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APPLICATION OF B/C METHOD FOR THE ANALYSIS OF ALTERNATIVE PROJECT SOLUTIONS IN HYDRO ENERGY

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ABSTRACT
Investments in hydro energy sector, from the aspect of the country is necessary in the first place in order to ensure the continuity and security of supply of electricity, as well as to its economic development. From the point of investors main reason is profit. In this paper, from the aspect of engineering economics, analyse variants of the reconstruction of the hydro energy sector. Used to benefit cost method, the research facility is hydropower Trebinje 1 were obtained exact results that give precise recommendations for investment.
Keywords: Benefit Cost Analysis, revitalisation, hydro energy

1. INTRODUCTION
Project evaluation processes for public and private sectors are fundamentally different. The difference is defined by the goals of those projects. In most cases, the goal of private sector projects is profit. On the other hand, primary goals of public sector projects are social needs of a population. It is clear that public investment projects have a much broader significance for one country than the private sector ones. Hence, public projects must be perceived and evaluated bearing that in mind. The most widely used method for public sector projects evaluation is Benefit/Cost method, which is applied in this paper's analysis.
From the aspect of engineer economy, this paper analyzes alternative solutions for the reconstruction of Hydro power plant Trebinje I which was built in B&H and started production 45 years ago. Life cycle of power plant's equipment is near its end. There are some other problems that have been recognized in the course of its exploitation. A delay in reconstruction will endanger production of electric energy which is essential for public use. This paper presents basic information about this HPP and analyzes alternative solutions for it reconstruction and improvements.

2. BENEFIT/COST ANALYSIS

A widely used process of collecting, organising and analysing information and impacts of public sector projects is called Benefit/Cost analysis. Properly set and managed, this analysis can produce an objective and unbiased evaluation of positive and negative effects of project alternatives. This method analyzes quality and quantity impacts and describes implications and insecurities that may arise from the eventual implementation of an alternative. The final goal is making a decision on the selection or rejection of an alternative, to ensure effective allocation of resource for implementation of project.
This method sets a simple rule for decision making process in which the only acceptable project is the one making profit by shadow price. Shadow price is the opportunistic cost of public sector projects.
Public sector projects are mostly infrastructural such as roads, power supply objects, water supply infrastructure, utility infrastructure, hospitals, schools, etc. Figure 1. shows characteristic steps during a B/C analysis.

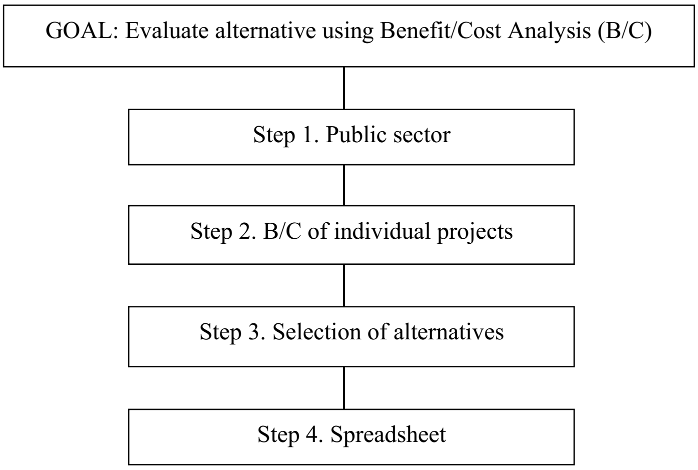

Figure 1. Basic goal and steps in application of B/C analysis [5]

Apart from the goal depicted above, other steps in the picture are:
- Identification of differences between public and private sector's alternatives;
- Evaluation of individual projects using method of B/C analysis;
- Selection of the best between two or more alternatives;
- Making tabular view of B/C analysis of one or more alternatives.

3. HPP TREBINJE I - BASIC DATA

Hydropower plant Trebinje I is part of a multistage hydropower system which was built on the Trebisnjica river in B&H, Republic of Srpska. To produce electric energy, HPP uses water from reservoir Bileca. Used water is then directed through reservoir Gorica to HPP Dubrovnik and HPP Capljina.
Construction of HPP began in 1963. First two generators, with a nominal power of 54 MW each, started production in 1968 and the third one has a nominal power of 63 MW and started producing in the year of 1975. From 1968 to 2015, average annual production of HPP was 394 GW h of electric energy. Maximum production of electric energy was in 2010 and it was 794 GW h. Minimum production of electricity was in the year of 1990, and it was 154 GW h.
In 1997, Power Utility of Serbia adopted a Study for evaluation of justifiability and urgency of reconstruction and modernisation of hydropower plants. In accordance to the criteria given in that Study and compatibility of two power systems, MDD Hidroinzenjering Beograd estimated HPP Trebinje I equipment's life cycle. The results of this evaluation were published in1999. For most components, expected life cycle is 50 years. According to those findings, all components are at the end of their life cycle at this moment and it is necessary to start revitalisation of HPP Trebinje I immediately.

