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# Assessment of Large-Scale Projects Based on CBA

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**Abstract**

CBA is a very important and strong tool for economic effectiveness evaluation of public investment projects. The outputs (NPV, IRR and BCR) are dependent on correctly set input data. As has been proved recently, an inaccuracy in forecast occurs very often. This paper deals with analysis of particular benefits, which help to create the total benefit for evaluation of road infrastructure projects and megaprojects based on CBA according to the Czech methodology. Moreover, it considers the overall inaccuracy of the project regarding the partial inaccuracies and their shares.

Monte Carlo simulation has been applied in order to determine the share of particular benefits and the closest similar probability distribution of these shares to the total benefit of the project. Research results have confirmed that the largest share and the most severe inaccuracy in the total benefit is represented by savings in travel time costs. They have revealed that the share of this benefit has the logistic probability distribution with mean of about 77% and 20.72% of standard deviation. The inaccuracies of the particular benefits have been studied in international research. As a result, very large differences were found. That means that there is still a large space for exploration.


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*Keywords:* Road infrastructure projects, cost-benefit analysis, benefits, probability distribution.

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## 1. Introduction

The large-scale transport infrastructure projects and megaprojects are typical public projects which are financed from public financial resources. According to the fact that public financial resources are scarce, the relevant decision-making technique tries to find out which methods are able to calculate and determine economic efficiency of these projects more accurately. For the choice of the most effective projects the basic methodological foundation is the CBA (cost-benefit analysis). This method is based on the creation of NCF as the difference between zero (the infrastructure without project) and investment (the infrastructure with project) variant of project. NCF of both variants consists of total agency costs and total benefits of the project. The total benefit is the sum of particular benefits which are in the Czech Republic created on the basis of the Instruction of Road and Motorway Directorate of the Czech Republic[1]. The analysis has been performed on the sample of 27 Czech large-scale transport infrastructure projects processed during 2013-2015 period and other international scientific resources.

All of these benefits consist of many particular variables, which are related to the technical data gained from the traffic models and their unit prices. As every model which consists of so many variables predicted is followed by an inaccuracy, this phenomenon occurs in this case as well. Not only optimism bias, but also other factors play their role. As a result, every partial benefit produces its volume of imprecision and altogether they cause total difference from the ex-post values.

The aim of this paper is to perform detailed analysis of the shares of partial benefits discussed above in project total benefit and then to use these values as weights for estimation of the possible total inaccuracy of the ex-ante appraisal of the transport infrastructure project.

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. Then, methodology employed in the research is explained. Consequently, results are presented, discussed and compared with other studies where applicable. Finally, the main findings and the outline of future research directions are provided.

## 2. Literature Review

The evaluation of transport projects has a long history, but there is no universal method that is collectively agreed upon. There are many differences between countries regarding the scope and method of evaluation on actual decision-making[2]. The time and international comparison showed which methods are suitable and what weak points they have. In the course of years, CBA is not the only tool used for the ex-ante evaluation of transport infrastructure projects, but it is one of the most common methods to be used together with MCA (Multi-criteria analysis) in the European Union countries[3] as well as in countries outside the Europe such as the USA or Japan, to name a few. Methods differ in each country due to their development of the theory and application but they have a lot in common[4].

An increasing number of studies have demonstrated that the economic evaluation of transport infrastructure projects via CBA has the largest explanatory power[5,6,7,8,9,10]. As can be seen in Fig. 1, for road projects, the CBA is not the only method of appraisal, but definitely the most widely spread one, in some cases combined with MCA or other quantitative methods[12,13]. Countries concerned in Fig. 1 are Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Netherlands, Sweden, Switzerland, the UK, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, the Slovak Republic, Slovenia, Cyprus, Greece, Italy, Malta, Portugal and Spain.

