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Analysis of extreme values of the economic efficiency indicators of transport infrastructure projects

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Abstract. Paper builds on previous research of the authors into the evaluation of economic efficiency of transport infrastructure projects evaluated by the economic efficiency ratio - NPV, IRR and BCR. Values of indicators and subsequent outputs of the sensitivity analysis show extremely favourable values in some cases. The authors dealt with the analysis of these indicators down to the level of the input variables and examined which inputs have a larger share of these extreme values. NCF for the calculation of above mentioned ratios is created by benefits that arise as the difference between zero and investment options of the project (savings in travel and operating costs, savings in travel time costs, reduction in accident costs and savings in exogenous costs) as well as total agency costs. Savings in travel time costs which contribute to the overall utility of projects by more than 70% appear to be the most important benefits in the long term horizon. This is the reason why this benefit emphasized. The outcome of the article has resulted how the particular basic variables contributed to the total robustness of economic efficiency of these project.

1. Introduction

In the Czech Republic, as well as in other economically developed countries, the construction sector is one of the main pillars ensuring the development of the economy. Construction, and related investment construction, contributes in the long term to the balanced development of the territory, including the effect on the environment, creating the conditions for business in other economic sectors and industries, maintaining social stability. Its high multiplier effect contributes significantly to the growth/economic recession.

According to statistical data, it is clear that the crisis in the construction ended in 2013. To improve the overall condition involved mainly civil engineering. According to statistical data [1] in 2016 there was an unexpected decline in construction production; civil engineering was the annual decrease of 16 %. In January of 2017 construction production decreasing trend continued. Although building permits issued about 12 % more than in the previous year, improvement is unexpected. Decisive is the status of the contracts awarded, and the constantly declining. The main cause of the unfavourable situation of the Czech construction is a long time licensing structures. On it depends also the recovery of investment construction in the coming years in all areas, but especially in the area of infrastructure and housing construction.
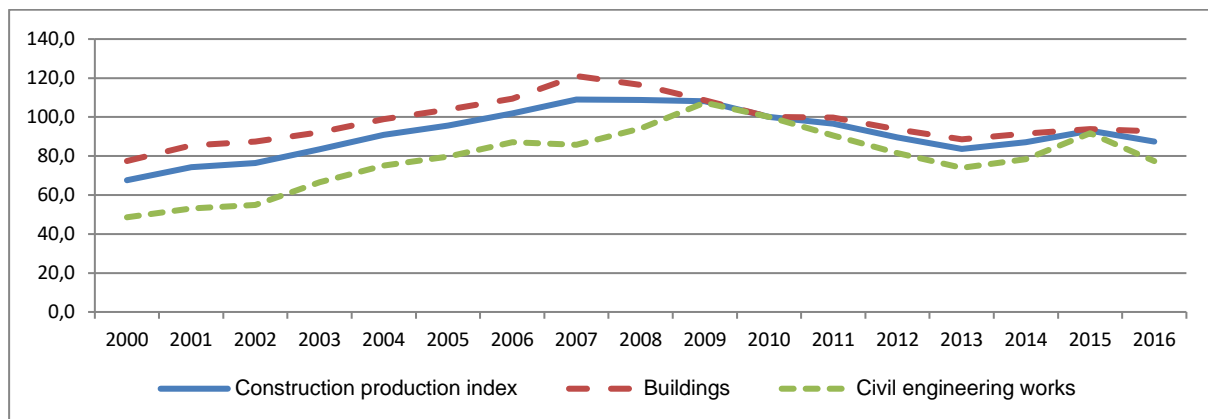
Figure 1. Construction production index (average of 2010=100, constant prices, source: In-house processing using data from Czech Statistical Office).

Civil engineering represents the construction and changes in road construction, telecommunication, electrical and pipe lines, construction for industrial purposes and other civil engineering works. The construction output volume affects the performances of transport and the parallel transport condition for the functioning of the economy as a whole. Transport cannot function without an adequate technical base, which includes transport infrastructure. Significant engineering and construction projects are becoming more and more important, because a lot of states renews and extends its existing infrastructure mainly due to its growth. [2]

Investment plans these projects must demonstrate, that they are economically efficient. The basic input variables for the evaluation of the economic efficiency are the investment costs and related costs for repairs and Maintenance. Social usefulness of the projects is determined by the particular demand of the users in the following years of operation. The aim of this paper is to determine how the total efficiency of the projects responds to the changes of two basic variables (total agency costs and socio-economic benefits) and which of them has a greater impact on the efficiency of projects. The paper is structured as follows: firstly, review of the literature dealing with the issue of transport infrastructure projects, their impacts and effectiveness is presented. Secondly, methodology employed in the research is explained. Thirdly, results are presented, discussed and compared with other studies where applicable. Finally, main findings and outline of future research directions are provided.

