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Cost Benefit Analysis: Bypass of Prešov city

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Abstract. The paper describes decision making process based on economic evaluation, i.e. Cost Benefit Analysis for motorway bypass of the Prešov city. Three variants were evaluated by means of the Highway Development and Management Tool (HDM-4). HDM-4 is a software system for evaluating options for investing in road transport infrastructure. Vehicle operating costs and travel time costs were monetized with the use of the software. The investment opportunities were evaluated in terms of Cost Benefit Analysis results, i.e. economic indicators.

1 Introduction

Project of road infrastructure are concurrently assessed by means of cost benefit analysis (CBA). CBA is a tool which purpose is to determine all impacts (financial, economic, social, environmental and others) of the project and quantify all costs and benefits of the project. Cost benefit analysis consist of four types of analysis: financial analysis, economic analysis, sensitivity analysis and risk analysis. For the evaluation of road infrastructure, paramount is the economic analysis, which is not evaluated only through financial flows, but, in addition, identification and quantification of societal benefits. These social impacts are: travel time savings, reduction of accident rate, vehicle operating costs savings, reduction of noise levels and reduction of pollution. These effects are easily identifiable in practice, but their quantification is difficult. Various types of software might be utilized for quantification of these effects. For the bypass of Prešov city, was used toll HDM-4 (Highway Development and Management system). Three variants were evaluated. The best variant was chosen according to economic indicators calculated in the CBA.

2 CBA for road infrastructure projects

CBA is used in feasibility studies with the objective to ascertain most viable variant of road infrastructure solution. Feasibility analysis identifies and analyses the limits of proposed alternatives, which include legal, technical, economic, environmental and personal limits. Feasible project must achieve investor´s objectives, and, at the same time, accept these limits. Following the feasibility analysis, investment cost for each alternative

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need to be quantified. Concurrently, reference period of the project needs to be set, usually starting in the year of the analysis and ending in the final year of the project lifecycle. The reference period consists of the investment period – time of design and construction of the infrastructure, and operation period – time when the infrastructure is open for users, thus generating benefits but also operation costs for the administrator. To take the time factor into account, all costs and benefits are discounted. The discount rate for economic analysis is prescribed by the European Commission. Another important factor for calculating cost benefit analysis is traffic intensity on both existing and newly constructed road network. On this basis, program HDM-4 computes operating, user and societal costs. Project benefits are calculated as a difference between higher user costs in the alternative without the investments, and lower user costs in the alternative with investment. When all costs and benefits have been quantified the program computes economic indicators for proposed alternatives. [5] [6]

2.1 Formatting the title, authors and affiliations

Economic analysis is conducted from the perspective of whole society, in which financial gain is not the most important aspect, instead, so-called societal benefit is the main point of interest in the evaluation. Economic analysis doesn´t evaluate project only through financial flows, but, in addition, quantify various impacts entailed by the project. All costs and benefits of the project are computed from quantifying all these impacts. After all costs and benefits have been quantified, economic indicators are computed: economic net present value (ENPV), economic internal rate of return (EIRR), economic payback period (EPP) and economic cost benefit ratio (ECBR). Economic efficiency of the project is evaluated on the base of these economic indicators. [1]

2.1.1 Economic net present value

Economic net present value (ENPV) is difference between discounted costs and benefits of project.

$$ENPV = \sum_{t=0}^{n} \frac{B_t - IC_t - OC_t}{(1+0{,}01.\mathrm{u})^t} \tag{1}$$

Where: $ENPV$– economic net present value, [€]
B_t – benefits from investment in year t, [€]
IC_t – investment cost in year t, [€]
OC_t – operating costs in year t, [€]
u – discount rate, [%]
t – individual years, [years]
n – reference period, [years]

Effective project has economic net present value more than zero. This economic indicator is together with economic internal rate of return the most decisive in assessing economic efficiency of the investment. [4]

2.1.2 Economic internal rate of return

Economic internal rate of return (EIRR) represents a rate of return of the investment. EIRR is a discount rate, at which is the economic net present value equal zero.

$$\sum_{t=0}^{n} \frac{B_t - IC_t - OC_t}{(1+0{,}01x)^t} = 0 \tag{2}$$

$$EIRR = x.100 \tag{3}$$

Where: $EIRR$ – economic internal rate of return, [%]
B_t – benefits from investment in year t, [€]
IC_t – investment cost in year t, [€]
OC_t – operating costs in year t, [€]
x – interest rate - searched value, [%]
t – individual years, [years]
n – reference period, [years]