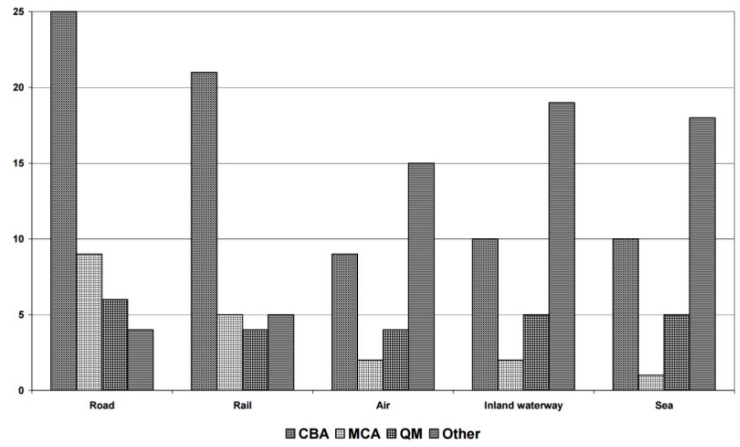


Fig. 1. Methodology used for transport project appraisal in EU-25, by mode. Source[13] CBA: cost–benefit analysis; MCA: multi-criteria analysis; QM: quantitative measurements; Other: other combination of appraisal method, mainly qualitative. If (for example) both CBA and MCA are used, the figure reflects CBA.

Nevertheless, the common use of CBA does not mean that the countries do the same things in the same way. There are some recommendations in the Guide of CBA analysis of investment projects but there is no strict regulation as such[14] European commission. As a result, many countries take into account different benefits. As Tab. 1 shows, the differences are not rare.

Table 1. System of transportation project evaluation in several countries. Source: [1,3,4,15,16,17].

| | United Kingdom | France | Japan | USA | Germany | Czech Republic |
|---|---|---|---|---|---|---|
| Method criterion | CBA (COBA, NATA) | CBA | CBA with MCA | CBA (MCA) | CBA | CBA |
| Criteria parameters/scope impact | Maintenance costs, vehicle operating costs, time savings, safety (environmental without explicit costs) | Vehicle operating costs, time savings, safety, noise, air pollution (local and global) | Time and costs savings, safety, (additionally regional impacts, global and local environment impacts, living standards, back up function for emergencies) | Time and costs savings, safety, induced demand, environmental pollution and noise | Maintenance costs, Operating costs, vehicle operating costs, time savings, safety, noise, air pollution – local, severance, economic development, employment, international traffic, regional policy | Travel and operating costs, travel time, safety, exogenous costs |

It can be concluded, that mostly these four criteria are solved and monetized in the large-scale transport infrastructure projects appraisal:

- travel time savings,
- travel and operating costs,
- safety,
- environmental costs in different views

However, these differences among countries are not the only thing that brings confusion. In early 90' some critical reviews of the application of cost-benefit analyses to transport projects were provided. This opened a great discussion about the accuracy and problems of this kind of forecasting. There are many points to be treated and many pitfalls that can fatally influence the investment decisions. During the time, the efficiency of the projects was not as high as was estimated by ex-ante analyses. This was proved in the past by some of the ex-post analyses such as the Channel Tunnel or the Great Belt Link and others[18], and many conclusions were gained. Some authors define the possible sources of these inaccuracies, such as problems in estimation of transport situation and a high cost of collecting this data, incorrect definition of the study area, incorrect definition of the „do-nothing" scenario, engineering problems carrying budget overruns, long period between planning based on the expected development and realization, incorrect inputs or project life assessment and others, which bring great differences in the resulting benefits[10,19].

It is obvious, that the forecasting needs more and more accuracy as well as finding weak points of the already realized projects that can be taken in regard in new analysing and applied on future decisions to prevent any mistakes when prioritizing the projects.

The way how to do it, is above all based on the ex-post evaluation of the megaprojects, which is not very common. In fact, countries like Germany, the UK, the USA or France do not have any explicit treatments or even do not plan to carry out any ex-post evaluation. Only countries like Japan decided that ex-post evaluation formally will be conducted[4]. There are some recommendations in the Guide of CBA analysis of investment projects but there is no strict regulation as such[14] European commission. Nevertheless, there are some projects analysed ex-post and some authors who have recently used this data for their research into this topic such as Salling[20] or Welde[21].

Finding the mistakes made as well as the sources of these mistakes, deviations between the values and application of these results would help in development of the CBA method. Research is heading for estimation of the probability distribution of these mistakes and some first possible results are outlined. The question remains how serious the deviations are and what impact they could possibly have if the particular variables were more accurate.