2. Literature Review

Public transport investment projects are typically long-lived, high cost and have a long lead time from the start of building to the time of operation when the benefits of the investment begin to be realised. This profile makes public transport projects difficult to justify using discounted cash flow evaluations which concentrate on the potential and summative impact on society's welfare (in terms of achieving a positive net present value or a benefit/cost ratio exceeding 1), – especially when market shares heavily favour the automobile. [3]

Transport infrastructure planning should be accompanied with relevant methods enabling appropriate decision-support [4], in the Czech Republic this process is based on CBA. CBA consists in assessing whether benefits accrued from a project are in excess of its social costs, thereby showing if the project represents a net benefit to the whole society. The key strength of this approach is that it produces information of the project's net contribution to the society. [5]

At the outset, it is worth distinguishing between investment appraisals by public versus private sector transport providers. In the majority of European member states, transport infrastructure is predominantly publicly owned [6], therefore infrastructure investment appraisal is usually concerned with achieving a range of social (as opposed to private) objectives. These typically include:

- economic efficiency, measured by the results of a social cost–benefit analysis (CBA);

- minimising environmental damage, measured using environmental impact assessment (EIA) methods; and
- other objectives concerned for example with equity, with accessibility, with long-term cash-flow implications for the state or with achievement of regional development policies. [7]

Net cash flow (NCF) consists of the savings in the costs of the suggested (investment) variant related to the zero variant (without investment). The calculation formula consists of 4 types of particular benefits – socio-economic savings. They are savings in travel and operating costs (TOC), savings in travel time costs (TTC), reduction in accident costs (AC) and savings in exogenous costs (EC). Many investments may actually represent a financial loss, but still be economically profitable when benefits for the operators and the passengers are taken into account. [8] NCF is determined as these benefits and total agency cost (investment and maintenance costs) and is reflected in the classic indicators of economic efficiency (NPV, IRR and BCR).

Travel time is one of the largest categories of transport costs, and time savings are often claimed to be the greatest benefit of transport projects such as roadway and public transit improvements. [9] Factors such as traveller comfort and travel reliability can be quantified by adjusting travel time cost values. On an average people devote 60-90 minutes a day to travel. Most people seem to enjoy a certain amount of personal travel, about 30 daily minutes, and dislike devoting more than about 90 minutes a day [10]

Savings in travel time costs were according to previous studies identified as the most important benefit with more than 70% proportion on the total benefit [11], [12], [13], [14], [15], [16]. Calculation of the economic benefits associated with travel time savings is based on the sum of all time savings related to consumer surpluses for all origin-destination movements [17].

If the overall rankings are relatively insensitive to changes, there can be greater confidence that they are a robust reflection of the relative importance given to the different criteria. Alternatively, a benefits, total agency costs, NPV, IRR, BCR, high level of sensitivity points towards the importance of being clear that the weights are indeed an accurate reflection of social preferences between the types of impact and to being confident that the assessments of impact for the relevant criteria have been accurately made. [18]

3. Methodology
Economic evaluation of transport infrastructure projects in the Czech Republic is based on CBA. Net cash flow (NCF) consists of the savings in the costs of the suggested (investment) variant related to the zero variant (without investment). The research sample represents Czech large-scale transport infrastructure projects in the period from 2014 to 2016. All data was identified in the pre-investment phase of the project life cycle, it means that ex-ante analysis was done. Individual items of the calculation formula currently used for the calculation of the investment plan efficiency by Road and Motorway Directorate of the CR have been studied on the sample of 47 projects of the transport infrastructure.

For all the projects, their efficiency according to the Benefit Cost Ratio and their robustness of change of two critical variables, total agency costs (TAC) and socio-economic benefits (B) during 30-year-period were studied. Benefit Cost Ratio was calculated according to the following relation

$$BCR = NPV/TAC$$

Where:
BCR… cost benefit ratio
NPV…net present value
TAC…total agency costs

The robustness was examined by the sensitivity analysis. A particularly relevant component of the sensitivity analysis is also the calculation of the switching values. This is the value that the analysed variable would have to take in order to the NPV of the project become zero, or more generally, for the outcome of the project to fall below the minimum level of acceptability [19].

4. Results and discussion

All research projects report very good results of BCR and also sensitivity analysis. BCR **>**1 in all of research cases was calculated. The minimum limit for changes of *TAC* and/or *B* was found to be 30%. It means that it is possible to increase *TAC* or decrease *B* until reaching NPV = 0. The majority of projects, however, have higher values. And so the research sample was divided into 6 levels according to switching values and the frequency of projects was determined. Frequency of projects in interval of total agency costs and/or benefits of switching values and their BCR are shown in Table 1 and Table 2.

