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Risk Assessment of Large-Scale Infrastructure Projects—Assumptions and Context

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Featured Application: The results of the presented research extend the methodology of economic analysis and risk assessment of large infrastructure projects.

Abstract: This article deals with the partial outputs of large-scale infrastructure project risk assessment, specifically in the field of road and motorway construction. The Department of Transport spends a large amount of funds on project preparation and implementation, which however, must be allocated effectively, and with knowledge of the risks that may accompany them. Therefore, documentation for decision-making on project financing also includes their analysis. This article monitors the frequency of occurrence of individual risk factors within the qualitative risk analysis, with the support of the national risk register, and identifies dependent variables that represent part of the economic cash flows for determining project economic efficiency. At the same time, it compares these dependent variables identified by sensitivity analysis with critical variables, followed by testing the interaction of the critical variables' effect on the project efficiency using the Monte Carlo method. A partial section of the research was focused on the analysis of the probability distribution of input variables, especially "the investment costs" and "time savings of infrastructure users" variables. The research findings conclude that it is necessary to pay attention to the setting of statistical characteristics of variables entering the economic efficiency indicator calculations, as the decision of whether or not to accept projects for funding is based on them.

Keywords: CBA; investment project; probability distribution; sensitivity analyses; risk assessment

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1. Introduction

Transport infrastructure projects are important carriers and supporters of economic growth for national economies. Implementation of investment projects, in addition to the direct benefits for which they are implemented, brings growth potential for the national economy; they reduce unemployment, increase the sales of design and implementation companies, and thus create revenue capacity on the demand side for purchases of goods and services. Implementation of investment projects will also be a key factor in alleviating the current COVID-19 pandemic effect in all national economies; e.g., the draft of the state budget of the Czech Republic brings record investments for the future, which have been increased by CZK 178 billion for 2021 (€6.7 billion). Even so, the supply of funds for project implementation is limited. Therefore, it is always necessary to choose for financing only those projects that are efficient. The efficiency of projects to be implemented is assessed in the ex-ante period, on the basis of feasibility study data, which is addressed in the form of a cost–benefit analysis (CBA).

The authors of this article have been carrying out research into development in economic efficiency assessment of public transport infrastructure projects for a long time. In the present article they focused on the analysis of the economic outputs of road infrastructure projects, motorways, and class I roads via CBA. CBA has the largest explanatory power [1–4], which is based on the determination of cost-effectiveness against the total societal benefits. Generally, four criteria are solved and monetized in large-scale transport infrastructure project appraisals: travel time savings, travel and operational costs, safety, and environmental cost, from different perspectives. In ref. [5] based on the modeling of economic cash flows determined by these variables, the following economic efficiency indicators were established: economic net present value (ENPV), economic internal rate of return (ERR), and benefit cost ratio (BCR) [6,7]. The values of the economic indicators were tested for critical variables and the switching values of indicators (threshold value of the indicator in terms of efficiency, e.g., ENPV = 0, ERR = discount rate) were determined. In the following step, a quantitative risk analysis using the Monte Carlo method was performed for the identified critical variables. At the same time, a qualitative risk analysis, which considered potential risk factors using a risk register [7], was performed. It monitored the project risk impact, the occurrence probability, and deduced the risk relevance for the implementation and operation of the project. Individual projects that demonstrated a positive evaluation from all perspectives examined are ready for funding, and further phases of their life cycle can be launched for them. The research question addressed by the implemented research team was which variables are risky, how strong is their influence on economic efficiency, and whether and how the projects are resilient; robust to the potential risk interaction. This concerns questions of the connection of the qualitative and quantitative risk analysis, which dependant variables are resulting from the qualitative analysis, and if they are also considered in the quantitative analysis. In the case of the important critical variable it was the objective to test the changes of the efficiency of projects while using different probability distributions.

Investors aim, not only to prevent project failure, but also to select the best alternatives among the available investment projects, so as to gain more benefits and achieve better results [8]. In the investment decision-making process of large-scale projects, many risk factors can cause decision failure [9]. This is also why decision-support systems are of high importance for investors in the construction industry [10].

