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APPLICATION OF AHP AND PROMETHEE METHODS FOR RANKING THE PROFITABILITY OF INVESTMENT PROJECTS

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Abstract: Making a decision about which project is the most profitable is not an easy task, especially when it comes to investments that require large investments. In practice, there are a large number of methods that are applied in order to make the right decision. The aim of this paper is to show, through empirical analysis, the application of AHP and PROMETHEE methods as extremely effective when deciding on the best alternative location for the construction of a mini-hydroelectric power plant. In order to demonstrate the application of these methods and the process of choosing the most profitable project, using these methods, real data obtained by the investor, who has three alternative locations for the construction of a mini-hydroelectric power plant, was used. First, an adequate discount factor, calculated net present value, Internal rate of RETURN project and dynamic investment payback period were selected, in order to then apply the AHP calculation, and then the PROMETHEE method in the Decision Lab 2000 program, based on all previously calculated indicators. The combination of these methods showed which of the projects is the most profitable and which should be implemented. The very application of these methods also showed us that several methods should be used before the final decision is made, in order to choose the most profitable alternative for the investor.

Keywords: AHP method, PROMETHEE method, project.
Field: Social sciences

1. INTRODUCTION

The project of building a small hydroelectric power plant represents a significant undertaking from the aspect of energy efficiency and energy independence of a country. Serbia's energy efficiency is a priority and one of the main goals in the coming period. The economic situation in Serbia is not in favor of development and investment in renewable energy sources, and this will be reflected in the future by increased energy imports and higher borrowing. The very fact that these are relatively large initial investments clearly indicates that the initiative of the state is necessary and that it is primarily necessary to adopt and implement legal regulations with financial incentives.

Although less significant in terms of energy, the importance of small hydropower plants is strategically much greater from the point of view of the security of supply of domestic capacities for the production of equipment and the execution of works. The effects of the construction of small hydroelectric power plants are reflected in the reduction of electricity imports, the use of renewable energy sources, the reduction of environmental pollution, the regulation of water flows, the employment of domestic industry, etc.

One of the most important factors that determine the success of the project is the location where the small hydropower plant will be built. (Burke, 1993) When making a decision on choosing the location and the project itself, it is important to choose the one that is the most profitable, that is, which will return the invested money in the shortest possible time and ensure profitability. Today, numerous mathematical and statistical methods of evaluating investment projects are applied in the world, which give the opportunity to choose the best of the offered ones. The methods that can be applied during the selection are AHP (Analytic Hierarchy Process) and PROMETHEE method (Preference Ranking Organization method for Enrichment Evaluations). (Nikouei et al., 2017) These two methods, which are the subject of research in this paper, are extremely often used in multi-criteria decision-making analysis. The AHP method has its basis in the hierarchical structuring of problems and implies the identification of goals, criteria and different alternatives on the basis of which hierarchical structures are defined that reflect the relationship between them. (Anjasmoro & Sangkawati, 2017)

The PROMETHEE method is useful for ranking different project alternatives based on their preferences in relation to defined criteria. Based on it, the net amount of overrun can be determined for each of the project alternatives, which facilitates decision-making. (Nikouei et al., 2017)

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Very often it is useful to combine these two methods. Namely, AHP gives the possibility to define a hierarchy of criteria and determine their weights, while PROMETHEE, based on defined and ranked criteria through the AHP model, is extremely useful for ranking alternatives.

2. MATERIAL AND METHODOLOGY

Data from the project documentation of three different project solutions for the construction of SHPPS (Project A at location 1, Project B at location 2 and Project C at location 3) were used for the preparation of this paper. The documentation with data on the project was obtained by the owner, that is, the person whose goal is the construction of the HPP. On the basis of these data, the evaluation, selection and selection of the best project solution was carried out, with the aim of showing the effectiveness of the combination of AHP and PROMETHEE methods in the process of making a decision on the most profitable project, whose expected investment life is 25 years.

