

COST-BENEFIT ANALYSIS OF BRIDGE RECONSTRUCTION

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Abstract

The paper presents a cost-benefit analysis in the construction industry. The aim is to assess the project's value for money and economic efficiency through the cost-benefit analysis. The paper offers procedures for developing project evaluations and decision-making processes based on economic criteria, with the goal of ensuring consistency and standardization in project evaluations. The outcome is a complex view of cost-benefit analysis in construction and a practical application of CBA to a bridge reconstruction.

Keywords

Cost-benefit analysis, value for money, bridge reconstruction

1 INTRODUCTION

Cost-benefit analysis, which is used as an analytical tool, offers the possibility of a thorough, professional and comprehensible evaluation of the project [1]. On the basis of this evaluation, responsible decisions can be taken regarding the allocation of scarce financial resources, taking into account the principle of value for money.

The current period emphasizes the efficient use of resources and value for money in various fields, including civil engineering. Construction projects have a significant impact on the economy and the environment. It is important to assess their costs and benefits in order to achieve economic efficiency and sustainability throughout their life cycle.

Value for money expresses the ratio between the price of a product or service and its value. This principle of value for money is to determine the value of projects that society receives from public funds. The aim of value for money is to reinforce the results-orientation in resource allocation for public investments, while assessing whether taxpayers' money will actually be spent in the best possible way to achieve objectives [2].

The main objective of the bridge reconstruction project is to ensure the maintenance of transport services, increase safety and minimise the negative effects of traffic on the population, the territory and the environment. The analysis considered benefits that are specific, measurable, realistic and time-bound [3].

2 METHODOLOGY

Cost-benefit analysis, which is used as an analytical tool, offers the possibility of a thorough, professional and comprehensible evaluation of the project and its alternatives. On the basis of this evaluation, responsible decisions can be taken regarding the allocation of scarce financial resources, taking into account the principle of value for money [1], [3], [4].

In order to properly understand the whole idea of evaluation and appraisal of construction projects, it is important to unify the analytical framework and describe the various basic principles that need to be followed in the preparation of a CBA. The development of a cost-benefit analysis is based on five basic principles that need to be followed [3]:

- long-term perspective,
- opportunity cost,
- calculation of economic performance indicators in monetary terms,
- microeconomic approach,
- incremental approach.

The structure of the cost-benefit analysis is divided into several parts [5]. Identification of the project – deals with explaining the overall content of the CBA in the context of the investment being appraised. In order to ensure

proper understanding and acceptance of the CBA, it is necessary to sufficiently describe and explain each evaluated project, summarising its history, stating its objectives and justifying its scope and technical description. Crucially, presenting and defending the traffic input data is key to the analysis.

Financial analysis – is the foundation of the model. It introduces the basic methodological background for the financial analysis, defines in detail the basic input data for the CBA, such as capital expenditure, lifetime of investment elements, calculation of the investment's residual value, operating expenditure and operating income. The last part of the financial analysis is devoted to financial ratios [1], [5].

Economic analysis – assesses the investment's non-market aspects, such as environmental, social and health benefits and costs. These non-market benefits and costs often cannot be expressed in monetary units and are therefore expressed through conversion factors. The analysis concludes with three resulting economic indicators to suggest whether or not the project under consideration should be implemented [1], [6].

Risk assessment – the process of identifying, assessing and managing risks that could affect the project's, enterprises or investment's success. This process involves identifying potential risks, determining the likelihood and severity of their impact on the project or investment, and then deciding what measures need to be taken to minimise them [1], [3], [7].

3 RESULTS

Identification of project

The traffic in the region of "Upper Orava" is provided mainly by road transport. The bridge over the Orava dam serves as a crucial link. More than 8000 vehicles pass over it daily. The project titled "Reconstruction of the bridge M7628 over the Orava Dam" deals with a reconstruction of the existing road bridge, the construction-technical condition of which is not sufficient.

The bridge structure was built in 1952. Due to the age of the bridge, a diagnostic assessment of the bridge structure was carried out in 2020, which resulted in the classification of the bridge at the sixth level of structural-technical condition, marked as 'very bad'. As of this paper (2023), the bridge is only opened for passenger traffic and freight transport up to 12 tonnes. In order to slow down the degradation of the bridge, the road owner has reduced the maximum speed limit to 60 km/h and restricted freight traffic access. Currently, the bridge's upper structure shows extensive damage and diagnostic assessments indicate that partial repairs would be ineffective and therefore the bridge requires comprehensive reconstruction. At the same time, as can be seen in Fig. 1, the bridge lacks sufficient traffic barriers, which results in many accidents.