2. Materials and Methods

The aim of the research described in this paper was to find the relations between the outputs of the qualitative risk analysis, sensitivity analysis, and quantitative risk analysis, which were performed in the evaluation of the economic efficiency of transport infrastructure projects, as part of the modeling of economic Cash Flow (CF) of their life cycle. For the case study, a set of projects being prepared for realization in the Czech Republic was chosen. The authors of the paper have many years of experiences in the evaluation of projects in Czech transport infrastructure, and during these years they were able to collect a large amount of input data. However, the authors would like to emphasize that for the presented procedures, and partly also for the results, it is possible, respecting individual specifics of economic evaluation in other countries, to relate them to projects carried out abroad. The research sample consisted of 20 large-scale transport infrastructure projects from the Czech Republic, which were the pre-investment phase in the 2018–2020 period, and with proven economic efficiency. Only those projects that could be compared with each other due to the fact that they were processed according to the same methodological procedure, e.g., according to the Departmental Methodology valid since 2017 [7], were included in the research sample.

Net cash flow (NCF) for the calculation of economic ratios consisted of the savings in the costs of the suggested (investment) variant related to the zero variant (without investment). The calculation formula consists of four types of particular benefits; socio-economic savings. They are savings in travel and operating costs, savings in travel time costs, reduction in accident costs, and savings in exogenous costs. The time value of money determining the amount of the discount rate for the calculation of the ENPV indicator was set at 5% for the Czech Republic in the EU programming period 2014–2020.

The research presented in this article examined project risk frequency, and the impact on their economic efficiency and robustness of economic efficiency indicators, using sensitivity analysis, and finally involved confirmation or refusing the robustness of projects according to the previous step by determining the cumulative probability of achieving project economic efficiency using the Monte Carlo method. To assess the real risk of failure associated with the investment, changes in the values of economic performance indicators deriving from the simultaneous change of several project variables had to be identified [11]. As stated by [12], one of the risk assessment tools is the Monte Carlo method, which combines and develops both sensitivity analysis, and scenario analysis, methods. In the resource material, Ref. [13] focused on the Monte Carlo method used in the case of the earned value management methodology. Bowers also provided a broader view of the issue of project risk assessment [14].

2.1. Data

Table 1 presents the research sample projects with their basic characteristics. It states the undiscounted economic investment costs (i.e., investment costs excluding VAT reduced by a conversion coefficient 0.807), economic internal rate of return (ERR), economic net present value (ENPV), and cost benefit ratio (BCR), which was calculated according to the following relation:

$$\frac{\mathrm{B}}{\mathrm{C}} = 1 + \frac{\mathrm{ENPV}}{\mathrm{IC}} \tag{1}$$

where:

BCR: Cost Benefit Ratio
ENPV: Economic Net Present Value
IC: Discounted Investment Costs

Table 1. Basic economic data on research sample projects.

No.	Name of the Project	IC €	ERR %	ENPV €	BCR
P1	Vestec connection	73,655,517	13.15%	134,141,506	2.90
P2	I/22 Draženov-Horažd'ovice	253,477,033	5.67%	25,929,610	1.11
P3	I/27 Kaznejov, bypass	91,192,128	9.50%	74,002,422	1.83
P4	I/13 Ostrov-Smilov, right bank	141,082,434	5.88%	19,811,383	1.15
P5	I/13 Ostrov-Smilov, left bank	116,820,770	7.52%	50,193,343	2.01
P6	I/26 Horšovský Týn	50,375,269	5.60%	4,578,849	1.09
P7	D0 Březiněves-Satalice var. 1	371,886,072	39.45%	2,576,573,157	8.28
P8	D0 Březiněves-Satalice var. 2	434,933,917	30.46%	2,395,820,591	6.92
P9	D0 Březiněves-Satalice var. 3	757,919,450	17.89%	1,934,644,942	3.81
P10	I11– Hradec Králové, tangent	111,776,135	17.24%	336,621,090	4.15
P11	I/18 Příbram-bypass var. 1	28,417,453	14.20%	54,410,634	2.96
P12	I/18 Příbram-bypass var. 2	49,497,029	13.21%	74,973,161	2.61
P13	I/50 Bučovice	78,579,450	7.56%	32,937,152	1.44
P14	I/36 Trnová-Fablovka-Dubina	53,652,370	19.20%	190,286,624	4.73
P15	I/11 Nové Sedlice-Opava Komárov	91,436,523	5.52%	7,834,232	1.09
P16	I/26 Holysov, bypass	56,624,471	9.19%	42,452,457	1.80
P17	D10 Praha-Kosmonosy	361,367,050	5.72%	35,994,616	1.11
P18	I/67 Bohumín-Karviná	83,937,876	5.33%	4,067,671	1.05
P19	D43 Bořitov-Staré Město	56,624,471	9.19%	42,452,457	1.80
P20	D27 Přeštice-Klatovy	128,638,259	5.12%	22,333,326	1.02