## 3. Methodology

The research sample represents 27 Czech large-scale transport infrastructure projects. The economic evaluation of these projects has been done according to the Instruction of Road and Motorway Directorate of the Czech Republic[1]. All of these projects have reported positive value of NPV at 5.5% discount rate, average IRR was 10.83% and BCR at 1.95. All data was identified in the pre-investment phase of the project life cycle, it means that ex-ante analysis was done.

The results of the first, empirical part of the research were processed in the following steps. Firstly, the particular percentage monitoring benefits of individual projects were identified. Secondly, the closest similar probability distribution of the share of particular benefits to the total benefit of the project has been determined. These calculations were carried out with the support of Crystal Ball software by simulation using the Monte Carlo method. Research results have confirmed that the largest share of the total benefit is represented by saving in travel time costs and have revealed that this benefit has the logistic probability distribution.

Second part of the research uses the gained parametric values regarding them as weights of the partial benefits. Their multiplication with the possible errors is then used for calculation of the total possible deviation between the predicted ex-ante net present value and a real value of the project. This calculation leads to finding the most important variable that has the most severe impact on the total inaccuracy of the project ex-ante appraisal and gives possible directions of what details to focus on to find more exact results of ex-ante assessment of the road transportation projects.

## 4. Results and Discussion

In the Czech methodology, 4 types of particular benefits mentioned above are monitored. 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). "Savings in travel time costs" were identified as the most important benefit with a high proportion of the total benefit. For the share of TTC, logistic distribution has been selected as the closest similar one, which is shown in Fig. 2.

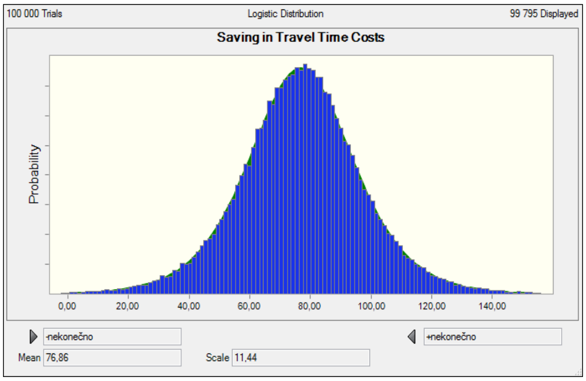


Fig. 2. Probability distribution of the share of "Savings in travel time costs". Source: In-house processing using data from economic efficiency studies and Crystal Ball software.

The statistical characteristics of the share of benefit "Savings in travel time costs" which have been set with support of Crystal Ball software is shown in Tab. 2.

Table 2. Statistical characteristics of the share of "Savings in travel time costs". Source: In-house processing using data from economic efficiency studies and Crystal Ball software.

| Statistics | Forecast values |
|---|---|
| Trials | 100,000 |
| Base Case | 0.00 |
| Mean | 76.87 |
| Median | 76.93 |
| Mode | --- |
| Standard Deviation | 20.3 |
| Variance | 429.65 |
| Skewness | -0.0067 |
| Kurtosis | 4.9 |
| Coeff. of Variability | 0.697 |
| Minimum | -74.78 |
| Maximum | 231.77 |
| Range Width | 306.55 |
| Mean Std. Error | 0.07 |

Tab. 3 summarises the results of specification of the expected value of the contribution of "Savings in travel time costs" to total benefits of the projects.

Table 3. Summary of the contribution of TTC. Source: In-house processing using data from economic efficiency studies and Crystal Ball software.

| Expected value | Results |
|---|---|
| Mean | 76.87 |
| Median | 76.93 |
| Standard Deviation | 20.73 |

A high share of TTC (mean about 76%) indicates that remaining three benefits contribute to the total benefit on a smaller scale. The results of this present research are shown in Tab. 4.

