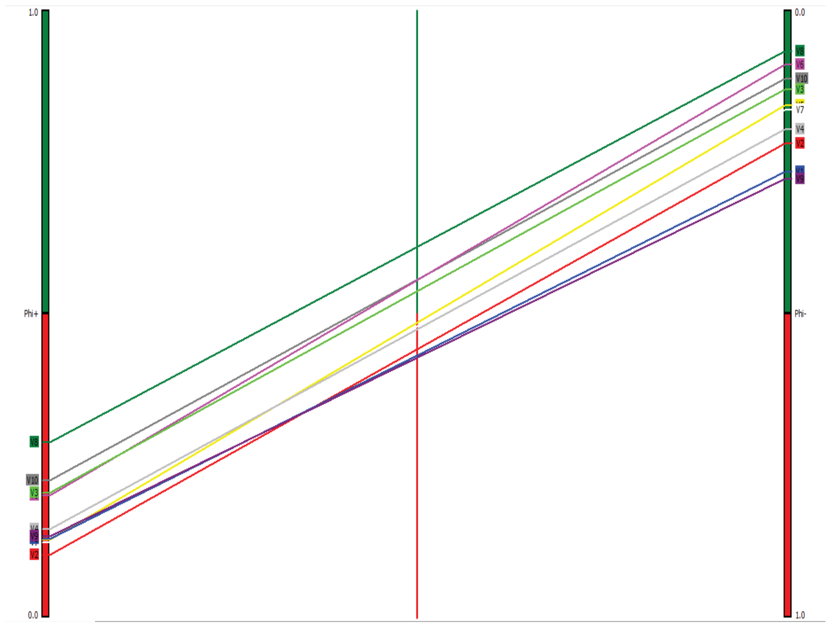

Figure 1 Graphical output for the PROMETHEE I method

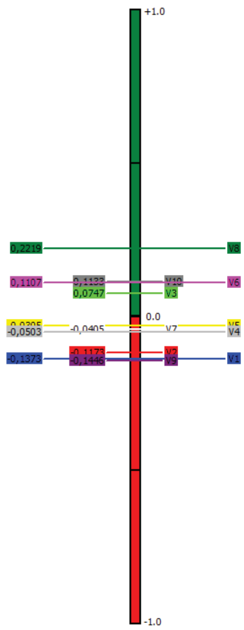

Figure 2 Graphical output for the PROMETHEE II method

Figure 3 shows the preference tree, which connects the results from both methods. The vertical coordinates correspond to the output from the PROMETHEE II method and the oriented edges connect the mutually comparable alternatives (PROMETHEE I method output). Apart from those, other graphical outputs can also be used, e.g. the GAIA method (to project all criteria and alternatives graphically into the *n*-dimensional space) or the PROMETHEE rainbow (denoting profiles of the alternatives), for more information see [6] or [7]. Moreover, PROMETHEE provides many possibilities for deep sensitivity analyses, see [8].

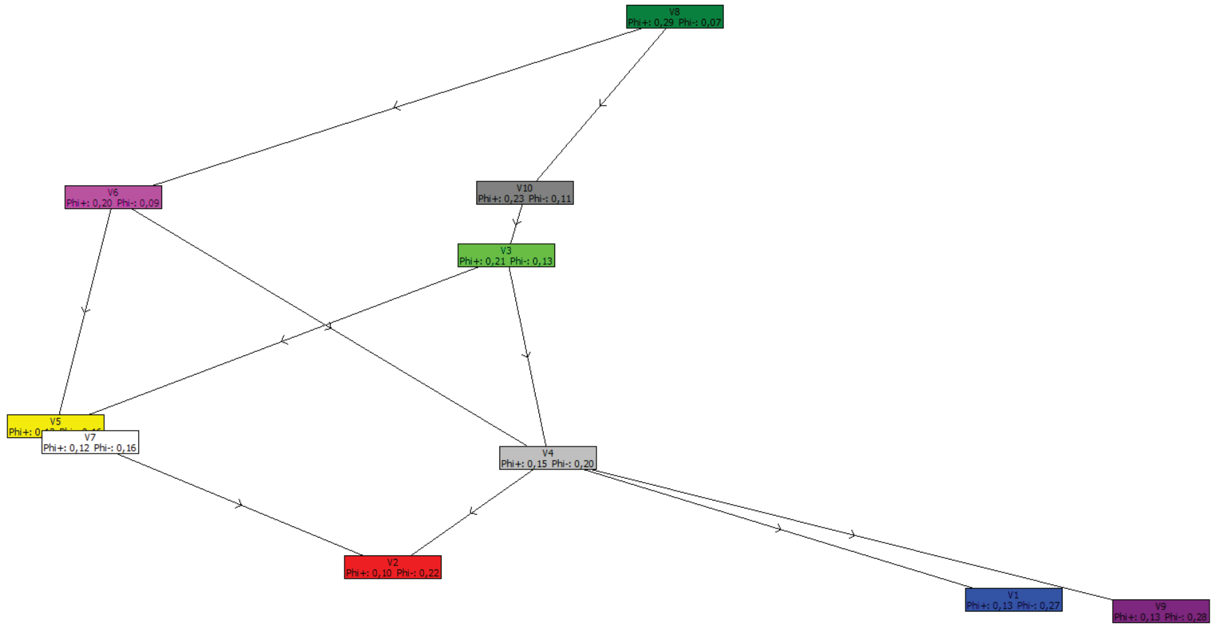

Figure 3 Preference tree

Table 3 Comparison of results

	Usual (no weights)	V-shape (no weights)	Usual (with weights)	V-shape (with weights)
1.	V8	V8	V8	V8
2.	V10	V3	V6	V10
3.	V6	V10	V10	V6
4.	V3	V6	V5	V3
5.	V5	V4	V3	V5
6.	V7	V1	V7	V7
7.	V4	V5	V4	V4
8.	V1	V7	V9	V2
9.	V9	V9	V2	V1
10.	V2	V2	V1	V9

Table 3 shows that the best rated were the location variants V8, V6, V10 and V3, which are then suitable for the subsequent technical-economic study.

5. CONCLUSION

In metallurgical practice, multi-criteria decision methods are seldom applied. In most cases, only the economical side of the problem is decisive, because metallurgy is among the most capital-intensive industries. The remaining decision criteria are assessed rather intuitively, especially based on the experience of the involved managers. The main reason reported by the metallurgical enterprise managers is especially the complexity and time demand of the application of the majority of the multi-criteria decision-making methods. According to the authors' opinion, the PROMETHEE I and II methods are a useful tool which can change that situation. These methods represent an appropriate compromise, guaranteeing adequate quality of the final decision with a relatively simple application of the available software solutions. A distinct advantage is their high explanatory power based on transparent graphical outputs.

The modification capable of making the best decision (out of the four assessed modifications,) is the „V-shape“ method with weights. **Table 3** shows that the results from this modification are almost identical to the modification „Usual“ without weights, which is much easier to process. The authors therefore recommend using the second from the mentioned procedures for multi-criteria decision making in the area of metallurgy.

ACKNOWLEDGEMENTS

The work was supported by the specific university research of the Ministry of Education, Youth and Sports of the Czech Republic in VSB - Technical University of Ostrava No. SP2016/107, by grant No. GA 16-01298S of the Czech Science Foundation and the Operational Programme Education for Competitiveness - Project CZ.1.07/2.3.00/20.0296. The support is greatly acknowledged.

REFERENCES

[1] HÄMÄLÄINEN, E. et al. *Evolving logistic roles of steel distributors*. Helsinky: Helsinki School of Economics, 2003.

[2] ZMESKAL, Z. Application of decomposition multi-attribute methods AHP and ANP in financial decision-making. In *6th International Scientific Conference Managing and Modelling of Financial Risks*. Ostrava: VŠB-TUO, 2012, pp. 689-699.

[3] SPRONK, J., STEUER, R. E., ZOPOUNIDIS, C. Multicriteria decision aid/analysis in finance. In: *Multiple criteria decision analysis: State of the art surveys*. New York: Springer, 2005, pp. 799-848.

[4] FÜLÖP, J. Introduction to decision making methods. In: *BDEI-3 Workshop*, Washington, 2005.

[5] SISKOS, Y., GRIGOROUDIS, E.. MATSATSINIS, N. F. UTA methods. In: *Multiple criteria decision analysis: State of the art surveys*. New York: Springer, 2005, pp. 297-334.

[6] BRANS, J. P., MARESCHAL, B. *PROMETHEE-GAIA: Une Methodologie d'aide a la Decision en Presence de Criteres Multiples*, Bruxelles: SMA, 2002.

[7] MARESCHAL, B., DE SMET, Y. Visual PROMETHEE: Developments of the PROMETHEE & GAIA multicriteria decision aid methods. In *IEEE International Conference on Industrial Engineering and Engineering Management*, IEEE, 2009, pp. 1646-1649.

[8] SULTANA, A., KUMAR, A. Ranking of biomass pellets by integration of economic, environmental and technical factors. *Biomass and bioenergy,* 2012, vol. 39, pp. 344-355.