Before starting the application of the mentioned methods for ranking the criteria and choosing the most profitable project, dynamic criteria were used in the work: NPV, Internal rate of return and the payback period, which is defined as a period expressed in years.

The NPV (net present value) method is the basic method from the group of methods based on the concept of time value and the discounting procedure. Net present value (NPV) is the difference between the present value of cash inflows and the present value of cash outflows. (Komchornrit, 2021) This is the value obtained by discounting the value of the net cash flows of the investment project. The evaluation criterion when applying this method is the amount of NPV. An investment project where NPV > 0 can be considered acceptable, if NPV= 0 the project is marginally acceptable, and if NPV< 0 the project should be rejected. (Özdemir et al., 2020; Brans & Mareschal, 1994) Choosing an adequate discount rate is not an easy task. (Fatih et al., 2020) Namely, in order to obtain as reliable data as possible, it is necessary that the discount rate prescribed by the central bank, in the case of the Republic of Serbia, the National Bank of Serbia, be corrected by appropriate factors. The rate prescribed by the Central Bank of the Republic of Serbia is 6.5% at the time of writing this paper. By analyzing the literature, in order to obtain the most reliable data, a decision was made to correct the prescribed discount rate with the interest rate on savings. This correction of the discount rate increases the security of calculations and the application of the mentioned statistical and mathematical methods through the inclusion of the risk of the investment itself. By analyzing the trend of interest rates on savings at banks in the RS, by correcting the discount rate, the result is 10%, and the discount rate that will be applied is 10%.

The internal rate of return method implies that discount rate that equates the present value of cash inflows with the present value of cash outflows. In other words, it is the discount rate for which NPV = 0. (Özdemir et al., 2020; Saaty, 1980)

Internal rate of return refers to the profitability of the investment project, i.e. the maximum interest rate that can be paid on borrowed funds from the project and that the business is operating at the break-even point. According to this method, any investment whose Internal rate of return is higher than the threshold rate r min is acceptable, that is, the project is evaluated as acceptable if r > r min. The project is not acceptable if r < r min, and in the case where r = r min the project has marginal importance. The marginal rate r min represents the minimum acceptable capitalization rate of investment capital. If several alternatives are compared, the project with the highest internal rate of return should be chosen, provided that it is greater than the threshold rate. (Macharis, 2004; Lee et al., 2001)

The assessment of investment projects with the help of the dynamic payback period criterion implies that each project is considered efficient and justified for implementation if its payback period is less than a normatively determined payback period t max, where it is understood that this period is shorter than the life of the project or duration, or technological equipment requirements. Among several projects, the best is the one with the shortest payback period, provided that it is less than t max.(Goswami & Behera, 2021; Prascevic & Prascevic, 2017;)

After calculating the NPV, internal rate of return and the return term, the data were used for the applied AHP and PROMETHEE method, with the aim of obtaining a criteria comparison matrix and determining the weight coefficient, and then through the PROMETHEE method, the selection of the best alternative is made based on all previously conducted statistical and mathematical calculations.

Summarized data from the documents received from investors, which were used as a basis for the application of the mentioned methodology, are presented below, before proceeding to the presentation of the results and their discussion.

Table 1. Investments and net inflows from different alternatives of the SHPPS construction project

Investments			
Kind of investment	Project A – location1	Project B – location 2	Project C – location 3
Investments in three pipe turbines and a generator	600.000,00	800.000,00	900.000,00
Investments in construction works	400.000,00	500.000,00	600.000,00
Investments in auxiliary hydromechanical and electrical equipment	400.000,00	500.000,00	600.000,00
Investments in the project and legal obligations	400.000,00	500.000,00	500.000,00
Investments in labor and education costs	200.000,00	200.000,00	300.000,00
Sum	2.000.000,00	2.500.000,00	2.900.000,00
Annual net inflows			
The amount of projected inflow	350.000,00	400.000,00	490.000,00

Source: Author's calculation based on project documentation collected from investor

3. RESULTS AND DISCUSSION

As the first criterion for project ranking, NPV of all three project proposals were first calculated. At the same time, the values of another criterion for project ranking - the dynamic return period - were determined. Table 2 shows the net inflows by year, the net present value (NPV) for the defined discount rate, as well as the discounted net inflows, which are used to determine the dynamic return period of invested funds in the project.