The project is effective, if the internal rate of return exceeds the used discount rate. This indicator is usually the most decisive in economic efficiency evaluation of the investment. EIRR allows to compares projects of different sizes. [4]

2.1.3 Economic payback period

Economic payback period (EPP) is the year, at which discounted benefits of project equal the discounted costs of a project. Project is effective, when its payback period is shorter than the lifecycle of project respectively shorter then reference period. This indicator is not decisive in project effectiveness assessment, but may be used as an additional criterion. [4]

$$0 = \sum_{t=1}^{EPP} \frac{B_t - IC_t - OC_t}{(1+0{,}01u)^{(t-1)}} \tag{4}$$

Where: EPP – economic payback period, [year]
B_t – benefits from investment in year t, [€]
IC_t – investment cost in year t, [€]
OC_t – operating costs in year t, [€]
x – interest rate - searched value, [%]
t – individual years, [years]
n – reference period, [years]

2.1.4 Economic cost benefit ratio

Economic cost benefit ratio (ECBR) is a complementary economic indicator. ECBR is calculated by dividing the net present value of all benefits and the net present value of all project costs. Project is effective, when the EBCR exceeds one.

$$ECBR = \frac{\sum_{t=0}^{n} B_{t,DIS}}{\sum_{t=0}^{n} CC_{t,DIS}} \tag{5}$$

Where: $ECBR$ – economic cost benefit ratio, [-]
$B_{t,DIS}$ – discounted benefits from investment in year t, [€]
$CC_{t,DIS}$ – discounted capital cost in year t, [€]
t – individual years, [years]
n – reference period, [years]

2.2 Software HDM-4

The software endorsed World Bank HDM-4 (Highway Development and Management System) is a versatile tool for the road management of existing or planned roads. HDM-4 has a defined system of relations and mathematical equations which describe traffic, pavement performance and road user effects. [2]

Based on input fed by the evaluator in the software and calibration file for particular region, HDM-4 monetizes travel times costs, vehicle operating costs and accident costs as well as administrator's cash flows. [2]

Travel time is considered in terms of passenger-hours during working and non-working time, and cargo holding hours. [6]

Vehicle operating costs include: fuel consumption, oil and lubricants consumption, tyre consumption, parts consumption, maintenance labour hours, depreciation, interest, crew hours and overheads. [6]

An accident is an event involving one or more road vehicles, which results in death, personal injury and /or damage to property. In HDM-4 are analysed three types of accident: fatal, injury and damage only. [6]

Administrator's cash flows include investment costs, maintenance and repair costs of the road. [2]

3 Road infrastructure of Prešov city

At present, Prešov is lacking motorway transport infrastructure directing traffic outside of built-up part of city. Full traffic volume is led throughout the communication system of the city with all the negative impacts on habitants and the environment of Prešov city. Traffic serviceability of Prešov is provided by municipal communications and trunk roads of first, second and third class. The brunt of traffic volume is distributet on first class roads I/18 and I/68. Daily intensity on critical sections on these roads exceeds 34 000 vehicles per day.

The main objective of the bypass is divert transit traffic outside of built-up area of Prešov, which significantly enhance the quality of life in the city. Second objective of the bypass is completion of highways and expressways connection of cities Bratislava and Kosice, i.e. fifth Pan-European transport corridor leading through Slovakia. The bypass, will provide safe, quick, and convenient connection in both North – South and East – West direction.

4 Bypass variants of Prešov city

Three variants were assessed: Red variant, Red modified variant and Blue variant. The following figure (Fig. 1) shows the assessed variants.

