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Možnosti a meze kvantifikace rizikové expozice dopravních projektů

Possibilities and Limitations of Quantifying the Risk Exposure of Transportation Projects

Summary

In his working experience in research and at the Czech Technical University, the author worked mainly on the elaboration and application of the methods of comparing costs and benefits and the methods of multicriterial analysis in assessment of infrastructure constructions.
The author was aware of the fact that when the values of certain indicators are to be calculated, it is often necessary to use assumptions or estimates, which can influence the resulting assessment, or the result can be burdened with certain uncertainty. This was why he welcomed the opportunity to study this field after he started working at the Faculty of Transportation Sciences of the Czech Technical University (CTU). He is grateful to the implementers of the task "Alternative Options of Financing Railway Corridors" (Faculty of Transportation Sciences of CTU, December 1999) for their having invited him to participate in this pioneering work, leading to creation of a proposal for a model of financing infrastructure projects with the involvement of private capital, and for their having made it possible for him to prepare some of the solutions in this field and similar fields at an application level.
The lecture has a focus on three partial fields of project risk modelling. The first one is the methodology of direct quantification of transportation project economic risk [1] with the existence of a criterial function of the project. In accordance with this methodology, a computer software was created to quantify the economic risk of transportation projects, which was used, for example, in assessment of the risk associated with the project of the Ae 270 Ibis aircraft at Aero Vodochody, a.s.
The second part of the lecture deals with the quantification of project risk exposure with quantitative assessment of the risk factors, that is, when the criterial functions of the project are unknown. The software solution has been successfully used, for example, in the assessment of the risk degrees of the variants of railway link between Prague and Prague Ruzyně Airport and the town of Kladno [23].
The third part of the lecture is a contribution to indirect identification of a project risk. It deals with possible graphic representation of the project quality, respecting the multicriterial nature of project assessment. If a project is overvalued for any reasons, such a project becomes a risky project. A new analytical approach was derived and a computer model was created to include the time factor in the multicriterial assessment of project quality [21], [28], which was used, for example, in the cooperation between the author and SEVEn as a supplementary tool for land-use studies.

Souhrn

Ve své praxi ve výzkumu i při působení na ČVUT se autor zabýval také na jedné straně rozpracováváním a aplikací metod srovnávání nákladů a užitků a metod vícekriteriální analýzy na straně druhé při hodnocení infrastrukturních staveb.
Byl si přitom vědom toho, že při výpočtu hodnot určitých ukazatelů je třeba často vycházet z předpokladů nebo odhadů, které mohou ovlivnit výsledné hodnocení nebo může být výsledek zatížen určitými nejistotami. Proto po svém nástupu na dopravní fakultu ČVUT přivítal možnost zabývat se i touto problematikou. Je zavázán řešitelům úkolu „Alternativní možnosti financování železničních koridorů“ , (FD ČVUT, prosinec 1999), že ho přizvali ke spolupráci na této průkopnické práci vedoucí i k návrhu modelu financování infrastrukturních projektů se zapojením soukromého kapitálu a umožnili mu některá řešení této a další souřadné problematiky připravit do aplikační úrovně.
Přednáška se zaměřuje na tři dílčí problematiky modelování rizika projektů. První z nich je metodika přímé kvantifikace ekonomického rizika dopravních projektů [1] při existenci kriteriální funkce projektu. V souladu s ní byl vytvořen počítačový program pro kvantifikaci ekonomického rizika dopravních projektů, který byl např. aplikován při posuzování rizika projektu letounu Ae 270 Ibis v Aeru Vodochody, a.s.
Druhá část přednášky je věnována kvantifikaci rizikové expozice projektu při kvantitativním ohodnocení faktorů rizika, tedy při neznalosti kriteriální funkce projektu. Programové řešení bylo úspěšně aplikováno např. při posuzování rizikovosti variant železničního spojení Praha – Letiště Praha Ruzyně – Kladno [23].
Třetí část přednášky je příspěvkem k nepřímému stanovení rizika projektu. Je věnována možnému grafickému vyjádření kvality projektů při respektování vícekriteriálního charakteru hodnocení projektu. Pokud dojde z jakýchkoliv důvodů k přecenění projektu, stává se takový projekt rizikovým. Byl souřadně odvozen nový analytický přístup a vytvořen počítačový model pro zahrnutí faktoru času do vícekriteriálního hodnocení kvality projektu [21], [28], který byl aplikován např. v rámci spolupráce autora se SEVEn jako doplňující přístup u územních studií.

Klíčová slova: kvantifikace rizikové expozice projektu při existenci kriteriální funkce projektu, kvantifikace rizikové expozice projektu při kvantitativním ohodnocení významnosti faktorů rizika, konstrukce globálního vyjádření rozvoje lokality jako charakteristiky pro nepřímé stanovení rizika projektu

Keywords: project risk exposure quantification with the existence of a criterial function of the project, project risk exposure quantification with the quantitative assessment of the significance of risk factors, construction of a global formulation of a development of a locality as a characteristic for indirect identification of a project risk

CONTENT

1. Introduction

Transportation is described as an activity associated with purposeful relocation of persons and tangible items in various volume, time and spatial contexts by use of various means of transport and transport technologies. Like every purposeful activity associated with the consumption of limited resource, transportation, too, has its economic dimension, which can be described as a set of factors, which lead to a certain arrangement of the individual elements of transportation, within which the transportation needs are satisfied.

In their essence, transportation projects are visions of the future needs for transport development, particularly with respect to the needs of transport users. The approach to the creation and assessment of these visions is guided by the wish to harmonise the technical and technological aspects with the economic possibilities (mostly limited by limited resources) as well as with the future needs in order to ensure regulation and to contribute to a more balanced development of the transport sector, based on current knowledge. Due to the effects of the factors and influences impacting the efficiency and social benefits of the development of transport on one hand and the still limited knowledge of its consequences on the other hand, there is a need to extend the factual and methodological knowledge in this field.

If we set aside the transport-engineering, construction-technical and legislative aspects, then from the economic point of view, the key problem is to assess the resources invested under individual projects into the development of transportation infrastructure in accordance with the goals of transport policy and the criteria of performance, efficiency and social benefits.

In a number of cases, the implementation of transport projects requires sufficient capital, including loan assistance from banks. The above-mentioned development of the techniques of assessing the quality of transportation projects corresponds to this. The methodologies for assessing project quality are created in order to prove both financial and economic efficiency. If, for any reasons, a project is overvalued, such a project becomes a risk even in connection with the participation of the banking sector in its implementation.