Table 2. NPV of the project alternatives A, B i C

Year	Cash flow	Discount factor	NP_k	Cumulative
Project A – location1				
0	-2.000.000,00	1	-2.000.000,00	-2.000.000,00
1	350.000,00	0.90909	318.181,00	-1.681.818,50
8	350.000,00	0,46650	163.275,00	-132.788,50
25	350.000,00	0,09229	32.301,50	1.176.922,00
		NPV=	1.176.922,00	
Project B – location 2				
0	-2.500.000,00	1	-2.500.000,00	-2.500.000,00
1	400.000,00	0.90909	363.636,00	-2.136.364,00
10	400.000,00	0,38554	154.216,00	-42.192,00
25	400.000,00	0,09229	36.916,00	1.130.768,00
		NPV=	1.130.768,00	
Project C – location3				
0	-2.900.000,00	1	-2.900.000,00	-2.900.000,00
1	490.000,00	0.90909	445.454,10	-2.454.545,90
9	490.000,00	0,42409	207.804,10	-78.099,80
25	490.000,00	0,09229	45222,10	1.547.690,80
		NPV=	1.547.690,80	

Source: Authors

The NPV of project A for the projected lifetime of the investment of 25 years is 1,176,922.00 euros. The return period of invested funds is after the eighth year, which can be seen based on the cumulative figures in Table 2, as well as on the graph in Figure 1 (the dynamic return period is read at the intersection of the curve of cumulative discounted net inflows and the time axis).

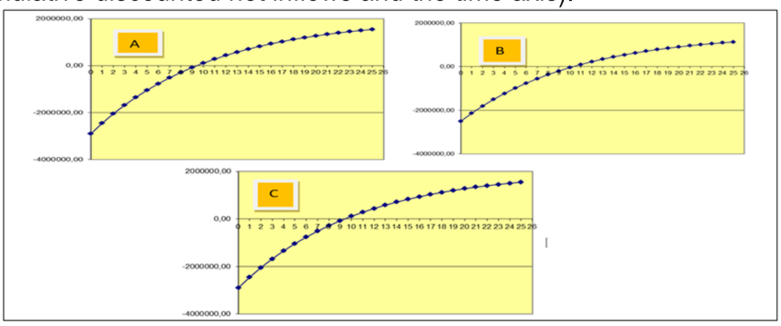

Figure 1. Dynamic payback period of investment project alternatives A, B and C
Source: Authors

Table 2 also shows the NPV of project B for the projected lifetime of the investment of 25 years, which amounts to 1,130,768.00 euros. The term of return of the invested funds is after the tenth year, which can be seen based on the cumulatives in graph one. And the same values can be seen in table 2 and graph 1 for the third alternative location of the SHPPS construction project, i.e. project C.

Table 3. Analytical framework for the application of the graphic method of determining the value of the internal rate of return alternative of project A, B and C