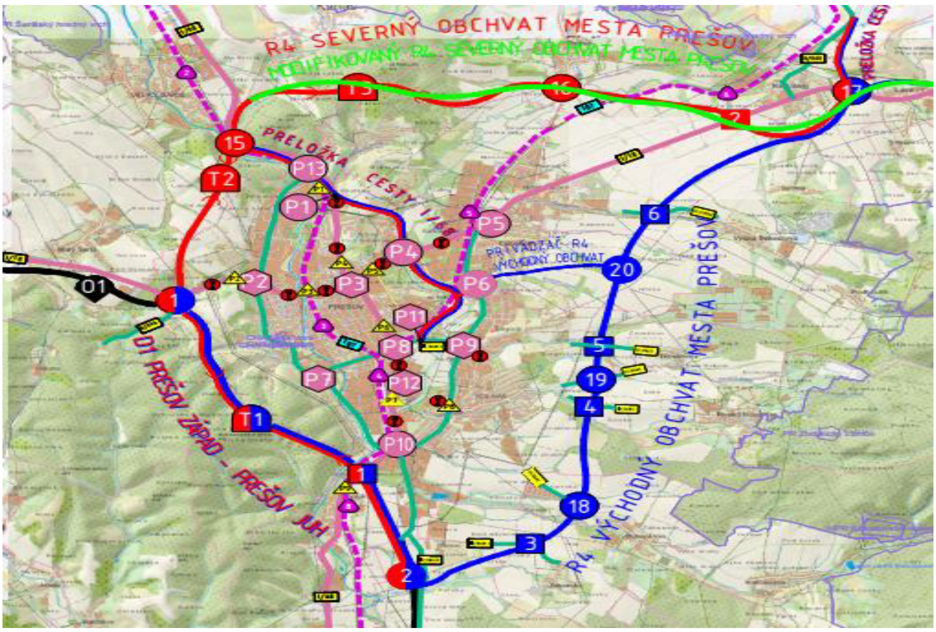

Fig. 1. Assessed variants of Prešov city [3]

4.1 Technical parameters of assessed variants

Assessed variants have different technical parameters such as: horizontal and vertical alignment, numbers of bridges, tunnels, elevated crossings, etc. The section of highway: D1 West Prešov – South Prešov, has the same technical parameters in all assessed variants. Red variant and Red modified variant are the same for elevated crossing – Dúbrava (ref.15). From this elevated crossing is the change in horizontal and vertical alignment, which is illustrated at Figure 1 by green colour. Technical parameters of assessed variants are listed in following table (Table 1). [3]

Table 1. Technical parameters of assessed variants

VARIANT	Category of communication	Length	Number of elevated crossings	Number of bridges	Number of tunnels
Red	D 26,5/100 R 24,5/100	7,87 km 14,5 km	2 3	18 21	1- Prešov 2 - Bikoš and Okrúhliak
Red modified	D 26,5/100 R 24,5/100	7,87 km 13,86 km	2 3	18 18	1 – Prešov 1 - Bikoš
Blue	D26,5/100 R 24,5/130 R 22,5/80	7,87 km 14,8 km 3,73 km	2 4 -	18 21 5	1 – Prešov - -

4.2 Traffic intensity

The aim of bypass is divert the transit traffic from Prešov on newly constructed motorway infrastructure. Traffic intensity is assumed the same in Red variant and Red modified variant, but different in Blue variant. For Prešov city, forty-three road sections, both new and existing, were evaluated. For each road section, HDM-4 requires input data regarding: construction parameters, pavement defects, actual traffic volume for Variant "Do nothing", traffic volume distribution for "Do something" variants. Design files as well as traffic study of the Bypass were supplied by design company DOPRAVOPROJEKT a.s. - division of Zvolen. Data regarding existing road network were obtained from the portal of road network database of Slovak Road Administration.

5 CBA for bypass of Prešov city

CBA was used for assessing economic efficiency of proposed variants of bypass Prešov city. CBA was performed in HDM-4 software.

5.1 Inputs into the software HDM-4

All necessary data about existing road network and proposed variants, which are mentioned higher, were inserted into the software HDM-4. Other data, which were inserted into HDM-4, were reference period and discount rate. Reference period of 35 years was set for evaluation, of which 5 years is the investment period and 30 years is the operation period, i.e. life expectancy. Discount rate for economic analysis is prescribed by the European Commission, and, currently it is 5 %.

5.2 Capital costs of assessed variants

Capital costs consist of investment and operating costs. Investment costs were quantified by project engineer and operating costs were quantified by program HDM-4. In the following table (Table 2), discounted and undiscounted capital costs are listed.

Table 2. Capital costs of assessed variants [mil. €]

	UNDISCOUNTED			DISCOUNTED		
Variant	**Red variant**	**Red modified variant**	**Blue variant**	**Red variant**	**Red modified variant**	**Blue variant**
Capital costs	924.96	816.21	785.55	821.61	724.67	696.46

5.3 Benefits of assessed variants

Benefits for individual variants were calculated as a difference between higher user costs in the alternative without the investments, and lower user costs in the alternative with investment. Benefits were quantified in the software HDM-4. In the following table (Table 3), discounted and undiscounted benefits for assessed variants are listed.

Table 3. Benefits of assessed variants [mil. €]

	UNDISCOUNTED			DISCOUNTED		
Variant	**Red variant**	**Red modified variant**	**Blue variant**	**Red variant**	**Red modified variant**	**Blue variant**
Benefits	1973.83	1975.46	1407.64	777.95	778.60	558.19

5.4 Economic indicators

After all costs (Table 2) and benefits (Table 3) were quantified, the HDM-4 software computed economic indicators of assessed alternatives. The most effective variant was chosen according to economic indicators. An effective variant must fulfil following rules: ENPV must be greater than zero, EIRR must be greater than discount rate 5%, EPP must be lower than lifecycle of project respectively lower than reference period, in this case it is 35 years and ECBR must be more than one.