The starting point for assessment can be the principle of comparing costs and effects. This principle can be applied through various methods and indicators, often in special modifications and versions. This is determined by the following:

(a) the purpose of the assessment: the assessment methods, especially the cost-income method, are used for various purposes, such as to compare similar variants, to determine the urgency order or to choose the optimum period of construction.

(b) the stage of assessment: there are differences in the requirements for data between the preliminary and detailed assessments;

(c) other factors connected, for example, with the availability of data and uncertainty in the estimates of the future development.

For example, the calculation of indicators often needs to be based on assumptions or estimates, which can influence the resulting assessment, or the result can be burdened with uncertainty. The starting point of an analysis is then to determine the indicators, which particularly influence the result of the assessment. A sensitivity analysis provides the first idea about the possible project risks and it is a basis for the subsequent risk analysis, which includes uncertainties of all significant variables. The result then consists of quantifiable risks associated with choosing the assessed variant or with the implementation of the chosen project.

In [1], some models for a financing analysis were designed and tried. The methodology is created in such a way so as to be in accordance with the methodology recommended by the World Bank. The methodology forms a self-contained whole defined on a modular basis. The result of such a financial analysis is the financial study of feasibility. analytical tables were designed to identify sales and incomes, costs of materials, soil and land, staff and wages and salaries, capital expenditures structured by types and sources of financing and by the years of construction. The tables are a source material for a CASH FLOW analysis carried out by means of a similar model, which is also designed and documented in the quoted paper. The logical next step was to interconnect the financial analysis and the risk analysis.

2. The objectives of modelling the economic risk of a project; the options of identifying project risk exposure

The basic objective of risk modelling is to contribute to increasing the probability of success or to minimise the risk of failure of the assessed projects. Identifying the project risk exposure is an important part of its risk analysis. There are two ways of identifying project risk exposure:

- derivative (indirect, using certain characteristics of the project, which, in their aggregate, provide the information on higher or lower project risk exposure);

- quantitative (cardinally, numerically, directly)

The fundamental principle of the approaches to quantification is to find out what variables, events (risk factors, generally speaking) are significant and have the highest influence on the risk of the project concerned and how high that risk is (the actual project risk exposure quantification). It has become apparent that an appropriately constructed quantitative assessment of the significance of risk factors can be used to derive the quantified project risk exposure.

Therefore, the author distinguishes between two groups of projects as regard the project risk exposure quantification:
- in the first group, the criterial function of the project is known, and in that case, it is possible to answer questions such as what the probability is that the project will not be loss-making or questions such as what the probability is that a certain value of a criterial function of the project will or will not be reached. Or if the criterial function of the project is known for answering these and other questions, the work deals with the probability field of the project;
- in the second group, the objective of project risk analysis (or the analysis of the risks associated with several variants of a single project) is to minimise the risk of failure of the project – that is, to identify the lowest-risk variant of the project. Only the contingencies, which have an unfavourable impact on the project's goals, are known. It has become apparent that even in this case, it is possible to quantify project risk exposure, if the assessor succeeds in quantitatively assessing risk factors in a certain way and if he or she then works with the Cartesian product of the obtained assessment and the created indifference map of the project.

3. Approach to project risk exposure quantification with the knowledge of the criterial function of the project

Investment decision-making in the environment of a market economy is associated with uncertainty, which results from fast and variable development of many factors, some of which were mentioned in the previous chapter. This uncertainty can influence the achieved economic results of investment projects in such a way that they are often different from the expected or desired results. Therefore, a risk analysis must be an integral part of economic assessment of transport projects and it is a tool, which examines whether the data, on which the assessment of the investment project and, consequently the decision on its implementation are based, are realistic or not.

In professional literature, the definition of the concept of risk varies according to the field, in which this concept is used (insurance risks, financial risks, business risks, etc.). For the purpose of this paper, the concept of what is referred to as the "economic project risk" is the most suitable one.

> *An economic risk can be generally understood as a degree of risk that the achieved economic results of the project will deviate from the expected results* [2].

The cause of the risk are the possible future changes in what is known as "*risk factors*" or, in other words, variables, which influence the criteria of the project's efficiency. From the point of view of the theory of decision-making, it is often distinguished between situations, in which the risk factor probability distribution is known, and situations, in which the probability distribution is unknown. According to this, it is distinguished whether it is *decision-making based on risk* or *decision-making based on indeterminateness (uncertainty).*

The purpose of a project risk modelling process is to identify (quantify) the risks of the project or possibly its variants, with subsequent preparation of correction measures, leading to increase of the probability of achieving success with the project.

Risk modelling can be divided into the following stages [1], [2].:

- Identifying the functional dependence of the decision-making criterion on the influencing variables
- Identifying the risk factors and their significance

- Construction of the probability distribution of the decision-making criterion under consideration
- Quantification of the project risk exposure

Carrying out a risk analysis requires the knowledge of what is known as the “decision-making criteria” (the criterial functions of the project). If there is a higher number of decision-making criteria, then a considerable complicated problem of how to express the aggregate risk with regard to all the assessment criteria arises in the risk modelling process.

In the field of investment decision-making, it is most often a case of risk modelling with regard to a single decision-making criterion, which is the criterion of the economic assessment of the efficiency of the investment. Therefore the following text will concentrate mainly on a risk analysis involving a single decision-making criterion, specifically the criterion of economic efficiency.

Therefore, at the first stage of risk modelling, it is necessary to determine the functional dependence of the assessment criterion on the influencing variables as follows

$$K = f(x_1, x_2, ..., x_n; y_1, y_2, ..., y_m)$$

K is the value of the decision-making criterion (the criterial function)

x_i is the i-th value of a random variable, $i = 1, 2, \ldots, n$

y_j is the j-th value of a non-random variable, $j = 1, 2, \ldots, m$

The functional dependence of the assessment criterion makes it possible to construct the assessment criterion probability distribution according to the knowledge of the distribution of the probabilities of the individual random variables or it may make it possible to identify the basic numerical characteristics of such a distribution (the mean value, variance).

The criteria of assessing economic efficiency of investments are used to compare the economic results of the projects with a comparable risk. In the risk modelling process, these criteria are used to test the stability of the economic results of a single project in connection with the changes of input variables. Regardless of whether the efficiency of the investment is assessed in an economic analysis (from the project’s point of view) or in a financial analysis (from the investor’s point of view), it is desirable to include the time factor in the assessment criterion. From this point of view, criteria can be divided into discount criteria and the other criteria. Discount criteria can include modifications such as the net present value (NPV) criterion or the internal rate of return (IRR).