Fig. 1 Lack of traffic barriers.

The reconstruction project envisages rebuilding both the bridge structure and the embankments. These do not meet the requirements to ensure a safe and smooth ride. The total length of the reconstruction is 966 m and will be carried out in one stage. The estimated time for the bridge rebuilding ranges from 22 to 26 months. The implementation time will depend on the contractor's technical and technological capabilities and construction staffing.

The time horizon (reference period), spanning 30 years from 2025 to 2024, allows for the evaluation of development over time and the investment's value. The year of project construction commencement is 2025, with completion expected in 2026 and commissioning in 2027.

The demand analysis describes expected transportation uses for the project. Since this is a reconstruction project rather than a new segment, the input data for the traffic model is from the 2015 traffic counts. Traffic intensity is shown in Fig. 2. At the time of that count, the segment was fully utilized as it will be after reconstruction. This data was then recalculated with traffic development factors that provide a sufficient assumption of traffic development in the area.



Fig. 2 Traffic intensity in 2015.

The option analysis describes various approaches to implementing the project, with the total reconstruction of the bridge currently positioned as the last option for maintaining transport connectivity across the Orava Dam. Therefore, there are only two scenarios, both shown in Fig. 3.

- Scenario with the project – it considers a complete reconstruction, including the implementation of a new load-bearing structure, modifications to the embankment and the extension of the bridge to incorporate a cycle path and a pedestrian walkway. The construction period is estimated at 24 months.
- Scenario without the project – the bridge would be closed due to its deteriorated state, traffic would be moved to the shortest detour route, which would lead through the villages of Oravská Jasenica and Vavrečka along roads I/78 and II/520. This detour route would be 5 km longer and would increase travel time for a passenger car by approximately 6 minutes.



Fig. 3 Different scenarios.

Financial analysis

For the financial analysis, all financial flows associated with the project were considered. The analysis has been prepared considering the parameters listed below:

- The real financial discount rate is set at 4.00%,
- the estimated reference period is 30 years (2025–2054), including construction,
- the analysis is carried out from the perspective of the infrastructure owner,
- does not generate additional revenue,
- the analysis is carried out in constant 2023 prices.

The investment costs are the largest financial cost for the investor. It includes the funds required for implementing the entire project, including construction works, as described in the project documentation. The amount of investment costs is a key factor in the decision to start the investment. During the project preparation phase, investment costs are only assumed. In the analysis, the investment costs are calculated according to comparable projects, price lists and the experience of the designers and the author of the work. Assumptions leave room for error and therefore the CBA also makes provision for contingencies. At the same time, possible inaccuracies in price estimation are also taken into account in the risk analysis.

Operating costs represent the necessary costs of operating and maintaining the investment to keep the project operational over its lifetime. The calculation includes both current and recurrent expenditure. The annual operating cost is produced by multiplying the pavement area by the average annual operating expenditure.

Tab. 1 provides a summary of the result values. The analysis does not include calculations for operating revenue, as the project does not generate toll or any revenue. For clarity, only calculations from some years are shown. The first two years are considered for the construction of the bridge. Therefore, no savings are realised and the scenario with the project is the same as without it. The third to twenty-ninth years of investment are adjusted only for estimated GDP growth with elasticities. In the last year of the reference period, the financial residual life of the investment is also seen.

Tab. 1 Summary of financial analysis.

	Discounted €	2025	2026	2027	2028	...	2053	2054
Investment costs	15,821,769	8,066,000	8,066,000	0	0	...	0	0
Operating costs	2,289,096	0	0	142,871	142,871	...	142,871	142,871
Operating revenue	0	0	0	0	0	...	0	0
Fin. residual value	3,604,122	0	0	0	0	...	0	11,240,000
Total	-14,506,744	-8,066,000	-8,066,000	-142,871	-142,871	...	-142,871	11,097,130

Determining the investment and operating costs, operating income and residual value allows for an assessment of the project's profitability, measured by its financial net present value (FNPV) and financial rate of return (FRR) [6].

The financial net present value is -14,506,744 €. This means that the project is unprofitable and will never return the financial value that must be invested in the project. A negative value is typical for publicly funded transport projects.