Year	Cash flow	Discount factor a_k (i=10%)	NPk (i=10%)	Discount factor a_k (i=20%)	NPk (i=20%)	Discount factor a_k (i=25%)	NPk (i=25%)
Project A – location 1							
0	- 2.000.000,00	1	- 2.000.000,00	1	-2.000.000,00	1	- 2.000.000,00
1	350.000,00	0,90909	318.181,50	0,83333	291.665,50	0,80	280.000,00
5	350.000,00	0,62092	217.322,00	0,40187	140.654,50	0,32768	114.688,00
10	350.000,00	0,38554	134.939,00	0,16150	56.525,00	0,10737	37.579,50
15	350.000,00	0,23939	83.786,50	0,06490	22.715,00	0,03518	12.313,00
20	350.000,00	0,14864	52.024,00	0,02608	9.128,00	0,01152	4.032,00
25	350.000,00	0,09229	32.301,50	0,01048	3.668,00	0,00377	1.319,50
		NPV=	**1.176.922,00**	**NPV=**	**-268.389,00**	**NPV=**	**-605.327,00**
Project B – location 2							
0	-2.500.000	1	- 2.500.000,00	1	-2.500.000,00	0	-2.500.000
1	400.000	0,90909	363.636,00	0,83333	333.332,00	1	400.000
5	400.000	0,62092	248.368,00	0,40187	160.748,00	5	400.000
10	400.000	0,38554	154.216,00	0,16150	64.600,00	10	400.000
15	400.000	0,23939	95.756,00	0,06490	25.960,00	15	400.000
20	400.000	0,14864	59.456,00	0,02608	10.432,00	20	400.000
25	400.000	0,09229	36.916,00	0,01048	4.192,00	25	400.000
		NPV=	**1.130.768,00**	**NPV=**	**1.130.768,00**	**NPV=**	**-521.016,00**
Project C – location 3							
0	-2.900.000	1	- 2.900.000,00	1	-2.900.000,00	0	-2.900.000
1	490.000	0,90909	445.454,10	0,83333	408.331,70	1	490.000
5	490.000	0,62092	304.250,80	0,40187	196.916,30	5	490.000
10	490.000	0,38554	188.914,60	0,16150	79.135,00	10	490.000
15	490.000	0,23939	117.301,10	0,06490	31.801,00	15	490.000
20	490.000	0,14864	72.833,60	0,02608	12.779,20	20	490.000
25	490.000	0,09229	45.222,10	0,01048	5.135,20	25	490.000
		NPV=	**1.547.690,80**	**NPV=**	**-475.744,60**	**NPV=**	**-475.744,60**

Source: Autors

The third criterion for ranking proposed project solutions is internal rate of return. The value of internal rate of return for all three projects was determined by a combination of analytical and graphical methods. During the calculation, we started from the defined discount rate, which was determined in the methodology. Then the NPV was determined for the extremely increased value of the discount rate, so that the NPV value would change its sign (from + to -, or vice versa). Finally, the exact value of the internal rate of return for all three alternatives of the investment project was determined using the graphic method.

Table 3 shows the analytical framework for the application of the graphic method for determining the internal rate of return of projects A, B and C, while the graphic method itself is shown in Figure 2. This table does not show values for all years, but for every fifth year , due to the scope of the table itself, but the results are shown in their entirety through graphical analysis.

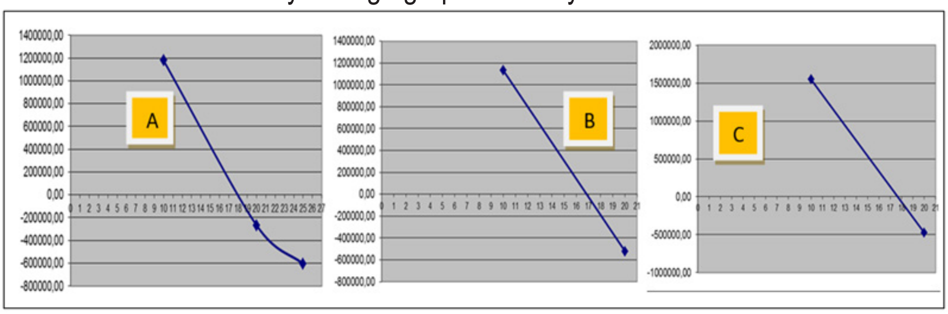

Figure 2. internal rate of return of projects A, B and C

Source: Autors

In Figure 2, it can be seen that the internal rate of return of project A, which is approximately 18%, of project B is approximately 17%, and in the case of project C, that is, the third alternative location of the project, is approximately 17.8%.