Source: Feasibility Studies of Investment projects, The State Fund for Transport Infrastructure SFDI, authors' own processing.

Qualitative risk analysis is generally based on expert opinions on the risks that threaten a particular investment project. Lists of risks are usually created, based on the knowledge of the issues addressed, which contain risks that are relevant and common for the given type of projects. A risk register was created in the Czech Republic for the purposes of risk assessment of the road infrastructure projects specified above [7]. The list of risks according to the risk register is given in Table 2.

Table 2. Risk register according to the Departmental Methodology of the Czech Republic.

No.	Risk Description
	Demand-related risks
R1	Different development of demand than expected
	Risks related to the project design
R2	Inadequate surveys and inquiries in the given locality
R3	Inadequate estimates of project work costs
	Administrative and public procurement risks
R4	Delays in awarding
R5	Building permit
	Risks related to the land purchase
R6	Land price
R7	Delays in land purchase
	Risks related to construction
R8	Exceeding investment costs
R9	Floods, landslides, etc.
R10	Archaeological findings
R11	Risks related to the contractor (bankruptcy, lack of resources)
	Operational risks
R12	Higher maintenance costs than expected
	Regulatory risks
R13	Environmental requirement change
	Other risks
R14	Public opposition

Source: Departmental methodology of the Ministry of Transport [7].

2.2. Methods

The methodological procedure was based on collection, analysis, and examination of relevant data concerning the economic efficiency assessment of individual investment projects. The outputs were aimed at answering research questions concerning the interconnectedness of individual analyses of future project uncertainties.

2.2.1. Qualitative Analysis

The significance of project risks (R) was divided into four categories: very high (VH), high (H), medium (M), and low (L). This was determined on the basis of the product of the project risk impact intensity (I) and its occurrence probability (p), with a five-interval scale of both variables, according to the following relation:

$$R = I \times p \tag{2}$$

The probability (value) and the impact intensity had the determined ranges presented in following Tables 3 and 4.

Table 3. Scale of risk occurrence probability (p).

Classification	Verbal Description	Percentage Expression
A	Very improbable	0–9%
B	Improbable	10–32%
C	Neutral	33–65%
D	Probable	66–89%
E	Very probable	90–100%

Source: Departmental methodology of the Ministry of Transport [7].

Table 4. Scale for risk impact intensity (I).

Category	Name	Verbal Description
I	Imperceptible	no significant effect on expected social benefits of the project
II	Mild	long-term project benefits are not affected but corrective measures are needed
III	Medium	loss of expected social benefits of the project, mostly financial loss and in medium- and long-term time horizon, corrective measures may solve the problem
IV	Critical	large loss of expected social benefits of the project, occurrence of adverse effects causes a loss of the project's primary function; corrective measures, even if taken on a large scale, are not sufficient to prevent major losses
V	Catastrophic	significant to complete loss of function of the project, project objectives cannot be achieved even in the long term

Source: Departmental methodology of the Ministry of Transport [7].

Table 5 shows the occurrence frequency of very high, high, and medium risks in the researched sample of projects, according to the risk register (see Table 1). In addition to the risk frequency, the table also shows the dependent variable, which enters the economic CF of the projects as a basis for the calculation of economic efficiency indicators.

It is clear from the overview given in Table 5 that the most significant risks for transport infrastructure projects identified in the pre-investment phase lie in the estimation of future demand for new infrastructure use (R1), design and preparatory work (R2), (R3), delays in obtaining construction permits (R5), land purchase (R7), and excess of project costs (R8).

The R1 risk is related to the demand, which affects the income part of the projects in the operational phase of their life cycle by a possible reduction in their expected socio-economic benefits.

The influence of other risks has a direct impact on investment costs, which thus become a significant variable in the economic assessment.

Table 5. Risk frequency according to their significance, including the dependent variable identification.

Risk No.	VH and H Risks	M Risk	Total	Dependent Variable
R1	3	5	8	Revenues alias operating phase savings
R2	5	8	12	Investment costs, beginning of the construction
R3	4	6	10	Investment costs
R4	0	5	5	Beginning of the construction
R5	0	9	9	Beginning of the construction
R6	0	2	2	Investment costs
R7	12	2	14	Beginning of the construction
R8	8	5	13	Investment costs
R9	0	1	1	Investment costs, extension of construction, delay/shortening of the operational phase for evaluation
R10	0	1	1	Investment costs, extension of construction, delay/shortening of the operational phase for evaluation
R11	0	2	2	Investment costs, extension of construction, delay/shortening of the operational phase for evaluation
R12	0	0	0	Operating costs, reduction of benefits under "Infrastructure operating costs" item
R13	0	0	0	Changes in benefits under "Externalities" item
R14	0	0	0	Influence on the beginning of construction

Source: Feasibility Studies of Investment projects, SFDI, authors' own processing.

2.2.2. Sensitivity Analysis

The outputs of the sensitivity analysis (elasticity coefficients and switching values of economic efficiency indicators) were investigated for individual projects in the following phase of the research in order to determine project resilience to changes in variables potentially affected by risks. The elasticity coefficients were determined both for investment costs and for all relevant socio-economic benefits, which as a total amount, form the income part of the economic CF (following the R1 risk).

It can be seen from the data in Table 6 that variables such as accident rate, externalities, and/or total operating costs generally have low elasticity coefficients, and are not in most cases identified as critical variables. Investment costs and the time savings of infrastructure users already showed that they very often become critical variables (EC > 1). For this reason, occurrences of switching values (i.e., ENPV = 0), which show the influence of these critical variables, were investigated in the following phase of the research. Outputs were divided into the interval of changes up to 10%, up to 30%, and over 30%. It can be clearly seen from Table 7 that the projects showed a relatively high efficiency robustness; about 70% of projects met a limit of efficiency when changing one of these critical variables up to 30%.

Table 6. Frequency of elasticity coefficient (EC) values.

Variable	$0 \leq$ EC < 0.5	$0.5 \leq$ EC < 1	$1 \leq$ EC < 1.5	EC ≥ 1.5
Total investment costs	5	4	4	5
Vehicle operating costs	16	1	1	0
User time costs	1	7	5	5
Accident rate	13	3	0	2
Other externalities	13	2	0	3

Table 7. Switching values of project efficiency.

Variable/Switching Value	$0 \leq \mathrm{PH} < 10\%$	$10\% \leq \mathrm{PH} < 30\%$	$\mathrm{PH} \geq 30\%$
Total investment costs	3	3	13
Time savings of users	2	3	14

The outputs of the sensitivity analysis and qualitative risk analysis showed that the total investment costs and time savings of transport infrastructure users represented fundamental risk variables that affected the efficiency of the investment projects. For this reason, these independent variables were tested by subsequent quantitative analysis, which was carried out by the Monte Carlo method, using Crystal Ball software [15].

In the case of the quantitative analysis, a relative index BCR was chosen, because it allows comparing the efficiency of projects of different sizes (investment demanding), and it shows the benefit of one invested currency unit. The utilization of the BCR index as one of the criterial indicators for the evaluation of the economic efficiency of public projects is methodically described in references [6,7]. The authors focused on comparing two assumptions of the probability distribution of the investment costs critical variable. The simulations were therefore performed in two variants, in the first variant the beta-PERT probability distribution was chosen for the investment costs, in the second variant a triangular asymmetric probability distribution was used. In order to be able to correctly compare the impact of the use of partial probability distributions of investment costs on the overall project results, an equally normal distribution was used for the second critical variable "time savings of infrastructure users" for both simulation variants.

The parameters of the probability distribution of investment costs in the case of the beta-PERT probability distribution assumption were therefore chosen as follows:

Minimum	project value reduced by 10%,
Most likely	project value,
Maximum	project value increased by 50%.

The parameters of the probability distribution of investment costs in the case of the asymmetric triangular probability distribution assumption were, in accordance with the recommendations arising from the background source [9], set with parameters comparable with the beta-PERT probability distribution, i.e., as follows:

Minimum	project value reduced by 10%,
Most likely	project value,
Maximum	project value increased by 50%.

Probability distribution for the time savings of infrastructure users was chosen as a normal probability distribution, where the mean value corresponded to the project value of time savings and standard deviation 10%.

3. Results

The performance of the quantitative analysis can be demonstrated on one of the projects of the tested set. The D10 Prague-Kosmonosy project, with a total investment cost of CZK 9,272,678,497 (€361,367,050), was used as an example. Simulation results when the beta-PERT probability distribution of total investment costs and the normal probability distribution for time savings of the infrastructure users were chosen, are shown in Table 8 and Figure 1. The simulated quantity dependent variable was cost-effectiveness (BCR).

Table 8. Results of the simulation of a random cost-effectiveness variable. Investment costs beta-PERT probability distribution.

Statistics	Forecast Values
Trials	10,000
Base Case	1.112
Mean	1.045
Median	1.047
Standard Deviation	0.047
Variance	0.002
Coeff. of Variation	0.0449
Minimum	0.876
Maximum	1.194
Range Width	0.318

The resulting probability distribution for the random BCR variable is shown in the following chart.

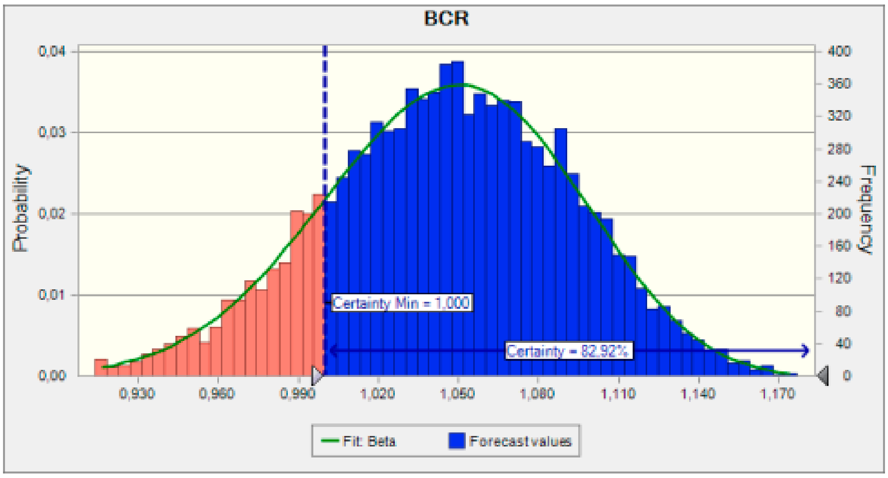

Figure 1. Probability distribution for a random cost benefit ratio (BCR) variable. Investment costs beta-PERT probability distribution.

Simulation results, when an asymmetric triangular probability distribution for total investment costs and a normal probability distribution for time savings of the infrastructure users were chosen, are shown in Table 9 and Figure 2. The simulated quantity dependent variable was cost-effectiveness (BCR).

Table 9. Results of the simulation of a random cost-effectiveness variable. Investment costs: asymmetric triangular probability distribution.

Statistics	Forecast Values
Trials	10,000
Base Case	1.112
Mean	0.978
Median	0.980
Standard Deviation	0.060
Variance	0.004
Coeff. of Variation	0.004
Minimum	0.747
Maximum	1.146
Range Width	0.400

The resulting probability distribution for the random BCR variable of the project D10 Prague-Kosmonosy is shown in the following chart.

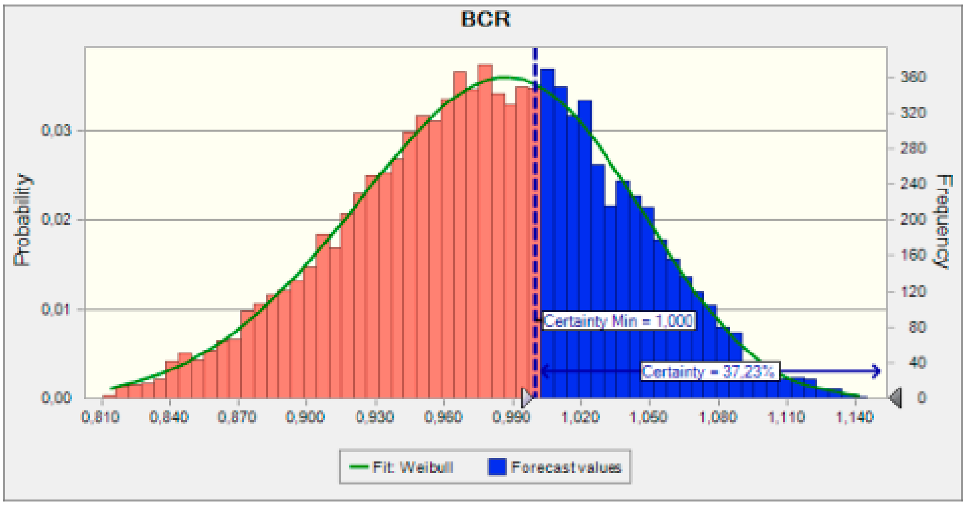

Figure 2. Probability distribution for a random BCR variable. Investment costs: asymmetric triangular probability distribution.

It is evident from the probability distribution shown in Figures 1 and 2 that with a certain probability the random BCR variable will take values below the critical value, and the project will therefore be economically inefficient.

Table 10 shows the outputs of the quantitative analysis of all the researched projects for both variants of the considered probability distribution of the investment costs critical variable. The table for each project presented the following statistical characteristics indicators: BCR: mean, median, standard deviation (σ), and certainty level (CL).

Table 10. Statistic characteristics of project BCR values.

No.	BCR	Variant 1				Variant 2			
		Mean	Median	σ	CL	Mean	Median	σ	CL
P1	2.90	2.73	2.73	0.15	100	2.57	2.57	0.17	100
P2	1.11	1.00	0.97	0.06	47	0.94	0.94	0.06	18
P3	1.83	1.50	4.51	0.07	100	1.43	1.44	0.10	100
P4	1.15	1.09	1.09	0.05	96	1.02	1.02	0.06	64
P5	1.43	1.35	1.35	0.06	100	1.28	1.28	0.06	100
P6	1.09	1.03	1.03	0.07	66	0.97	0.97	0.08	37
P7	8.28	8.19	8.19	0.13	100	8.12	8.12	0.14	100
P8	6.92	6.85	6.85	0.11	100	6.78	6.78	0.12	100
P9	3.81	3.74	3.74	0.07	100	3.68	3.68	0.08	100
P10	4.15	3.97	3.97	0.08	95	3.91	3.91	0.09	100
P11	2.96	2.05	2.05	0.08	100	1.98	1.99	0.10	100
P12	2.61	2.46	0.46	0.12	100	2.31	2.31	0.14	100
P13	1.44	1.22	1.23	0.06	100	1.15	1.16	0.08	97
P14	4.73	4.44	4.44	0.07	100	4.37	4.38	0.09	100
P15	1.09	1.02	1.02	0.06	65	0.96	0.96	0.07	31
P16	1.80	1.69	1.70	0.08	100	1.60	1.60	0.09	100
P17	1.11	1.05	1.05	0.05	83	0.98	0.98	0.06	37
P18	1.05	0.99	0.99	0.05	41	0.92	0.92	0.07	11
P19	1.80	1.69	1.70	0.08	100	1.59	1.59	0.09	100
P20	1.02	0.96	0.96	0.04	16	0.90	0.90	0.05	2

The outputs of all projects showed a normal distribution of the BCR indicator. The research in [11] came to the same results, where an experiment which was identified as a pseudo-random number sequence as normally distributed was carried out.

In the interpretation of results it is necessary to respect certain limits connected with the elaborated analysis. As mentioned above, in this paper is presented the case study elaborated using projects being prepared for realization in the Czech Republic. Even if the original methodical steps used in this paper are generally accepted and used, it is necessary to respect certain national specificities in the evaluation of public investment projects. The next limit, which it is necessary to consider, is the definition of probability distributions for the simulation. In the presented analysis it was for the random variable "investment costs", and the triangle and beta-PERT probability distributions were alternatively used, which is in harmony with the present state in the references, and opinions of other experts. However, it is not possible to exclude that the real probability distribution of investment costs of partial projects will be different. However, for the correct evaluation, and the identification of the influence of the selected probability distribution on the results of the evaluated projects it was necessary to uniformly use the chosen probability distributions. In a similar limitation, it is necessary to also note the probability distributions of the random variable "time savings of infrastructure users". In this case it was uniformly selected for both variants of the simulation normal probability distribution, even if the real probability distribution of this variable can be, for partial projects, slightly different.

4. Discussion

It can be concluded from the above-stated calculations that one of the important settings of the input variables is their assumed probability distribution. From the available literature research and the authors' own expert opinion, it can be assumed that the investment costs variable tends to have a rather asymmetric probability distribution. This was also confirmed by the CBA guide [6], which considers an asymmetric triangular probability distribution in the range −5% to 20%. Makovšek [16], who dealt with a long-term analysis of cost over-runs of road constructions in Slovenia, addressed this issue in detail. Two fundamental conclusions emerged from his analysis: the fact that cost over-runs are systematic (not randomly distributed around zero) and that cost over-runs appear constantly over a time period of several decades and do not decrease (and thus do not show signs of improved forecasting tools and methods). A conclusion can also be drawn from these deductions, that the probability distribution of investment costs tends to be rather asymmetric.

An interesting comparison was published by Emhjellen [17], who dealt with the difference of values when setting different limits of normal distribution and their effect on the resulting values. Kumar [18] noted that the concessionaire aims to bear minimal cost, so maximum probability occurs at lower cost values, and hence it followed a lognormal probability distribution. Jakiukevicius [19,20] worked with normal and triangular distributions, for which he set theoretical parameters which he, based on simulations, converted to log logistics parameters. Kumar [18] adhered to a lognormal distribution of project costs. Gorecki [21] used a triangular distribution. The Czech author Hnilica [22] worked with the beta-PERT distribution, which he considered to be smoother, with possible values more concentrated around the most probable value, and the probability decreases towards the limit values faster than linearly. The authors of this article believe that the beta-PERT distribution best fits an expert estimate of the investment costs behaviour in comparing their values in the ex-ante and ex-post phases. The authors of this article carried out project simulations as mentioned above, assuming both a probability distribution of beta-PERT, and an asymmetric triangular one, and state that the results of the outputs in the expected value of "BCR-mean" ranged up to 7% for all of the projects. The outputs of all projects in both variants of solutions proved the normal distribution of the BCR indicator. The authors of the background research [4] reached the same results, where they stated that an experiment which identifies a pseudo-random number sequence as normally distributed was carried out. The reading of the frequency distribution of the evaluation indicator provides information of extreme importance, as regards the riskiness of the investment project [23].

5. Conclusions

It is clear from the above-stated findings that attention must be paid to the setting of statistical characteristics of variables which enter into the calculations of economic efficiency indicators, and on the basis of which it is decided whether or not to accept projects for financing. At present, data on post-audits of major transport infrastructure projects are beginning to be collected and analysed in the Czech Republic, and it is expected that the analyses will make possible, among other things, reaching more precise assumptions.

Although the projects proved efficient, a combination of negative changes to both variables can already bring projects with a certain value of probability into negative results. Based on the analysis of the research sample, it is clear that it cannot be clearly established for projects that a certain value of the BCR ratio predicts 100% stability of the project under the action of several critical variables. It is obvious from the mean value simulations determining the expected BCR value that projects with BCR < 1.1 show, at a certain percentage of probability, and at the critical variable limits specified above, that they shall not be 100% effective. However, the variance of the results obtained was large. Project P10 also showed an interesting result; a relatively high mean BCR ratio showed with a 5% probability that it will not be effective.

The results of the research point to the fact that it is always necessary to perform a quantitative analysis, since the results of the combination of the interaction of critical variables cannot be derived from the partial results of the sensitivity and qualitative analyses. The result will always depend on the absolute values of the critical variables of each unique project.

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