Net present value (NPV):

$$NPV\ CF = \sum_{t=0}^{T_p} \frac{CF_t}{(1+d)^{-t}}$$

NPV	net present value
T_p	time of comparison
t	year of comparison
CF_t	cash flow in the t year of comparison where CF_0 means the investment in the zero year of commencement of the project
d	discount rate

3. 1 Identifying the risk factors and their significance

Risk factors – referred to as FR_i – are variables of a random nature, which influence the variability of the assessment criterion. Specifically, when NPV is used, these risk factors can be all the income or expense items, which cannot be estimated with sufficient accuracy and which are transferred to the criterion through the cash flow.

It can be assumed that most variables in the criterial function can be of a random nature, and therefore with their probability distribution, they can influence the resultant criterion probability distribution. This assumption considerably influences the complexity of the resultant criterion probability distribution. This is why the number of factors is artificially reduced and some factors are considered to be determined in the following steps and therefore they are considered to be non-random and consequently they are excluded from the group of risk factors.

In the real-life environment, some risk factors can be interdependent. This interdependence needs to be respected especially in the process of composing the resultant probability distribution of the optimisation criterion (for example, when simulation methods or scenario calculations are used), or possibly in the process of identifying the significance of risk factors (for example, when multi-parameter sensitivity analyses are used).

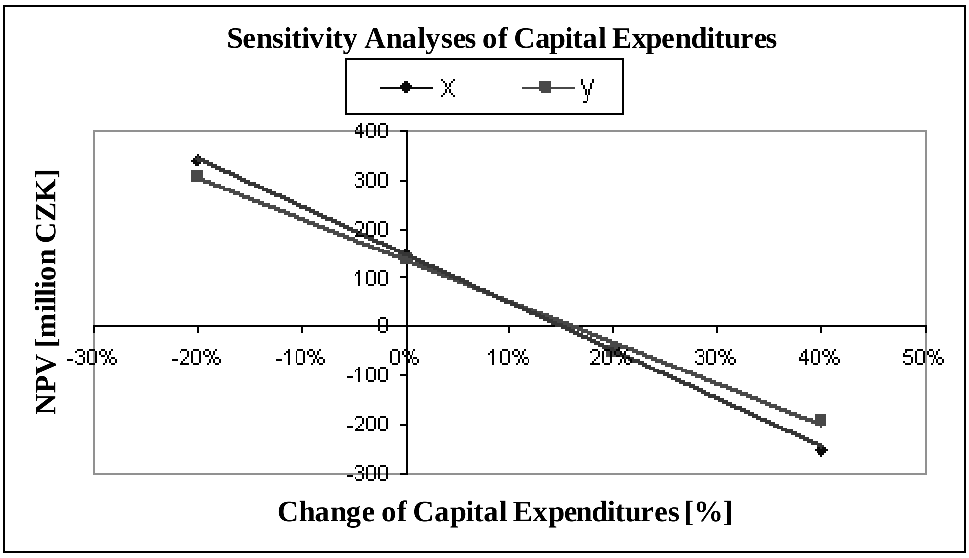
Constructing conditional probability distribution is an exact, albeit considerably laborious way of respecting the interdependence of certain risk factors. In practice, considerable laboriousness and sometimes even impossibility of the numerical identification of the conditional probability distribution of the risk factors leads to the use of simpler ways of respecting interdependence of risk factors. One of them is to identify and use a single aggregate variable instead of considering the interdependent risk factors on an individual basis.

Another way of respecting the interdependence of risk factors is to limit the types of the considered statistical dependencies. In this method, two types of risk factor dependence are distinguished – direct dependence and indirect dependence. With direct interdependence, risk factors more often reach higher or lower levels simultaneously. With indirect interdependence, risk factors more often combine higher levels of a single risk factor with the lower levels of another risk factor. In addition to the type of statistical dependence, the degree of intensity of this dependence is also distinguished into, for example, weak, medium and strong dependence. The nature and degree of interdependence intensity are identified by means of expertise.

For assessment of the intensity of a negative influence of a risk factor on the project's results, it is beneficial to use the instruments of a sensitivity analysis for the sake of objectivity of the results. The purpose of a sensitivity analysis is to provide information on the stability of the chosen criterion of efficiency and on the stability and the order of variants with regard to the individual risk factors. Based on this information, it is possible to choose risk factors, which most influence the resultant optimisation criterion and the random nature of which cannot be neglected. The other influencing factors are then regarded as deterministic factors.

In a single-parameter sensitivity analysis, the correlation of the value of the criterial function to the changes of the individual risk factors is identified on a step-by-step basis. Values of the analysed risk factors are changed within a certain range of possible values and the values of other influencing factors are considered to be constants.

A frequent method of presenting sensitivity analyses is the presentation in the form of a chart due to its illustrative nature. One of the frequent methods used for graphic presentation is to compare the correlation between the criterial value and the individual risk factors; another frequent method used for graphic presentation of the results of a single-parameter sensitivity analysis is the summarised visualisation of the criterial values for all the assessed projects (or variants of one project), depending on the change of one risk factor; this is the case shown as an example on the illustrative figure [13].



The sensitivity analyses do not give any answer to the question regarding the identification of the probability of the changes in the individual risk factors and do not capture the changes in the risk factor during the period of comparison. They do capture the influence of possible changes in the analysed risk factor as compared to the expected values but they assume that the changes of the risk factor are constant throughout the comparison period.

Single-parameter sensitivity analyses do not respect the possible statistic correlations of the risk factors and consequently considerably simplify the assumptions about the real environment. This shortcoming can be partly removed by the use of multi-parameter sensitivity analyses. As opposed to single-parameter analyses, the multi-parameter sensitivity analyses examine the impact of the current effects of multiple risk factors on the results of the optimisation criterion. In the real environment, it is not possible to expect that only a single risk factor will change, while the other risk factors will remain constant.

A big problem with multi-parameter sensitivity analyses is their presentation. In practice, only two-parameter sensitivity analyses are used, which can still be visualised in the form of a 3D chart or possibly in the still “acceptable” tabular manner. Sensitivity analyses dealing with more than two parameters can only be visualised in the form of tables, which are very difficult to read and lose their informational value due to the large quantity of data. Just as single-parameter sensitivity analyses, the multi-parameter analyses also do not tell anything about the risk factor probability distribution and do not capture the possibility of change of risk factor values over time.