The financial internal rate of return on investment is -2.32%. This value shows what discount rate must be applied to make the cash flow balance equal to zero.

Economic analysis

The economic analysis considers the effect of the investment on the welfare of society. This part of the cost-benefit analysis is an assessment of the social impact of the investment and serves as an indicator for assessing the project according to the value-for-money principle.

Project impacts that are relevant to society but do not have a readily available market value should be taken into account in the economic analysis of the project appraisal. These impacts should be considered as benefits of the project. Examples of positive non-market impacts include time savings, accident avoidance, noise reduction, and environmental benefits [3], [5]. For the purposes of this paper, the following impacts have been analysed:

- Investment costs.
- Operating costs.

- Travel time.
- Freight time.
- Fuel consumption.
- Vehicle operating costs.
- Safety.
- Air pollution.
- Greenhouse gases.
- Noise.
- Economic residual value.

Once all aspects of the economic analysis have been taken into consideration, the savings of the individual parts are clearly shown in the summary table. The analysis is guided by several basic principles, which include setting the economic discount rate at 5.00%. Additionally, the reference period spans 30 years from 2025 to 2054, encompassing the construction phase. Fiscal corrections are taken into account, as well as the conversion from market prices to shadow prices.

The summary also includes the investment costs and the costs necessary for operation, which also need to be included in the economic evaluation. The economic residual value is also seen in Tab. 2.

Tab. 2 Summary of economic analysis.

	Discounted €	2025	2026	2027	...	2053	2054
Investment costs	-14,173,114	-7,259,400	-7,259,400	0	...	0	0
Operating costs	-1,824,431	0	0	-128,583	...	-128,583	-128,583
Travel time	66,124,613	0	0	3,860,890	...	5,852,340	5,937,305
Freight time	610,719	0	0	39,506	...	48,272	48,674
Fuel consumption	10,369,531	0	0	656,192	...	839,558	846,970
Vehicle operating costs	35,363,606	0	0	2,236,517	...	2,863,986	2,888,588
Safety	131,071,465	0	0	7,431,081	...	12,038,026	12,256,231
Air pollutions	173,099,928	0	0	9,017,947	...	17,428,295	17,904,734
Greenhouse gases	23,275,516	0	0	626,971	...	3,223,370	3,251,805
Noise	9,459	0	0	568	...	819	833
Econ. residual value	9,634,286	0	0	0	...	0	10,116,000
Total	426,384,937	-7,259,400	-7,259,400	23,741,088	...	42,166,083	53,122,555

The results show that all socio-economic aspects are positive, and savings are generated by them. The greatest benefits arise from the reduction in the number of pollutants produced. There are also major safety savings. These savings are mainly due to the significant reduction in the number of kilometres travelled. These divisions are seen in Fig. 4.

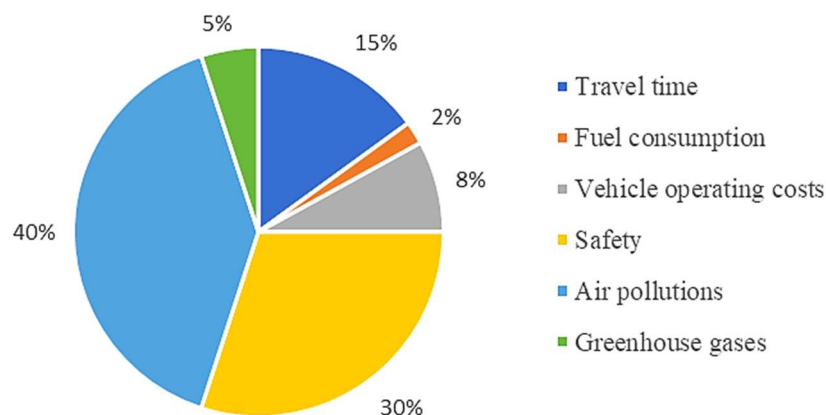


Fig. 4 Economic benefit of the project.

The economic indicators of the project are measured through three main indicators: the economic net present value of the investment (ENPV), the economic rate of return (ERR) and the benefit-cost ratio (B/C). Taken together, these indicators should determine whether the investment being assessed is worth making.