Table 4. Statistical characteristic of shares of particular benefit on total benefit. Source: In-house processing using data from economic efficiency studies and Crystal Ball software.

| Benefit | Probability distribution | Mean | Median | Standard deviation |
|---|---|---|---|---|
| Savings in travel and operating costs (TOC) | logistic distribution | 11.88 | 11.84 | 23.83 |
| Reduction in traffic accidents costs (AC) | triangular distribution | 7.10 | 6.14 | 8.60 |
| Savings in exogenous costs (EC) | lognormal distribution | 4.84 | 2.70 | 7.59 |

This Czech study confirmed the results of international studies which brought also conclusions that travel time savings are the most important part of the total benefit and represent between 50-80% of the total benefit. Others benefits have much less significant shares. Savings in travel and operating costs are estimated between 10-15%, Reduction is accidents costs oscillates between 5-10% and exogenous costs' share is between 0-10% Parker[19,] Salling[20], Persson & Song[22], Priemus & al.[23], Börjesson[24] state that the largest contributors to direct benefits from any transport project, are the travel time savings.

These results are considered to represent the weights of these values in the calculation of the total possible deviation of NPV ex-ante calculation from the ex-post value. NPV is calculated as follows:

$$NPV_{(m-n)} = \sum_{y=1}^{Y} \frac{NCF_{y(m-n)}}{(1+r)^{(y-1)}} \tag{1}$$

where

*m* NCF of transport infrastructure with project (investment variant)

*n* NCF of transport infrastructure without project (zero variant)

*Y* evaluation period

*y* year of evaluation (y = 0, 1, 2, 3 …)

NCF are created as sum of particular benefits minus total agency cost (investment and operational costs):

$$NCF = TTC + TOC + AC + EC - TAC \tag{2}$$

Probability deviation as the value of inaccuracy of calculation ratios in ex-ante phase of the project can be described as follow:

$$IA_{NCF} = IA_{TTC} \times W_{TTC} + IA_{TOC} \times W_{TOC} + IA_{AC} \times W_{AC} + IA_{EC} \times W_{EC} - IA_{TAC} \times W_{TAC} \tag{3}$$

where

*IA* inaccuracy of NCF

*W* weight of the share of particular variable on the total

| | |
|---|---|
| *TTC, TOC, AC, OC* | partial benefits |
| *TAC* | total agency costs |

If the values of possible inaccuracy of particular benefits are known, the total inaccuracy could be found. All of economic data depends on traffic forecast. The current international studies have presented very different values of inaccuracy of this variable. For example Flyvbjerg[25] showed BetaPert probability distribution with parameters min. -78.5%, max. 179.34% mean 9.6%, Welde[21] presented Weibull probability distribution with parameters min. -31.2%, max. 32.6%, mean -1.5%, Salling[30] presented Gamma probability distribution and Guide CBA[14] recommended the use of asymmetrical triangular probability distributions with parameters min. - 30%, max. +15%. So far it seems that every national economy will have to necessarily work with national data. That means there is still a large gap for exploration.

## 4. Conclusion

This paper has focused on forecast accuracy of economic efficiency ratios of road infrastructure projects and megaprojects. For the calculation, Czech data was used as well as the data from international studies. A major concern has been to determine how the particular benefits (TTC, TOC, AC and EC) contributed to the total benefit and what inaccuracies of this data between ex-ante and ex-post evaluation are.

The research monitored the shares of particular benefits on the set of 27 Czech road infrastructure projects with the support of Crystal Ball software by simulation using the Monte Carlo method. All the benefits are described by their statistical characteristics. Saving in travel time costs (TTC) was identified as the most important benefit with a high proportion of the total benefit. The second part (inaccuracy between ex-ante and ex-post data) was devoted to search for international sources because complete Czech ones are not available. Formula for probability deviation as the value of inaccuracy of calculation ratios in ex-ante phase of the project was described, but from general point of view. The current international studies have presented very inconsistent results of behaviour particularly benefits between ex-ante and ex-post calculation. That means there is still a large space for exploration.

Finally, it should be said that inaccuracies in the data are very important for decision-making process because in the pre-investment phase (ex-ante) the evaluator has to decide among more projects with high acquisition costs. For this decision the evaluator needs information about current values which are determined by national methodology and also information about their possible behaviour. Therefore, further research should address these items in the Czech Republic area and their comparison with international data.

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