<table>
<tr><td colspan="4">**Table 1.** Changes of TCA.</td><td colspan="4">**Table 2.** Changes of B.</td></tr>
<tr><td>Interval of switching values</td><td>Average value of BCR</td><td>Number of projects with changes of TAC</td><td>Share of total number of projects</td><td>Interval of switching values</td><td>Average value of BCR</td><td>Number of projects with changes of B</td><td>Share of total number of projects</td></tr>
<tr><td>< 30%</td><td>1.02</td><td>14</td><td>29.79%</td><td>< 30%</td><td>1.08</td><td>17</td><td>36.17%</td></tr>
<tr><td>31-50%</td><td>1.40</td><td>4</td><td>8.51%</td><td>31-50%</td><td>1.66</td><td>12</td><td>25.53%</td></tr>
<tr><td>51-100%</td><td>1.68</td><td>11</td><td>23.40%</td><td>51-100%</td><td>3.22</td><td>18</td><td>38.30%</td></tr>
<tr><td>101-200%</td><td>2.43</td><td>11</td><td>23.40%</td><td>101-200%</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>> 201%</td><td>4.70</td><td>5</td><td>10.64%</td><td>> 201%</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>> 400 %</td><td>6.49</td><td>2</td><td>4.26%</td><td>> 400 %</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td colspan="2">Total number of projects</td><td>47</td><td>100%</td><td colspan="2">Total number of projects</td><td>47</td><td>100%</td></tr>
</table>
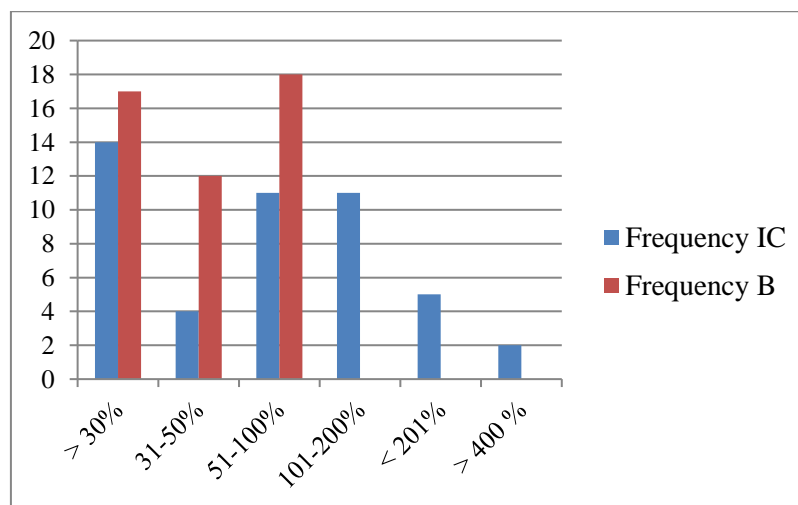
Figure 2. Frequency of projects in individual levels of switching values.

While the robustness of projects is given by sensitivity to changes in the input values and does not differ for individual projects, in case of limit values the differences are significant [20]. From the data in Tab. 1, Tab. 2 and Fig. 2 is evident that transport infrastructural projects in the Czech Republic are more sensitive in social-economic benefits area than in total agency costs. For the switching values the change of total agency costs are higher than the change of benefits for extreme result of TAC (679%). Analysed results, however, cannot be interpreted that total agency costs could rise significantly. Robustness of the project in relation to the total agency costs is given explicitly by high degree of the utility of this type of projects for the society.

Analysis also shows that projects placed in individual levels of the switching values induced by change in total agency costs have slower BCR than projects in the same levels of the switching values induced by change in socio-economic benefits (see Tab. 3).

Table 3. Values of BCR.

Interval of switching values	Average value of BCR	
	Changes of TAC	Changes of B
< 30%	1.02	1.08
31-50%	1.40	1.66
51-100%	1.68	3.22
101-200%	2.43	-
< 201%	4.70	-
> 400 %	6.49	-

From the above stated findings, it is evident that in detail it must be the determination of socio-economic benefits which more significantly affect the value of efficiency. It is known that benefits consists of 4 types of particular benefits and one of them – savings in travel time costs – are the most important. Their calculation is not easy; it is dependent on a well-built traffic model and a proper evaluation value of travel time. In the Czech Republic it is nowadays being prepared a new methodical document, which should clarify the calculations under the current and prospective state of transportation in the country.

Total agency costs as the sum of investment and maintenance costs are very important, too. The advantage is, that for their determination exit relevant methodological procedures and especially generally accepted pricing database [21].

5. Conclusion

This paper has focused on the changes of input variables and their impact on economic efficiency ratios of transport infrastructure projects. For the calculation, Czech data was used. A major concern has been to determine how the particular basic variables, total agency costs and socio-economic benefits, contributed to the robustness of economic efficiency of these projects and what the development of their BCR is. The research monitored the values in the sample of 47 Czech road infrastructure projects.

BCR and switching value were calculated for all projects as changes in the total agency costs and socio-economic benefits. Based on the analysis results it is possible to deduce that changes in socio-economic benefits have more significant impact on the change in the indicators of the economic effectiveness than changes in the total agency costs (investment costs and maintenance costs), established for the evaluation period of 30 years. Further research will be directed towards to a detailed examination of socio-economic benefits (especially travel time costs transport), particularly setting time values and verification of transport models.

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