Risk factor probability distribution is most often constructed according to an expert estimate. With discrete risk factors, an expert can either estimate directly the probabilities of individual values or can estimate the parameters of some of the theoretical discrete probability distributions. However, the risk factors with discrete probability distribution occur fairly rarely; the risk factors with continuous probability distribution are far more frequent. With continuous risk factors, the probability distribution is mostly approximated by means of one of the theoretical distributions and the parameters of this distribution are estimated.

Practical experience confirms that most risk factors in a financial and economic analysis can be fairly well described by a triangle distribution. This distribution makes it possible to represent the pointedness and obliquity of the real distribution and it is easier for an expert to estimate its parameters (the minimum value, the most probable value and the maximum value).

3.2 Construction of the risk factor probability distribution and the criterial function of a project

Identifying the probability distribution of the assessment criterion and its numerical characteristics is the final stage of the risk modelling process. The exact construction of the probability distribution of the assessment criterion carried out by calculation based on the knowledge of the probability distributions of the individual risk factors is considerably difficult (especially if there is a higher number of continuous risk factors).

If the number of risk factors is limited to an “acceptable” quantity and if the risk factors acquire only a finite “reasonable” number of values with estimated probabilities, it is possible to determine the resultant probability distribution of the assessment criterion by calculation or by a probability tree.

If there is a higher number of continuous risk factors, it is appropriate to use simulation methods. The term simulation model designates an abstract model describing the behaviour of a real system, on which the behaviour of the system is analysed through simulation by examining the dependence on the changes of the input variables and parameters of the system. The meaning of this definition also includes the above-mentioned sensitivity analyses carried out by means of a simple simulation model.

Most economic applications fall into the category of what is referred to as "discrete systems". This means that all the parameters or input variables in such a system only change at a finite number of moments and the existence of the system is limited in time. The models of risks associated with economic projects fully comply with this assumption. With the models of investment projects, the limitation of the existence of the system is given by the chosen period of comparison; the discreteness of the system is guaranteed by the choice of interval-based monitoring of economic values (usually with the interval being one year) so it only makes sense not to monitor even the changes, such as risk factors, otherwise than discretely.

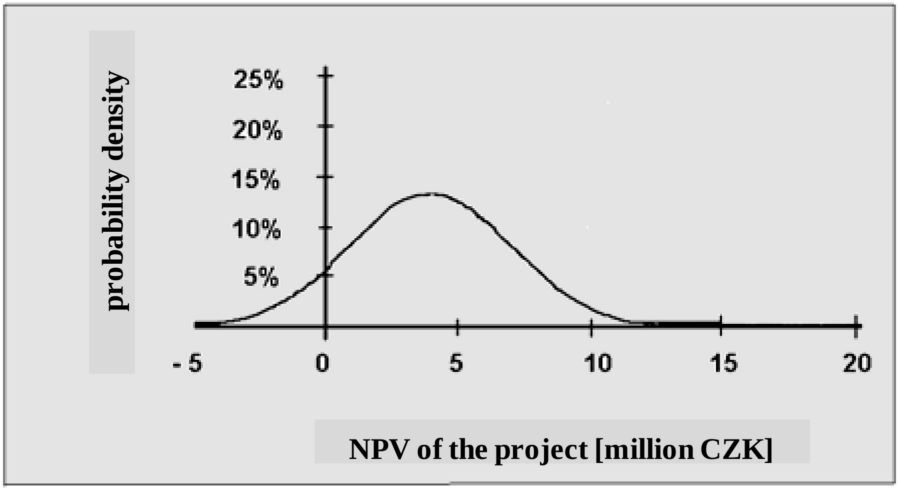
The Monte Carlo method has been used in [1] for modelling discrete systems. This method belongs among stochastic methods; the inputs are generated randomly according to the defined probability distribution by means of the inversion transformation method.

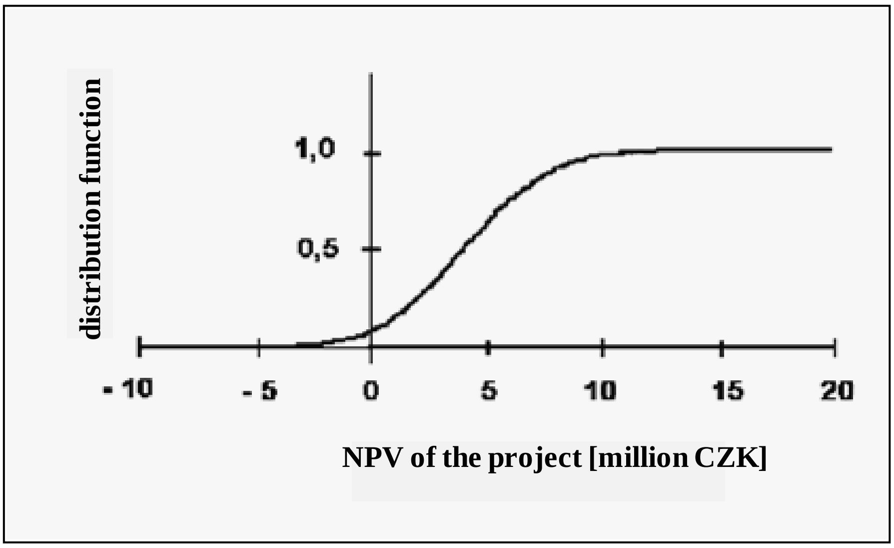
In [1], this method is used in the following steps:

1. Defining the functional correlation between the assessment criterion and the input variables.
2. Choosing the risk factors, which substantially influence the value of the assessment criterion. This is based on the results of single-parameter sensitivity analyses.
3. Determining the distribution of probability of occurrence of possible values for the individual risk factors.
4. Generating sets of random values of factors according to the probability distributions, while respecting the mutual statistical correlations between the individual risk factors.
5. Putting the generated data into the functional correlation and calculating the criterial value.

6. Repeating the iteration procedure from item 4 until the sufficient number of iterations is reached. The fact that a sufficient number of iterations has been reached can be checked, for example, by calculating the confidence intervals for the characteristic values (such as the mean value) of the identified probability distributions of criterial values.
7. Constructing the resultant probability distribution of the assessment criterion values and possibly finding the characteristic values (mean value, variance) of this distribution.

The results of the Monte Carlo method used in this way consist of statistical characteristics of an investment project or possibly its variants or possibly the statistical characteristics of more projects at the same time. It is the probability density and the distribution function of the criterial values. These are called the project risk curves [1], [2]:





The basis for assessing the acceptability or unacceptability of the project risk consists of the results of sensitivity analyses and the assessment criterion probability distribution.

Regrettably, there is no simple and generally acceptable manual on how to assess the acceptability or unacceptability of an investment project risk. The conclusion on the acceptability of the risk is the subjective decision of the decision-maker; it depends on his/her personal attitudes to the risk and on many other factors (such as the capital standing of the company; the possibilities of obtaining a financial support; information on the implementation of similar projects by competitors).

Rules based on logical considerations have been designed as a support for a decision-maker for the assessment of the risk degree of projects, if there is a single decision-making criterion. If we do not know the probability distribution, the rule referred to as the "rule for decision-making in uncertainty" can be used.

In the cases, in which the probability distribution of the assessment criterion is known, the rule of mean value and variance, the rule of stochastic dominance and other rules can be used to identify the order of the risk variants.

A decision-maker usually arrives at the decision on the acceptability of a variant, regarding the risk, according to the visual assessment of the shape of the assessment criterion probability distribution and its numerical characteristics (most often its mean value and variance), or possibly according to other factors, which characterise the risk (the probability of not reaching the chosen level of assessment criterion; the probability of undesired deviations of the values of the criterion from the planned values, etc.). The acceptable risk is associated with that variant, which gives considerable hope that results satisfactory for the decision-maker will be achieved.

3.3 Comparing the risk variants of a project

The following rules can be used to compare the risk variants:

The rule of the expected (mean) value and the variance

This rule is based on the assumption that the decision-maker prefers variants

- with a higher expected (mean) value of a criterion of an income type to a variant with a lower expected value
- with a lower risk, expressed by the variance, to a variant with a higher variance

The rule does not make it possible to sort the risk variants completely; it only makes it possible to identify the set of dominated (ineffective) variants.

Variant X is preferred to variant Y, if

$$E(X) \geq E(Y) \text{ and } D(X)<D(Y) \text{ or}$$
$$D(X) \leq D(Y) \text{ and } E(X)>E(Y), \text{ where}$$

E(X), E(Y) are the mean (expected) values of variants X, Y
D(X), D(Y) are the variances of the variants X, Y

In the cases where neither of the conditions is met, the rule on the preference of variants is unable to decide.

The rule of the expected value presupposes aversion of the decision-maker to risk and it can only be used if the probability distributions of the variants are approximately symmetrical.

Rules of Stochastic Dominance

There are more rules based on stochastic dominance; I will only mention here two of them, the ones that are used most often, i.e. stochastic dominance of the first and second degree. Just as the rule of the mean value and the variance, the rules of stochastic dominance make it possible to exclude the dominated and therefore ineffective variants.

The advantage of the rules of stochastic dominance rules is that they are not limited only to the cases of symmetrical probability distributions but that they can be used for any shape of the distribution function of the assessment criterion.

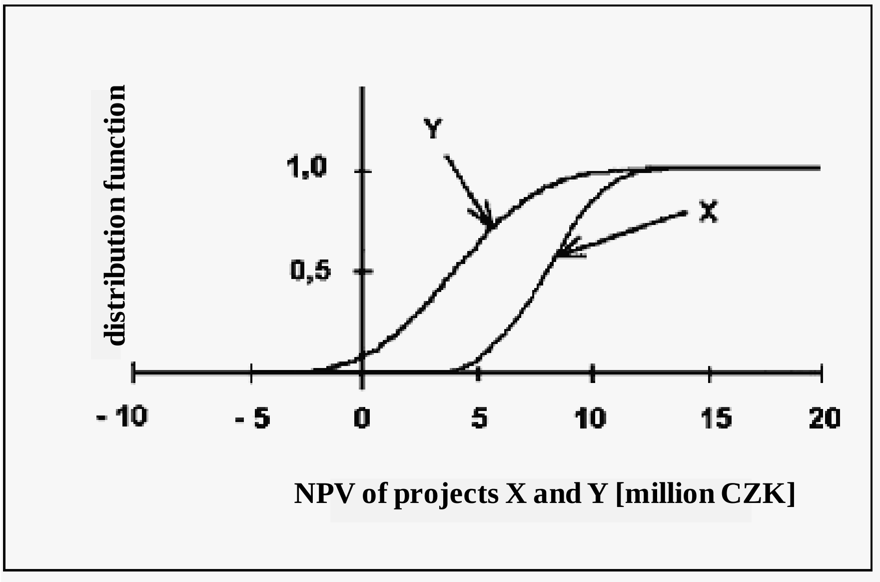
The Rule of Stochastic Dominance of the First Degree

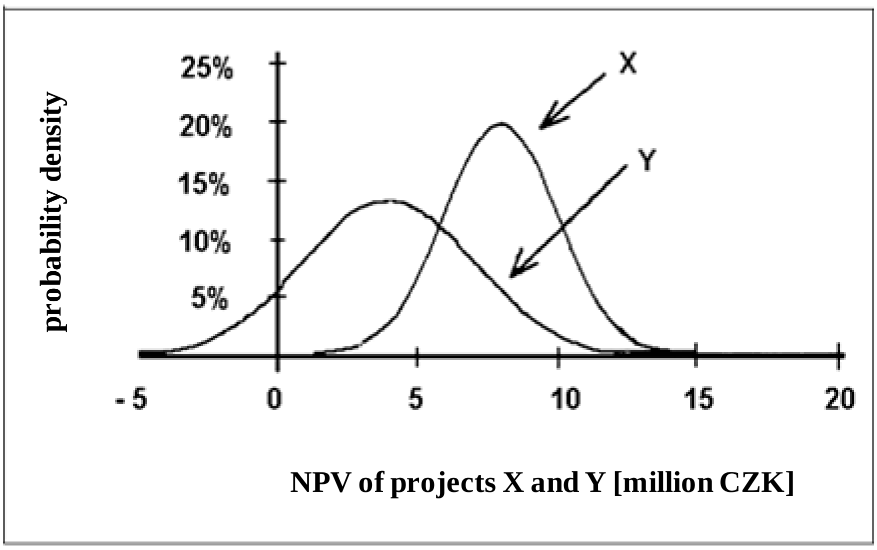
Variant X is preferred to variant Y, if the probability of achieving any value of the criterial function is higher with variant X or is equal to the probability of achieving the same value in variant Y. This is written in the form of distribution functions as follows:

$$F_X(K) \le F_Y(K), \textit{ where}$$

K	is any value of the assessment criterion
$F_X(K), F_Y(K)$	are the values of the distribution functions of variants X, Y

The rule of stochastic dominance of the first degree is not only limited to decision-makers with aversion to risk but it applies to all entities that prefer higher values of the assessment criterion:

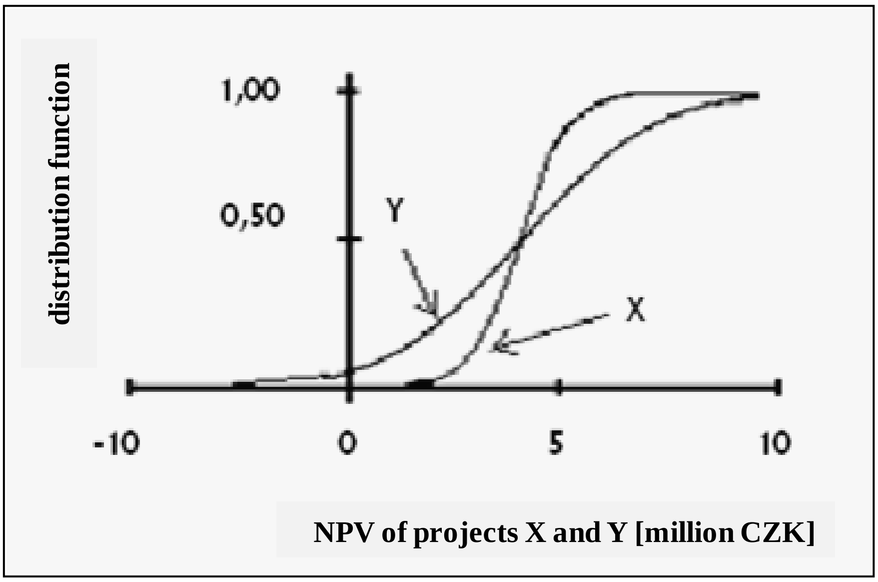


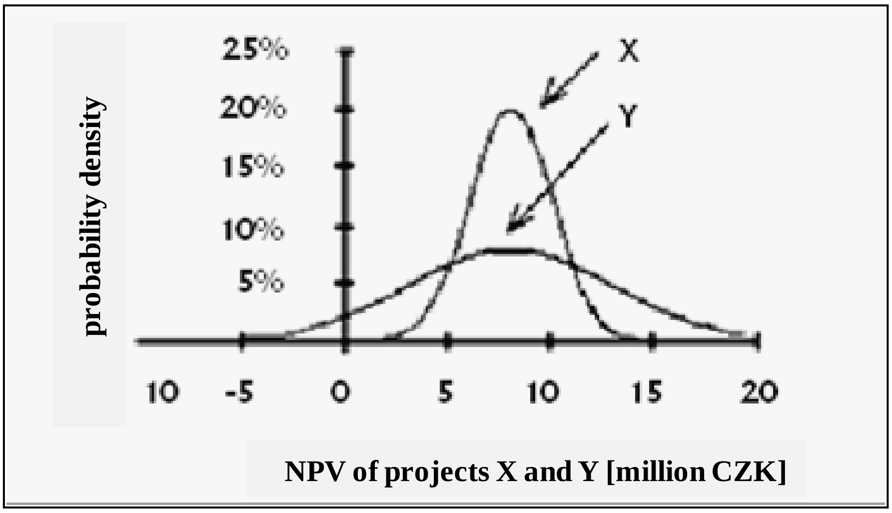


The Rule of Stochastic Dominance of the Second Degree

This rule assumes aversion of the decision-maker to risk. Variant X dominates variant Y if the following applies to all the values of the criterion K of the income type:

$$\int_{-\infty}^{K} [F_Y(K) - F_X(K)]dz \geq 0$$

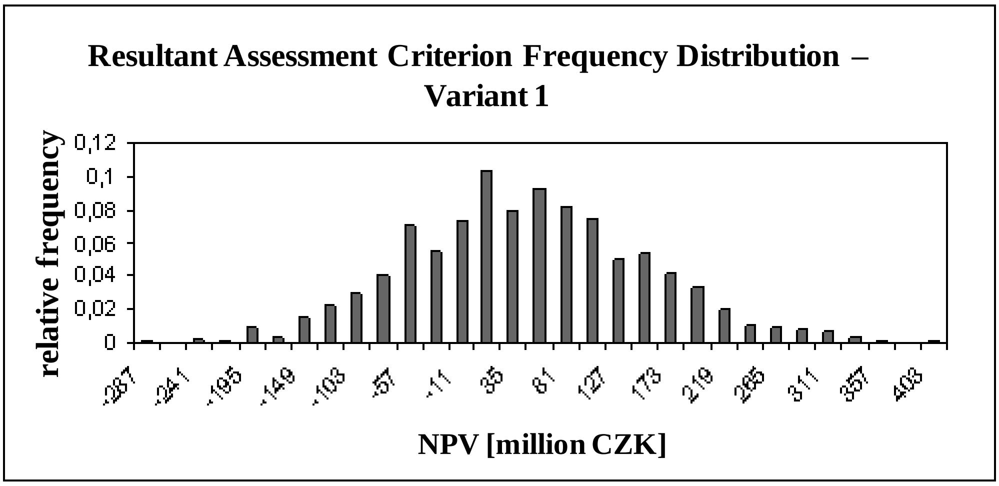




The integral in the equation will be higher than zero if the area demarcated by the distribution functions $F_Y(K)$ and $F_X(K)$ to the left of their intersection point is larger than the area demarcated by the distribution functions to the right of their intersection point. In the case of symmetrical distribution functions, the two areas are identical but the order of the variants cannot be changed because otherwise the condition would not apply to all the values of the income criterion K. As it is apparent from the figure, this condition is met for distribution with the same mean value, if the variance of variant X is lower than the variance of variant Y.

It is possible to apply the rules of stochastic dominance in practice, for example, when comparing the probability distributions described by the frequency distributions. With frequency distribution, it is possible, assuming the categories of the compared frequency distributions are the same, to replace integration with summation in the equation, with certain inaccuracy. The rules of stochastic dominance then make it possible to compare the non-symmetrical probability distributions even without the knowledge of their exact mathematic expressions. The inaccuracy of such a method is given by the sizes of the categories of the compared frequency distributions [20]:

Results of a simulation calculation for variant 1		
number of iterations	1,000	
minimum value	-310.26	million CZK
maximum value	425.65	million CZK
number of frequency intervals	31	
Step	23	million CZK
mean value	55.45	million CZK
standard deviation	102.86	million CZK



4. Approach to project risk exposure quantification based on the quantitative assessment of risk factors

The basic step to quantify the project risk exposure is to identify, which events are significant and influence the project risk the most. If the criterial function of the project is unknown, it is possible with some projects to use a suitably constructed quantitative assessment of the significance of risk factors to deduce the quantified risk exposure of such projects. The methodological basis of this approach consists in construction of an indifference map of the project – the isolines of the same project risks.

The actual quantification of project risk exposure is preceded by the following: expert identification of n risk factors (FR_i , i = 1, …, n) or, in other words, events the occurrence of which might negatively influence the success of the examined variants, and the expert identification of the significance of these risk factors.
The essence of the expert identification of the significance of a risk factor consists in examining this significance from two points of view – according to the probability of occurrence of the risk factor (p_i) and the intensity of the negative impact of the factor, if it occurs, (D_i) on the project results. The expert examination is carried out within the previously defined scales of occurrence probability and intensity of the negative impact.
A risk factor is the more significant the more probable its occurrence is and the higher is the intensity of the negative impact of this factor on the project results.
If certain numerical ratings are assigned to the individual degrees of occurrence probability of the factors as well as to the degrees of the negative impact, we can arrive at a numerical (quantitative) assessment of the significance of risk factors, referred to as score S_i:

$$\forall\, FR_i \;\rightarrow\; (\,p_i\,, D_i\,) \;\rightarrow\; S_i$$

$$S_i = p_i \;.\; D_i$$

p_i - occurrence probability FR_i
D_i - intensity of the negative impact FR_i

The quantitative assessment of the significance of risk factors can now be used, for example, to construct the isolines of the project risk. Most often, the differentiation into an acceptable risk, conditionally acceptable risk and unacceptable risk is used in order to identify the priorities with respect to further project risk management (see the Fig. titled Isolines of the Same Project Risks). Then, the following is possible:

- to arrange the risk factors in order from the most significant factors to the least significant ones
- to divide the risk factors into groups with different significance; for example, with PRAK, three groups of factors were created and then analysed: the risk is acceptable (factors with a score within the interval of 1-8); the risk is conditionally acceptable (factors with a score within the interval of 10-24); the risk is unacceptable (factors with a score within the interval of 32-80). The chosen groups (actually intervals) were also differentiated by colours (the isolines of the same risks were colour-coded). The scope of the intervals is given by the scales used for quantitative assessment of the significance of risk factors [23];
- to identify the overall risk of the project (the project variants)

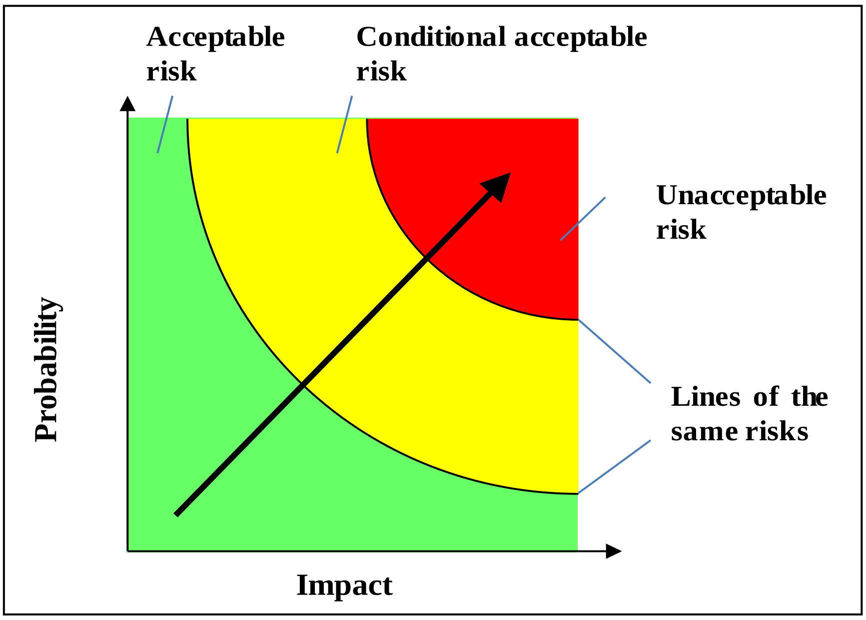


Fig.: Isolines of the same project risks

The score results (the map of the isolines of the project risks) are then graphically represented in the form of a bar chart where the individual risk factors are sorted by their scores for the project variant concerned. Then, it is possible to effectively create the derived aggregate results of the risk analysis from various points of view as the bases for decision-making [23].

Although the above-mentioned method of identifying (quantifying) the significance of risk factors is useful, it is necessary to point out that the numerical assessment of significance is always subjective to a certain extent because it depends on the choice of the scales for assessment of the probability of occurrence and intensity of the impacts and this choice can be better or worse but it is always the expression of the assessor's subjective opinion.

5. Contribution to indirect identification of project risk

The third part of the lecture is a contribution to indirect identification of a project risk, in which, unlike the direct (numerical) risk identification, it is not necessary to construct the probability distribution of the project assessment criterion but it is necessary to determine a certain characteristic of the project, from which higher or lower degree of its risk can be inferred. This characteristic can be what is referred to as the "operational space of a project".

In general, we can define a project as a set of interrelated expenses, actions and steps aimed at achieving specific project goals in the given area over a certain period of time.

With respect to the development of a certain territorial unit (locality), it is a desirable goal that this development, within the given time segments, takes place successfully, generally speaking, towards improvement of the initial state of the locality. The goals provide every system with a purpose and direction of its movement. The goal is correctly formulated, if it also reflects the interest, which is pursued by the assessed project, and if the desired orientation of the development of this interest is indicated.

Also, it is a global expression of a development of a certain locality in time, as a result of the expected effects and the requirements of the assessed project throughout the lifetime of the project (the development period of the territorial unit).

The areas for assessment of the project represent purposeful division of the elements, which are subjected to detailed assessment. For practical reasons, these elements are grouped into certain blocks – project goals – in which economisation of resources appears as an income (gain, benefit, effect) and the expenditure of resources appears as a cost.

The basic blocks of assessment of transportation projects can consist of the following:

direct needs of users:

In this block, the benefit for the users of the project to be implemented in the future is monitored and analysed. The benefits can be quantified by entities (individuals, transport operators), areas where the benefits occur (time, operating costs), purpose of drive (job, shopping) as well as in relation to the conditions, under which the operation will be taking place (safety, the level of awareness of users). The category of benefits, within which the said aspects are analysed, must also include the possibility that the project to be implemented will "attract" more transportation (generated transportation or redirected from some other route). This specifically includes the quantification of savings in time, savings in fuel, savings resulting from reduction of traffic accidents, benefits from increase of the quality of the traffic route).

direct and indirect requirements of the transportation system:

In this block, particularly the capital expenditures and the related costs of ensuring functionality and performance of the traffic route are monitored.

indirect external influences:

This is a block of external effects and attendant phenomena, which, with their nature, exceed the scope of the actual infrastructure. They concern particularly the environmental impact, the impact on the economic activity in the impacted area, the effect on recreational areas. This specifically includes the quantification of air pollution, excessive traffic-generated noise, traffic-generated vibrations, endangerment of recreational functions, the impact on regional development, etc.

5.1. Model of multicriterial assessment of variants

We must also deal with the system of goals in connection with the assessed project and the criterion for measuring the success of the decision in time. Each project is characterised with its requirements and effects. If I want to construct an overall indicator for assessing the success of the decision in time, which would express whether the chosen project improves or deteriorates the initial state of the locality, then I must do so with the knowledge that this is a multidimensional category. Therefore, the basis is what is called (generally in the theory of multicriterial decision-making) the model of multicriterial assessment of variants, presented in the form of a matrix [5]:

Variants	Characteristics				
	R_1	R_2	...	R_j	R_n
x_1	$u_1(x_1)$	$u_2(x_1)$	...	$u_j(x_1)$	$u_n(x_1)$
x_2	$u_1(x_2)$	$u_2(x_2)$	...	$u_j(x_2)$	$u_n(x_2)$
			...		
x_m	$u_1(x_m)$	$u_2(x_m)$	...	$u_j(x_m)$	$u_n(x_m)$

where

X = $(x_1, x_2, \ldots, x_m)$ is a set of examined variants

R = $(R_1, R_2, \ldots, R_n)$ is a set of their shared characteristics (assessment aspects, assessment criteria)

$u_j(x_i)$ is the rating of the i-th variant according to the j-th characteristic

The result of the process of assessing variants with regard to the chosen set of criteria is the determination of the preferential arrangement of the variants, i.e. the order of their overall advantageousness. However, this process usually requires supplementary information on the importance of the individual criteria.

5.2 Construction of global formulation of the development of a locality as a characteristic of the project risk degree

With regard to the construction of the global formulation of the development of a locality, I assume that the characteristics $R_1, R_2, \ldots, R_n$ are an expert formulation of the assessment criteria of the exogenously ordered goals. In other words, they are criteria (indicators), which characterise the requirements and effects as a consequence of the implementation of a certain variant (of a project), which influences the development of the locality concerned.

Let's assign a certain set of locality assessment criteria R_1, R_2, ..., R_n to the term "project". The impact of the success of the decision must be manifested in the assessment of the overall success of the entire development period RO, whose individual chosen (defined) periods (time segments) will be sequentially numbered 1, 2, ..., T. In these periods, we know the degree of compliance with the individual assessment criteria

$$x_1(1),\ x_2\ (1),\ \ldots,\ x_n\ (T),$$

measured on a cardinal or ordinal scale (some data can be missing).

Expressed in a table:

Period	Assessment criteria			
	R_1	R_2	...	R_n
1st period	$x_1(1)$	$x_2(1)$	…	$x_n(1)$
			…	
T-th period	$x_1(T)$	$x_2(T)$	…	$x_n(T)$

where $x_j(i)$ expresses the degree of compliance with the *j*-th assessment criterion in the *i*-th period.

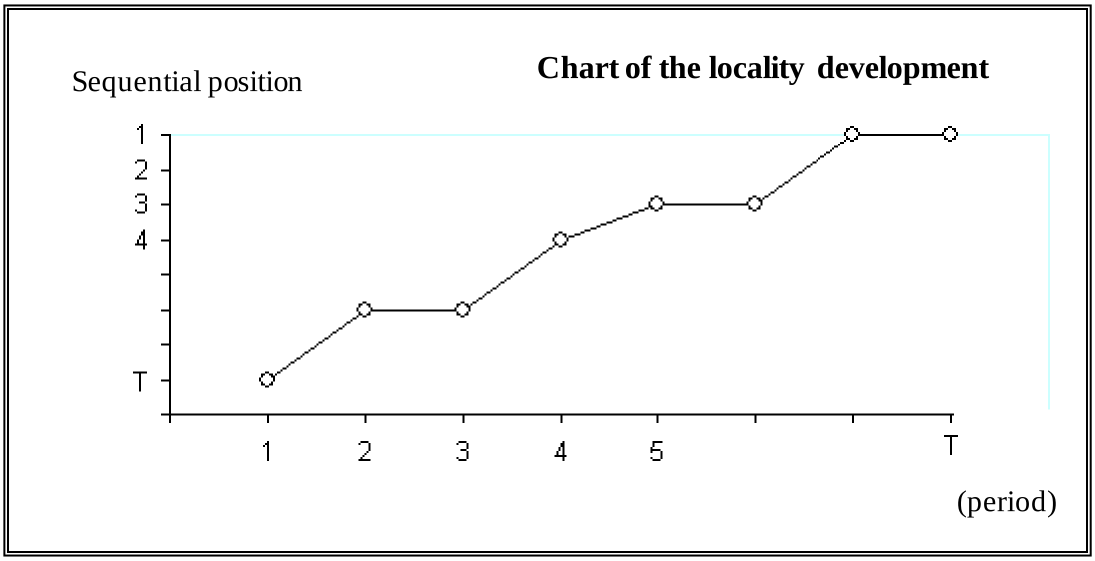
Based on the data $x_j(i)$, I can judge whether the development of the locality is taking place successfully due to the implemented project, that is, in the direction of improvement on the initial state of the locality or not. It is a task involving multicriterial assessment of variants where the variants represent the time periods of assessment of the locality and the characteristics are the assessment criteria of the locality development.

After application of one of the methods of multicriterial assessment (ELECTRA IV), the output I obtain is the order of the periods from the best one to the worst one, which I represent graphically in the sequence of the periods to obtain the overall indicator of the locality development. We can expect the following four courses of the order of individual periods and therefore the sought-for overall (graphic) representation of the success of the locality development due to the locality being influenced by the assessed project over time [21].

a) monotonous growth of success of the locality development

For each pair of periods t_1, $t_2 \in RO$, $t_1 < t_2$, it is true that: the sequential position t_1, ