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THE IMPLEMENTATION OF THE PROMETHEE-GAIA METHOD IN THE PROCESS OF DETERMINING THE BENCHMARKING PARTNER IN BUILDING A CHP PLANT

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Abstract

This paper presents the multi-criteria analysis conducted with the aim of selecting the benchmarking partner in the process of defining the project idea for building the CHP plant for biomass processing. PROMETHEE-GAIA analysis of previously collected data on potential benchmarking partners was used as a method for multi-criteria decision making and, on the basis of this analysis, their ranking was carried out according to the clearly determined criteria and the appropriate weight coefficients. In fact, this paper was prepared as a part of the project idea of building a plant for biomass processing, for which an example of good practice should be determined and an alternative, that would be defined as the best, should be found, according to all criteria.

Keywords: *PROMETHEE-GAIA method, CHP plant, benchmarking, multi-criteria decision making, biomass.*

1. INTRODUCTION

Today's world industry operates in conditions of high risk caused by many global economic problems. Because of that, the complex character of multi-criteria decision-making in the last decade has become very large. [1]
Due to the high applicability of multi-criteria decision-making methods in many areas, in this paper the PROMETHEE-GAIA method was used as a method for decision making with the aim of finding the benchmarking partner on a project which was applied to the Development Agency of Serbia by the department of Engineering Management, Technical Faculty in Bor.
The aim of this project was the construction of the cogeneration plant for the combined production of heat and electricity from renewable sources, by using a biomass in order to achieve the energy efficiency and independence of the Pirot region. Therefore, the aim of the investment idea was based precisely on the production of the heat energy intended for the heating the town of Pirot and electricity that will be sold to EPS. The installed capacity of the CHP plant in Pirot would amount 10 MW and a potential investment framework budget would be approximately 2.31 billion dinars (18.7 million euros). These two data will be crucial in the process of prioritizing the selected CHP plants from the different

countries and finding the benchmarking partner by using the PROMETHEE-GAIA method. [2]

In the first part of this paper, there were defined theoretical and methodological aspects of this research. *In the second one*, alternatives were ranked by the PROMETHEE-GAIA method, according to defined criteria. The aim of this paper is to get the one company from different countries that may be considered as a potential benchmarking partner in the process of implementing this project idea.

2. METHODOLOGY

In the process of making the list of alternatives of the CHP plants from the different countries in order to find the benchmarking partner, the authors have used a lot of documents and business plans of these facilities, which were thoroughly reviewed. Then, the prioritization of these alternatives (CHP plants), obtained through the documents and business plans, was carried out by implementing the PROMETHEE-GAIA method. [3]

The first PROMETHEE I (partial ranking) and PROMETHEE II (complete ranking) methods were developed by J.P. Brans and presented for the first time in 1982 at a conference organized by the University of Laval, Québec, Canada [4]. The methods of PROMETHEE have successfully been applied in many fields and a lot 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 to their particular friendliness of use. [5]

The reason for the application the PROMETHEE - GAIA method (PROMETHEE II - GAIA method, to be more precise) in this research paper is in the advantage of structuring the problem, in the amount of data that can be processed, in the possibility of quantifying the qualitative variables and in a good software support and presentation of the results by the GAIA modeling. [4]

The procedure for the implementation the PROMETHEE II method for the complete ranking alternatives with the presentation of the results through the GAIA diagram is given through the following steps [4]: 1) *creating a matrix / table of decision-making*, 2) *allocating the preference functions P(a,b) for each criterion*, 3) *calculating the Index of preferences IP (a,b)*, 4) *calculating the "outranking" flows for each alternative*, 5) *NetFlow calculating and defining the GAIA model*.

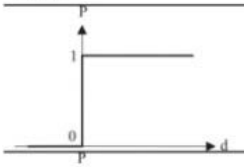
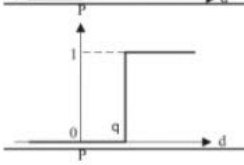
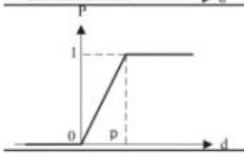
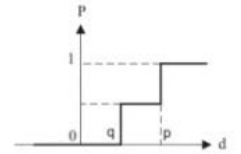
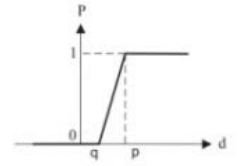
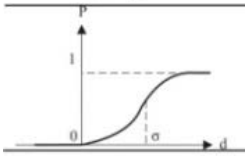
Shape	Mathematical justification	threshold
	Type I: Usual criterion $P(d)=\begin{cases}0, d \le 0\\1, d > 0\end{cases}$	-
	Type II: Quasi-criterion (U-shape) $P(d)=\begin{cases}0, d \le q\\1, d > q\end{cases}$	Q
	Type III: Criterion with linear preference (V-shape) $P(d)=\begin{cases}0, d < 0\\d/p, 0 \le d \le p\\1, d > p\end{cases}$	P
	Type IV: Level criterion $P(d)=\begin{cases}0, d \le 0\\1/2, q < d < p\\1, d \ge p\end{cases}$	Q,P
	Type V: Criterion with linear preference and indifference area $P(d)=\begin{cases}0, d \le q\\\frac{d-q}{p-q}, q < d \le p\\1, d > p\end{cases}$	Q,P
	Type VI: Gaussian criterion $P(d)=1-e^{-\frac{d^2}{2\sigma^2}}$	σ

Figure 1. Forms of preference functions [6]

3. RESULTS

The appropriate data on the potential benchmarking partners, which are systematized and presented in a Table 1, are based on the market research.

Table 1. The potential benchmarking partners

	Project name	**Company name**	**Location of building**	**Power of the plant (MW)**	**The amount of investment (€ million)**	**Recovery time of investment (years)**	**Number of employees**
1.	*10MW – scale Biomass based Power Generation*	Obayashi Corporation, EX Research Institute Ltd.	Ampara District, Eastern Province, Sri Lanka	10	26,2	5	60
2.	*CHP Technical Assistance Partnerships (Woody*	Freres Lumber	Lyons, Oregon, USA	10,5	24	7,5	50

	Biomass CHP System)						
3.	*Construction of bio-CHP in Ukraine with the use of biomass as a renewable energy source*	Industrial and financial corporation MUST-IPRA	Kupyansk, Kharkov Region, Ukraine	9,6	19,2	3,5	43
4.	/	SC Johnson Waxdale Plant	Racine, Wisconsin, USA	6,4	12	6	30
5.	/	Evergreen Communit Power Plant	Reading, PA, USA	33	140	15	100
6.	/	Kennecott Utah Copper Refinery	Salt Lake County, Utah, USA	6	10	5	30
7	/	Kuhmo Sawmill	Kuhmo, Denmark	12,9	16	7	50
8	*Biomass-fired combined heat and power plant*	Assens Fjernvarme Amba	Assens, Denmark	10,3	25	6	45

Basic alternatives between which will be determined the priority ranking list of the best are defined as follows: $\mathbf{A_1}$ – *Obayashi Corporation, EX Research Institute Ltd*, $\mathbf{A_2}$ – *Freres Lumbe*, $\mathbf{A_3}$ – *Industrial and financial corporation MUST-IPRA*, $\mathbf{A_4}$ – *SC Johnson Waxdale Plant*, $\mathbf{A_5}$ – *Evergreen Community*, $\mathbf{A_6}$ - *Kennecott Utah Copper Refinery*, $\mathbf{A_7}$ - *Kuhmo Sawmill* and $\mathbf{A_8}$ - *Assens Fjernvarme Amba*. The criteria by which will be carried out the comparisons are defined as follows: $\mathbf{C_1}$ – *Power of the plant (MW)*, $\mathbf{C_2}$ - *The amount of investment (€ million)*, $\mathbf{C_3}$ – *Recovery time of investment (years)* and $\mathbf{C_4}$ - *Number of employees*.

The PROMETHEE/GAIA method was used in the process of developing the project idea, in order of ranking and selecting the benchmarking partner. The aim of the process of choosing the benchmarking partner is the tendency to find a CHP plant which is similar to the plant that is the subject of this project idea and which can help in the process of project realization.

For the defined scenario which is consisted of eight alternatives, the ranking of the options was carried out by using the software package *Visual PROMETHEE.* On the basis of the input data, *positive, negative and network flows* of the alternatives were obtained and presented in the Table 2. The weight coefficients in the calculation were defined on the basis of subjective assessments of the authors.

Table 2. Ranking of the alternatives

Company name	Phi+	Phi-	Phi	RANK
Obayashi Corporation, EX Research Institute Ltd	0,313	0,093	0,220	2
Freres Lumbe	0,175	0,245	-0,071	6

Industrial and financial corporation MUST-IPRA	0,368	0,085	0,283	1
SC Johnson Waxdale Plant	0,154	0,246	-0,092	7
Evergreen Community	0,300	0,700	-0,400	8
Kennecott Utah Copper Refinery	0,221	0,213	0,008	5
Kuhmo Sawmill	0,207	0,184	0,023	4
Assens Fjernvarme Amba	0,176	0,147	0,029	3

Figure 2 shows the GAIA diagram, which is a projection of a set of alternatives and criteria. The diagram presents a decision-making stick (red stick) that shows the direction of the compromise solution.

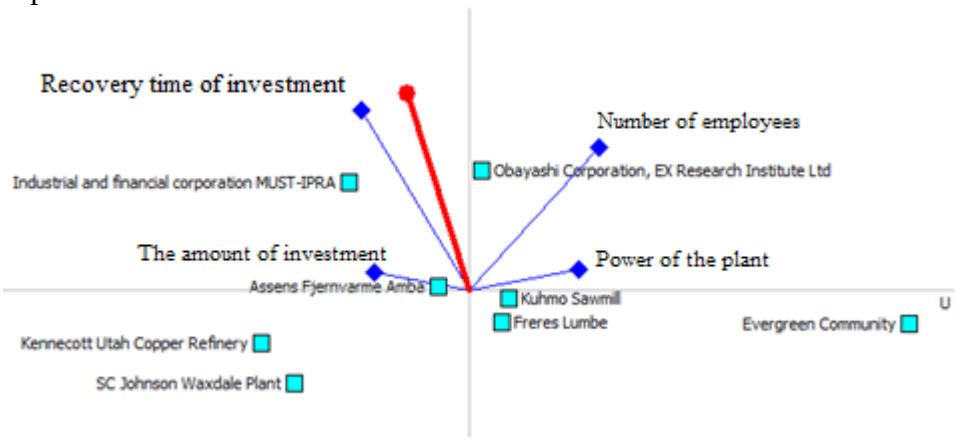


Figure 2. GAIA diagram

4. DISCUSION

Based on the results of ranking alternatives and GAIA diagram, the project of the relevant company which was chosen for the benchmarking partner is the project of the Industrial and financial corporation MUST-IPRA, named *Construction of bio-CHP in Ukraine (9,6 MW) with the use of biomass as a renewable energy source* [7]. One of the main goals of this project is the tendency to replace the natural gas, which was constantly being imported from Russia, with the renewable energy, specifically with the biomass. To some extent, it was expected that the applied methodology will give us this result.

The project costs of Ukrainian CHP plant for biomass processing are very similar to project costs of building a plant in the town of Pirot. Also, the installed plant capacity of 9.6 MW is similar to the one which would be installed in Pirot (10 MW). It was noted that the payback time of Ukrainian project is optimal and faster than the payback times of other companies and their projects. Also, the number of employees, as well as applied technology of MUST-IPRA's project completely fit into this project idea. All these facts have been taken into account in the process of implementing the PROMETHEE/GAIA methodology. Based on the case of the Ukrainian CHP plant, the biomass processing plant in Pirot would become a driving force of the economy of Southeastern Serbia and the excellent solution of many energy problems in that town. Also, all of the above would contribute to the significant progress in the process of preserving the existing ecosystem [8] in Pirot region.

Therefore, it can be clearly concluded that the applied method with clearly defined alternatives, criteria and weight coefficients yielded an adequate result.

5. CONCLUSION

The obtained final results of the overall priorities of alternatives have enabled their prioritization in descending order: *Industrial and financial corporation MUST-IPRA > Obayashi Corporation, EX Research Institute Ltd > Assens Fjernvarme Amba > Kuhmo Sawmill > Kennecott Utah Copper Refinery > Freres Lumbe > SC Johnson Waxdale Plant > Evergreen Communit*y. So, it can be concluded that, through the existing model, the authors defined the ranking list of the potential benchmarking partners (projects of the different companies that are similar to this project), where the best alternative and the ones that may be considered as a project that will support the implementation of the project idea of building the CHP plant in the town of Pirot is the project of the Industrial and financial corporation MUST-IPRA from Ukraine – $\mathbf{A_3}$ with the name "*Construction of bio-CHP in Ukraine (9,6 MW) with the use of biomass as a renewable energy source"*. Taking into account the different preferences in terms of defining the criteria weights, applied methodology yielded the adequate results. But, the subjectivist approach of the authors in the process of comparing criteria can be indicated as the main problem in the ranking of these alternatives. So, it would be probably obtained a slightly different ranking list if the weights were determined objectively and not subjectively - on the basis of the assessments of the authors.

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