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Improvement of Economic Effectiveness of Road Highway Projects

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Abstract

With regards to the strategic role of transport in a country's economic development and the large investments that are required, a thorough economic appraisal of these investments is of high importance. Therefore, it is appropriate to analyze and possibly modify existing methods for evaluating the economic efficiency of road construction at the scientific level, with the support of the real practice experience. Our research concentrates on evaluation of current methods of economic appraisal, their consecutive improvement and on incorporation of the LCCA agenda into the investment decision process. Consequently, it focuses on the possibilities to improve the effectivity of both, an investment decision process and a realization phase through the proposal of very concrete measures based on results of our research and on experience of real practice construction.

Keywords: economic efficiency; investment appraisal; life-cycle costs; HDM-4 software; road transport infrastructure

1. Introduction

This research paper deals with the major deficiencies in the current investment decision process to the highway network and with the major problems and ineffectivities in the consecutive phase of realization. Overall approach of this research paper is to reveal the possibilities to improve effectivity of above mentioned investment decision process and realization phase through proposal of the very concrete measures. In substance it concerns the purposeful synthesis of proper asset management with more effective investment program to achieve higher infrastructure quality. Although this paper depicts the current road infrastructure situation in the Czech Republic, talks about local state offices and agencies and uses local transport infrastructure data, it also analyses global experience and its findings aspire to be of general validity and applicability.

Current importance of this topic is also given due to the currently increasing production of the construction segment and the present situation of financing the construction of roads and highways. In terms of the volume of investments it is favorable mainly due to various European Union's funds (Cohesion Fund and European Regional Development Fund). These funds are primarily to support routes, which should become part of the Trans-European Transport Networks (TEN-T). Czech Republic has committed to complete the TEN-T routes' infrastructure until the year 2030. This is to be carried through the European Union's framework of Transport Operational Programme. This means, that until the year 2030, Czech Republic should almost double the length of its motorway and highway network - from the actual 1242 km to 2180 km. Unfortunately, availability of these European Union's resources in such extent is limited by the year 2023 [1]. To secure sustainability of the development in preset speed of the construction even after this date, when financial resources will rapidly decrease, a significant change in overall approach and resultantly a significant increase in effectiveness is needed. This can be achieved only through increased emphasis on economical, procedural and managerial aspects of both phases of road infrastructure construction - investment decision process and construction realization phase.

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To achieve better understanding of the current practice of appraisal of economic effectiveness of the highway (respectively road) projects, we also analyze one such appraisal – an output of widely used HDM-4 software and the way its results are understood and interpreted.

2. Approach to economic appraisal of the investment

Based not only on vast experience of the American and Czech state highway agencies, main goals and/or areas to be considered during the highway investment's economic effectiveness appraisal are as following:

- transportation system eficiency – improvement of its reliability and efficiency;
- cargo movement and support of economic development - improvement of the road network capacity and regional interconnection;
- traffic safety – goal to significantly reduce human fatalities and injuries due to traffic on all roads;
- traffic congestion reduction - significant reduction of congestion on the road system;
- infrastructure asset development – maintainance, repair and rehabilitation strategy of all roads and structures;
- environmental impacts – To minimize the impact of transportation on nature, environment and population [2,3].

Without proper consideration of all above stated criteria, the investment decision making process cannot be complete.

The current method for evaluating the economic efficiency of road construction is carried out using the methodology of the Czech Road Assessment System (CSHS). For the actual economic assessment, CSHS methodology determines the software tool HDM-4, developed by Birmingham University (United Kingdom), with support from the World Bank [4]. Thanks to its complexity and flexibility to include high number of factors and inputs, this software is used in many European countries [5].

But there is a significant problem to this widely used assessment tool – or actually a problem of this whole assessment approach. It also has to implement data and information that are more of a qualitative and sometime even intangible nature. It is very hard to quantify the value of safety, human life or environmental impact. Of course the tool works mainly with the data of a quantitative kind, more appropriate for economical appraisal. But very often it is that small portion of mentioned soft data that can change the whole result of the analysis and the choice of the accepted variant of the projected investment. The result of the analysis is very sensitive to these data inputs and can be influenced marginally by artificial change in these qualitative indicators. Such a possibility to affect an overall result of the analysis by tweaking mentioned soft data is a major problem itself. An analyst should not have any option to willingly decide over the results of the analysis. Based on the above said, it seems that to achieve a decent level of comparability of individual investment projects, it is necessary to standardize the quantification and financial appraisal of these qualitative/intangible criteria.