The economic net present value of 465,556,668 € reflects the overall value of the investment in terms of the company's non-monetary benefits over the entire reference period. The calculation also determined an internal rate of return of 108.66%. This value significantly exceeds the expected assessment, guaranteeing the success of the project. The benefit to cost ratio (B/C) is an indicator that demonstrates the benefits of an investment exceed its costs by twenty-eight times.

Risk assessment.

The risk assessment of the project was prepared in two parts. In the project sensitivity analysis, input factors were selected that could have a significant impact on the results. These factors were supplemented in the qualitative risk analysis by other events that could have a negative impact on the success of the project.

The project sensitivity analysis compares the results of the financial and economic analysis with the results after changing the input data. The comparison involved varying one input parameter by 10% and then looking at the absolute change in net present value.

A critical change in absolute value was considered to be a change in FNPV or ENPV of more than 10% of the change in the input value [3]. Results are shown in Tab. 3.

Tab. 3 Sensitivity analysis.

Variable	Variation ±10%	Criticality judgement
Investment costs FNPV	±12.48%	Critical
Operating costs FNPV	±0.36%	Not critical
Investment costs ENPV	± 8.59%	Not critical
Traffic intensity	± 8.06%	Not critical
Change GDP	± 0.83%	Not critical
Price of Co2	± 0.26%	Not critical
Costs of traffic accidents	± 2.45%	Not critical
Costs of air pollution	± 6.23%	Not critical

From the results of the sensitivity analysis, it can be assessed that only capital expenditure is critical in the case of a change in the financial net present value. The economic NPV analysis is most sensitive to a change in investment expenditure and a change in traffic intensity. However, these values are not critical and even a 10% change should not jeopardize the project.

The assessed risks of the input data were also taken into account in the qualitative risk analysis. Other risks that may have a negative impact on the project objectives have been added to the risk matrix. These are mainly risks that did not enter into the calculation, but it is important to consider them in the analysis and apply appropriate measures to eliminate them. For proper assessment, each event was assigned a probability and severity and then the level of risk and the appropriate measure to minimize the effects were determined. The greatest residual risk was identified as the impact of insufficient financial resources, inappropriate selection of the contractor and extraordinary events.

Qualitatively, the risks of this project are addressable and should not jeopardize the achievement of the project objectives. From a risk management perspective, it is essential to continuously monitor and update the ongoing status of the project and events that could cause delays or stoppages.

4 DISCUSSION

The CBA analysis was able to review the approach to evaluating capital projects, considering all investments and savings resulting from the implementation of the Bridge Reconstruction. The CBA analysis offered to review the approach to the evaluation of investment projects and to take into account all investments and savings resulting from the implementation of the bridge reconstruction. All parts of the CBA that are recommended in the literature have been taken into account in the text.

The financial analysis of the bridge indicates an unfavourable development of the investment, which is caused by the fact that the project does not generate any financial income. On the contrary, the results of the economic analysis reveal a high rate of return and efficiency of the project caused by non-monetary aspects such as time and fuel savings, as well as changes in safety and environmental performance. The biggest savings are generated by the project in the areas of environment and safety improvements. A risk analysis is also included to help avoid adverse impacts that could jeopardize project implementation.

The main objective of the bridge reconstruction project was to ensure the preservation of regional transport serviceability, increase safety and minimize negative traffic effects on inhabitants, the territory and the environment. The analysis confirms that the reconstruction will fulfil these objectives, benefiting the community.

Compared to other CBAs, the results of this analysis are better. This positive result is due to large savings in kilometres travelled. Other analyses that evaluate, for example, city bypasses do not shorten the distance as significantly and thus do not generate as extensive benefits as the bridge rebuilding project.

5 CONCLUSION

In the paper, the project for the reconstruction of the road bridge over the dam was assessed by CBA analysis. From the results it can be concluded that CBA analysis is appropriate for evaluating such an investment. The analysis can determine the value for money and economic parameters with sufficient accuracy. CBA, as an analytical tool, is used to assess the efficiency of projects and also has a rationale in the construction sector. It is suitable for assessing major investment projects in the transport sector. Maintaining the principles of CBA allows for the comparison of individual projects with each other. This procedure guarantees expertise and objectivity in the assessment.

Research in this area can be extended by studying this analysis in more detail or by using other suitable methods to determine the value assessment of investments. For the future, changing trends in transport need to be taken into account. The increased availability of electric or hydrogen-powered vehicles will reduce environmental impacts and thus influence the results of the analysis.

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