5.4.1 Red variant

	Increase in Road Agency Costs			Savings in MT VOC	Savings in MT Travel Time Costs	Savings in NMT Travel & Operating Costs	Reduction in Accident Costs	Net Exogenous Benefits	Net Economic Benefits (NPV)
	Capital	Recurrent	Special						
Undiscounted	924.96	0.00	0.00	832.88	837.81	0.00	303.14	0.00	1,048.87
Discounted	821.61	0.00	0.00	330.13	329.56	0.00	118.27	0.00	-43.66

Economic Internal Rate of Return (EIRR) = 4.7% (No. of solutions = 1)

Fig. 2. Output from software HDM-4 for Red variant

Red variant has reached following economic indicators: ENPV is -43.66 million €, EIRR is 4,7 %, EPP is longer than lifecycle of project and EBCR is 0,95. All economic indicators of Red variant show, that this variant is not effective.

5.4.2 Red modified variant

	Increase in Road Agency Costs			Savings in MT VOC	Savings in MT Travel Time Costs	Savings in NMT Travel & Operating Costs	Reduction in Accident Costs	Net Exogenous Benefits	Net Economic Benefits (NPV)
	Capital	Recurrent	Special						
Undiscounted	816.21	0.00	0.00	830.54	841.79	0.00	303.14	0.00	1,159.25
Discounted	724.67	0.00	0.00	329.20	331.13	0.00	118.27	0.00	53.93

Economic Internal Rate of Return (EIRR) = 5.6% (No. of solutions = 1)

Fig. 3. Output from software HDM-4 for Red modified variant

Economic indicators for Red modified variant are following: ENPV is + 53.93 million €, EIRR is 5,6 %, EPP is in lifecycle of project and ECBR is 1,07. These economic indicators fulfilled conditions of efficiency. Red modified variant is effective.

5.4.3 Blue variant

	Increase in Road Agency Costs			Savings in MT VOC	Savings in MT Travel Time Costs	Savings in NMT Travel & Operating Costs	Reduction in Accident Costs	Net Exogenous Benefits	Net Economic Benefits (NPV)
	Capital	Recurrent	Special						
Undiscounted	785.55	0.00	0.00	541.67	613.69	0.00	252.27	0.00	622.08
Discounted	696.46	0.00	0.00	217.51	242.51	0.00	98.17	0.00	-138.27

Economic Internal Rate of Return (EIRR) = 3.5% (No. of solutions = 1)

Fig. 4. Output from software HDM-4 for Blue variant

Economic indicators for Blue variant are following: ENPV is – 138.27 million €, EIRR is 3,5 %, EPP is longer than lifecycle of project and EBCR is 0,80. Economic indicators of Blue variant show that this variant is not effective.

6 Conclusion

The dire current traffic situation in Prešov calls for the construction the bypass. The aim of the bypass is to divert the transit traffic outside the built-up area of Prešov city. Second objective of the bypass is completion of highways and expressways connection of cities Bratislava and Kosice, i.e. fifth Pan-European transport corridor leading through Slovakia. Three variants of bypass of Prešov city were assessed: Red variant, Red modified variant and Blue variant. The best variant was chosen according to economic indicators calculated in the cost benefit analysis.

Based on economic results presented in chapter 5, we conclude that the Red modified variant is the best choice from the economic point of view. Its economic indicators fulfilled a condition of efficiency. Red variant and Red modified variant have same traffic solution, but the Red modified variant has significant savings of investment costs 108.75 million €. This saving was achieved by removal of the tunnel Okúrhliak. The alternate route entailed to raise the motorway's longitudinal axis and requires significant earthworks as the motorway is positioned in the cut of hill Okrúhliak, the costs however justify this solution, i.e. capital costs of Red variant (Tab.2) has been higher than expected benefits of Red variant (Tab.3) and therefore this variant is not as effective.

The blue variant had the lowest capital costs (Tab.2), but, traffic wise, this variant is not as effective, thus scores poorly as shown in fig 4. Blue variant had scant benefits, because traffic study predicted less favourable relocation of freight transport compared to red variants. Traffic study expected that Blue variant takes over 19 % less of freight transport compared to red variants on the existing road network in Prešov. This fact reflected itself in the monetization of Blue variant's benefits which ultimately didn't exceed the capital costs.

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