3. Assessment tool HDM-4

Software HDM-4 was developed by Birmingham University, with support from the World Bank (WB). Its primary task is to assess the economic efficiency of transport infrastructure projects, but thanks to the comprehensive evaluation it also includes other modules focused on technical aspects of the project. From an economic point of view, the software is based on the principle of comparing zero variant (current status) with new variants, compared by main economic indicators as following:

- Net Present Value (NPV),
- Internal Rate of Return (IRR),
- Benefit-to-Cost Ratio (BCR).

Coming out of these standard and widely recognized indicators, we can compare two or more options among themselves and decide on the most effective solution. Overall assessment of the project is primarily based on the societal benefit [6]. Thus, the actual assessment will also include costs that are not only of the investment and operational nature, i.e. of qualitative/intangible nature as mentioned before, which represents a significant problem regarding their valuation.

From an economic standpoint the most interesting output from HDM-4 is the sum of the project's discounted flows. An example of such an output is shown in the Table 1 below. There are two basic groups of costs. The first group consists of costs associated with the transport route's operation. These are mainly the costs of maintaining

the roads, traffic vehicles (fuel, spare parts), accidents (material damage and human injury) and travel time. In the second group there are costs (externalities) related to environmental impacts. These are the costs of air pollution, excessive noise and exhaust fumes (CO2).

Table 1: HDM-4 output (in millions CZK; source: own research)

	Zero Variant (baseline scenario)						Proposed Variant					
	Costs						Costs					
Year	Manage-ment	Operational	Travel time	Accidents	Externali-ties Total	Total	Manage-ment	Operational	Travel time	Accidents	Externali-ties Total	Total
2016	0,79	19,32	18,26	1,62	7,02	47,01	18,72	19,32	18,26	1,62	7,02	64,94
2017	0,65	18,76	17,53	1,57	6,65	45,16	47,60	18,76	17,53	1,57	6,65	92,11
2018	2,48	18,03	17,22	1,50	6,35	45,58	39,20	18,03	17,22	1,50	6,35	82,30
2019	0,61	17,48	16,65	1,47	6,01	42,22	0,87	17,02	13,06	1,62	2,65	35,22
2046	0,16	5,51	5,36	0,46	1,59	13,08	0,21	5,41	4,20	0,59	0,74	11,15
2047	0,14	5,21	5,15	0,44	1,52	12,46	0,20	5,10	4,01	0,49	0,71	10,51
2048	0,14	4,70	4,89	0,42	1,44	11,59	-6,66	4,59	3,80	0,46	0,69	2,88
Celkem:	**15,28**	**362,36**	**349,88**	**30,78**	**115,56**	**873,86**	**116,27**	**353,67**	**286,66**	**33,85**	**62,05**	**852,50**
Net Present Value		NPV:	**10,90**	Internal Rate of Return			IRR:	**6,10%**	Benefit-Cost Ratio		BCR:	**1,2115**

Table 1 above represents an example comparing the two variants of the project. It compares the baseline scenario, i.e. how the situation was without the projected changes and the proposed variant, which represents an investment opportunity. This project is the construction of 4 km bypass of the village with the necessary anti-noise measures (barrier). Construction costs were roughly determined to CZK 110 million. Other necessary information were obtained using the combination of data from Czech state highway agency (ŘSD), HDM-4 and the Exnad model to calculate the externalities. The project was evaluated for a 30-year period of operation. The main criterion for assessing whether the project is economically viable is an indicator of IRR, which has to reach greater value as the discount rate itself. During evaluation of the project (resp. of the proposed variant), IRR reached the value of 6.1%, while the fixed discount rate was at 5.5%. That made the proposed variant acceptable and meant that it represented savings for the whole society and resulted in the project's implementation. The decisive moments of the overall evaluation of this variant were the total time savings found, the reduction of noise pollution and general environmental impact.

The very tight result also proves above mentioned problem of sensitivity of the qualitative and intangible data valuation with this appraisal approach. Subjective valuation of such inputs represents a serious danger to whole otherwise very sophisticated tool and approach.

4. Life-cycle costs analysis

The life-cycle cost analysis (LCCA) technique is commonly accepted as a useful investment/project evaluation tool. The LCCA now actually makes up one of the most actual topics not only in road constructio. It evaluates the costs associated with the project from its initial preparation until its dissolution. It helps to find the optimal variant of the project throughout its life-cycle. Complex LCCA reflects all the economic variables fundamental to the evaluation - user costs like travel time consumption / delay, safety costs connected with maintenance and rehabilitation projects, agency capital cost, and life-cycle maintenance costs. The need to optimize the cost of construction and operation in the current environment of rising energy prices and the deepening pressure on savings and cost-cutting is increasingly popular. The standard means for determining the LCCA is the Net Present Value (NPV), which represents the present value of future costs incurred during the project's life-cycle; as an optimal variant from the assessed scenarios is that with lowest final present value of future costs. However, there is a problem with selecting an appropriate discount rate. And there are few more technical problems with the LCCA's implementation. Acquiring credible supporting data and information, including the data on traffic or projecting future traffic flows are one of them. Despite such technical difficulties, limited research done and understanding yet achieved of this complex concept, the LCCA has the potential to provide us with valuable data and conclusions.

Figure 1: Life-cycle costs in highway infrastructure construction (source: own research)

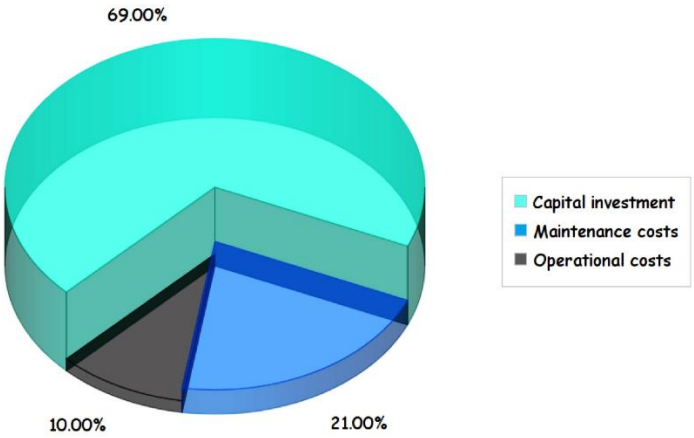

Figure 1 above shows the LCCA of the new motorway sections in the Czech Republic (without the liquidation phase). In the transport infrastructure construction - unlike in conventional building or heavy construction - the largest costs are associated with the investment phase of the life-cycle. The fact that roughly two-thirds of all the costs are connected with the project's capital investment phase gives us a great opportunity to reach significant savings exactly through an increase of effectiveness of the investment decision process and design and construction realization phase.

5. Effectiveness of the realization phase

Disclosing the infrastructure projects' construction business, it is essentially a very attractive business because of the relative ease of achieving extraordinary gains. It derives from the principles of the so-called "measured contract" when the price of the executed work is determined by multiplying the price per unit and the amount actually made of these units [7]. That actually applies to civil engineering in general.

In particular, it is the work not really executed that can be the source of above-average profit. This is the case when reported quantities are larger than actual and where there is an artificial increase in unit prices through change management. For example, a very common situation - the recognition of extraction and transportation of 150 thousand m3 of soil instead of really carried out 100 thousand m3 and not for the contractual unit price per m3, but for the price, increased via change management for inclusion into another class workability (e.g. due different geological conditions).

Such behavior patterns of the suppliers of engineering structures can be quite effectively faced with a combination of these essential measures that we propose and methods and practices, time-proven in the rest of the world:

- Flawless project documentation incorporating maximal standardization of all the project's sections (especially those most costly, when designed and built/produced, i.e. bridges, tunnels and anti-noise barriers). Thorough digital scanning of the terrain and application of Building Information Modeling (BIM) to not to leave much space for any major contract changes during construction. Regular/repetitive frequency of such three-dimensional scanning is also a way to gain an overview and control of really processed quantities (of soil, for example) and a chance to increase fairness of billing with the contractors.
- Correct cost estimate of all individual items (control budget) of the design based on exact bill of quantities prepared by the Highway Agency's own capacities and based on its own cost database (i.e. outsourcing of any of these activities being unacceptable, e.g. using designer's bill of quantities). Consecutive realization phase being in accordance with accepted cost estimate and bill of quantities. Project manager's personal responsibility for these tasks being of crucial importance.
- Evaluating competing bids on the basis of the state agency's own flawless control cost estimate (budget) and rejecting those bids of abnormally low or high values (±10-15% against the control budget). Such approach also eliminates most of the bidders' reasons to appeals against the results of the tender.
- Objective, independent and incorruptible execution of own technical supervision (supervisor / engineer) regarding performed quantities and approved changes to design during the realization phase.
- Confirmation of performed quantities and approved changes to design during the realization phase by an independent authorized subject (quantity surveyor / technical supervisor) beyond commonly used extent. An

additional third-party subject with the lowest possible probability of ties with the contractor is financially favorable especially on larger projects.

- In a sensitive area of environmental protection, clear need for many environmental measures is often a matter of opinion and is hard to determine with certainty. At the same time, such measures are often very money-demanding. To counter above mentioned with financial responsibility and to act in accordance with valid EU's directives, an investor should choose an approach of so called Adaptive Management.
- Applying any environmental protection measures or design variations based on the proportion of probability of a phenomenon and not in a form of precaution, holds a potential for significant savings in comparison to current practice.
- Legal option to foreclose from any further new projects' tenders those contractors, that are in any form of dispute over any past project with the state. Though that this principle has proven its efficiency in various states Europe, it is still not being implemented into the legal codes for public contracts of most of the states. When implemented and practiced, it significantly improves bargaining position of the state. It also fundamentally regulates the behavior of contractors towards the state agencies, bringing it closer to the standards of behavior / relationships of the owner-contractor in the private sector.

6. Summary and conclusions

There are significant inefficiencies in the current decision process regarding investments to the road network. There are different methodologies on investment decision process (based on a location) but for the actual economic assessment of the project, it is the software tool HDM-4, which is most widely used. Thanks to its complexity and flexibility to include high number of factors and inputs we have found this tool as suitable and verified that in a case study. However, main deficiency found was not found to the software but to the general approach to the assessment within every investment unit (i.e. resort or a country). Main inconsistency is in the various type of data that have to be processed. Both, standard technical and financial data and at the same time information that are of a qualitative and intangible nature have to be included into the decision process. Though technically possible, diferrent results based on the latitude of input data values are the problem. This is due to inconsistency in the valuation of those qualitative/intangible data. It is only proper and consistent unification of this valuation for all the projects assessed within every investment unit/area/country, that can improve inter-comparability and quality of the resulting investment decision. Based on the above said, it is evident that to achieve a decent level of comparability of individual investment projects, it is necessary to standardize the quantification and financial appraisal of these qualitative/intangible criteria.

Further analysing the structure of the life-cycle costs in highway construction projects, we affirmed that complex life-cycle cost analysis technique has the potential to provide us with valuable data and conclusions. The fact that roughly two-thirds of all the costs are connected with the project's capital investment phase evidently represents a great opportunity to reach significant savings through an increase of effectiveness of the investment decision process and design and construction realization phase.

Regarding above mentioned phase of realisation of the road infrastructure investment project we targeted major problems and ineffectivities. Based on the practice of project management in this type of projects we summarized the areas, that lead to economical inefficiency most often. We proposed a set of essential measures, methods and practices to effectively face them. Those of being highest importance are as following:

- flawless project documentation incorporating maximal standardization, thorough digital scanning of the terrain and application of Building Information Modeling to decrease the amount of major contract changes during construction, to increase control of really processed quantities and to increase fairness of billing;
- investor's own control budget prepared on the basis of his own bill of quantities and cost database, project manager's personal responsibility for the control budget a for the accordance of the consecutive realization phase with it;
- evaluating competing bids on the basis of the investor's own flawless control budget and rejecting those bids of abnormally low or high values by a pre-set strict rule;
- execution of own technical supervision, i.e. none outsourcing being acceptable for this task;
- if needed, employment of additional third-party authorized subject for the higher-level technical supervision;
- applying any environmental protection measures or design variations based on the proportion of probability of a phenomenon and not in a form of precaution;
- legal option to foreclose from any further new projects' tenders those contractors, that are in any form of dispute over any past project with the state to significantly improve bargaining position of the investor and to standardize contractors' behavior towards him.

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