The aim of the paper was the ranking of projects A, B and C based on the criteria of NPV, internal rate of return and dynamic return period. These criteria are actually the most important factors for choosing the best (optimal) project solution.

Table 4. Criteria for choosing the most favorable project solution

Criteria	**NAME**
K_1	NPV – net present value
K_2	Internal rate of return
K_3	Dynamic Return Period

Source: Autors

The weighting coefficients of the criteria used in the process of evaluating project proposals are determined using the AHP method.

The set of possible design solutions is A={A1, A2, A3}, while the set of criteria for selecting the most favorable solution is K={K1, K2, K3}. Based on this, a matrix is formed with the help of a scale: Equal - 1, Weak dominance - 3, Strong dominance - 5, Very strong dominance - 7 and Absolute dominance - 9, while 2, 4, 6 and 8 represent intermediate values on this scale. The comparison matrix, dimension 3 x 3, was obtained using the empirical assessment of the decision maker. In this way, the importance of each individual criterion for choosing the optimal solution for the construction of a small hydroelectric power plant was determined (Figure 3).

	K1	K2	K3
K1		3	6
K2	(3)		3
K3	(5)	(3)	

(a)

	K1	K2	K3
K1	1	3	6
K2	1/3	1	3
K3	1/5	1/3	1

(b)

Figure 3. Criteria comparison matrix
Source: Autors

In the matrix formulated in this way (Figure 3(b)), further calculation is performed. The column values are summed (sum values per column are respectively: 1.53; 4.33; 10) and then each value from the matrix is divided by the total value of the column to which it belongs, and the matrix takes the form as in Figure 4.

	K1	K2	K3
K1	0,654	0,693	0,6
K2	0,216	0,231	0,3
K3	0,131	0,076	0,1

Figure 4. Criteria comparison matrix during calculation
Source: Autors

In the continuation of the AHP calculations, the values in the matrix from Figure 4 are summed up by rows (1.947; 0.747; 0.307 respectively) and finally the values thus obtained are divided by the number of additions, i.e. by the number of criteria in the row, of which there are three in this case.

Table 5. Values of the weighting coefficients of the criteria obtained by the AHP method

Criteria	The weighting coefficients
K_1	0,6
K_2	0,3
K_3	0,1

Source: Autors

In this way, the values of the weighting coefficients of the criteria are obtained, which will be applied in the PROMETHEE method.

The PROMETHEE method was used for the final ranking of project proposals. This method has certain advantages compared to other methods of multi-criteria decision-making, which are reflected in the way the problem is structured, the amount of data that can be processed, the ability to quantify qualitative quantities, good software support and the presentation of the obtained results. In accordance with the explained criteria and their weight coefficients determined by the AHP method, the evaluation of three alternative proposals for the construction of a small hydroelectric power plant is carried out and is presented in Table 6.

Table 6. Evaluation matrix

Criteria	NPV	Internal rate of return	Dynamic Return Period
Unit	Euro	%	Year
max / min	Max	Max	Min
The weighting coefficients	0,6	0.3	0.1
Preference function	Linear	Linear	Linear
Project A	1.176.922,00	18	8
Project B	1.130.768,00	17	10
Project C	1.547.690,80	17.8	9

Source: Autors

After forming the evaluation matrix using the software package Decision Lab 2000, the evaluation of alternative project proposals for the construction of a small hydroelectric power plant is carried out. The PROMETHEE method is based on determining the positive (Φ+) and negative flow (Φ-) for each of the alternatives. A positive flow of preference shows how much a particular alternative dominates over other alternatives. If the value is higher (Φ+⟶ 1) the alternative is more significant. The negative preference flow shows how much a particular alternative is preferred over other alternatives. The alternative is more significant if the flux value is lower (Φ- ⟶ 0). The complete ranking according to PROMETHEE II is based on the calculation of the net flow (Φ), which represents the difference between positive and negative preference flow. The alternative with the highest net flow value is the best ranked and so on down to the lowest ranked alternative.

On the basis of the described and assigned required parameters of the criteria of project alternatives, a complete ranking (PROMETHEE II) of three alternatives for the construction of a small hydroelectric power plant was performed. The obtained results are shown in Figure 5.

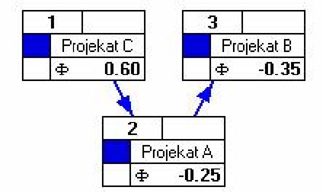

Figure 5. PROMETHEE II complete ranking of project solution alternatives
Source: Autors

Based on the obtained results, it can be seen that the best alternative is 3, i.e. project C, which would be implemented at location 3. Then follows alternative 1, i.e. project A, which would be implemented at location 1, and finally, the least favorable alternative is alternative 2, i.e. project B which would be realized at location 2, which has the lowest NPV, internal rate of return and the highest dynamic return period.

An additional strength of the Decision Lab 2000 software package is the comparative visualization of all alternatives according to each criterion - the GAIA plane. Using the GAIA plane, it is very easy to determine the strength or weakness and quality of each alternative according to each criterion. It is also possible to determine the agreement between certain criteria, as well as the strength of the criteria's influence. Figure 6 shows the position of given alternatives on the GAIA plane. Alternatives are represented by triangles, and criteria by axes ending in squares. The eccentricity of the position of the criterion square represents the strength of the influence of that criterion. The agreement between individual criteria is reflected in approximately the same orientation of the axes of the given criteria.

The position of the alternative determines its strength or weakness in relation to the criteria. If the alternative is closer to the direction of the axis of a criterion, that alternative is better according to that criterion. Alternative 3, i.e. project C, represents the best option, since it is closest to the direction of the axis of the criterion with the greatest impact - NPV, and besides, unlike the other alternatives, it is positioned very close to the axes of the other two criteria. The vector pi (decision stick) is represented by an axis ending in a circle and represents the optimal solution according to the given weight criteria.

The best alternative is the one closest to the decision stick, which is alternative 3, i.e. project C. On the other hand, from Figure 6, it is noticeable that the worst alternative is 2, i.e. project B. Project B is not good according to any criteria, and it is located opposite to the direction of the decision stick.

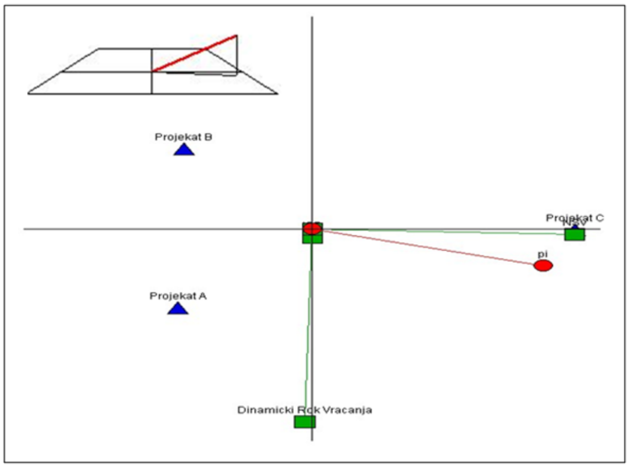

Figure 6. GAIA plane of choosing the most favorable alternative of the design solution
Source: Autors

4. CONCLUSION

In any business, the most important thing is to make the right and timely decisions. The decision-making process itself implies a choice between several alternatives. It is necessary to choose the one that contributes the most to the investor and is not harmful to the users. Various methods can be used as a decision-making tool. Multi-criteria decision-making enables decision-making not to be based on assumptions but on facts. The investor can see the criteria met by each alternative and their values, which in combination with the graphic display can reduce decision-making uncertainty and help him make a good decision.

5. LITERATURE

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