4. PROPOSED ALTERNATIVES OF REVITALIZATION

The goal of revitalisation is to extend the HPP life cycle and to increase energetic effects. MDD Hidroinzinjering has proposed five alternatives for revitalization and reconstruction. In our analysis we are taking into consideration the following three:

a. Revitalisation of turbines to bring them into the condition as they used to be when they were new. Rewind of generator and iron replacement of generator's stator. According to this alternative, the coefficient of efficiency of turbines and generators will be increased and as a result that will increase electricity production for 4,35 %.
b. Replacement of turbines shafts with new ones of larger diameter and modern construction. Rewind of generators and iron replacement of generator's stators. New turbine shafts will have a higher efficiency level, with a higher flow and power compared to alternative **a**. Overall effect of this kind of reconstruction will be an increase in production of 4,65 % compared to average production.
c. Installation of new turbines and generators and their flow rate and power are conditioned by the dimension of powerhouse and its penstocks and outflows. Increase of flow rate and water speed in penstocks will cause an increase in power loss. Overall effect will be less electric energy compared to **a** and **b** alternatives but 2,85 % more electricity compared to average production.

Alternative **c** is a prerequisite for the project for production capacity increase of HPP Dubrovnik. Impact of this project is the analysis of Alternative ***c+***. Scope of this project is building of new water supply tunnel, installing two additional turbines and generators in HPP Dubrovnik. By carrying out this project, annual electricity production will increase minimally, but daily production will be better organised, water overflowing and flooding of Popovo polje area will be decreased.

5. ECONOMIC ANALYSIS OF PROPOSED REVITALISATION ALTERNATIVES

By economic analysis of proposed revitalisation alternatives we want to determine which of the alternatives is acceptable. In case of Alternative **c** not being acceptable, we want to establish how the carrying out of HPP Dubrovnik 2 project will affect its profitability and what would be the most cost effective deadline.

Costs of alternatives

Table 1 shows the annual pace of investment for alternatives. HPS Trebisnjica plans to invest its funds and assets.

Table 1. Annual investment pace

Year	Alternative "a"		Alternative "b"		Alternative "c"	
	Minimum modernisation €	%	Replacement of impeller €	%	New components €	%
1	270.000	3%	480.000	3%	550.000	1%
2	4.050.000	45%	7.200.000	45%	1.650.000	3%
3	4.230.000	47%	7.520.000	47%	8.250.000	15%
4	450.000	5%	800.000	5%	14.850.000	27%
5	0	0%	0	0%	13.750.000	25%
6	0	0%	0	0%	11.550.000	21%
7	0	0%	0	0%	1.650.000	3%
8	0	0%	0	0%	2.750.000	5%
SUM	**9.000.000**	**100%**	**16.000.000**	**100%**	**55.000.000**	**100%**

Benefits of alternatives

Benefits of alternatives are revenues from the production of electric energy. Revenue is equal to annual quantity of produced electric energy multiplied by HPP Trebinje I ten years average production price from 23,5 € per MW h by alternatives.

In the case of finalizing the project, HPP Dubrovnik 2 installed capacity will double and it will produce energy of higher quality. Difference between the average and a 50% higher price gained by quality energy we treats as additional benefit in case of Alternative **c+**, and its value is 7.050.000€ annually.

Damage and maintenance & operational costs
Maintenance and operational costs [2] are increased by 10%. They start being calculated after the last period of investment, for every year of exploitation.
Alternative a, with minimum modernization, wouldn't completely eliminate the possibility of failure, so maintenance and operational costs will have an annual growth of 1%.
In 2013, Popovo polje area was flooded, which can have a consequence of 6.000.000 € in damage costs. The probability of flooding reoccurrence is high, so the same loss value should be planned. Only in case of HPP Dubrovnik 2 project flood damage will be eliminated.

B/C analysis of proposed alternatives
Table 2 shows cash flow for each of the alternatives. For the calculation of net present cost value and benefits we take discount rate of 5%. Period of calculation is equal to the life cycle of equipment after revitalisation which is 30 years for all alternatives. Table 2 gives results of modified B/C analysis.

Table 2 Modified B/C analysis for proposed alternatives

Alternative	BC category	a	b	c	c^+
PW Costs €	C	7.954.861	14.141.976	43.790.405	43.790.405
PW Benefits €	B	155.213.877	155.663.359	118.190.246	118.190.246
PW Additional benefits €	B'				73.366.041
PW Damage €	D	2.374.404	2.374.404	2.374.404	
PW Maintenance & Operational €	M&O	14.815.209	14.816.622	13.008.163	13.008.163
PW Overall benefits €	B+B'-D-M&O	138.024.264	138.472.334	102.807.679	178.548.124
Comparison of alternatives			b - a	c - a	c^+ - a
Additional Cost	ΔC		6.187.114	35.835.544	35.835.544
Additional Benefit	ΔB		448.069	-35.216.585	40.523.860
B/C ratio			0,07	-0,98	1,13
Increment justified			NO	NO	YES
Selected alternative			a	a	c+

6. CONCLUSION
Method B/C analysis is a tool for objective evaluation of public investment projects which is based on financial benefits in making the final decision. Possibilities of manipulation and errors in the preparation of data threaten the objectivity of the method. Precise implementation of these activities is essential for obtaining reliable assessments using the B / C analysis.
Table 2 shows that alternative c is not acceptable without carrying out of HPP Dubrovnik 2 project. Acceptability of alternatives depends on baseload and peak demand ratio which must be equal or greater than 1,5 and HPP Dubrovnik 2 which must start with production as soon as the reconstruction is completed and HPP Trebinje I starts producing. According to B/C ratio all proposed alternatives are acceptable, but analysis shows great sensitivity to electric energy market changes. It is evident that there is a necessity for reconstruction at the earliest possible time because the existing equipment is at the end of its life cycle. Minimal reconstruction (Alternative a) will give the fastest positive results, but installation of new equipment (turbines i generators) proposed by HPP Dubrovnik 2 project, sets the conditions for the biggest economic effects (Alternative c+).

7. REFERENCES

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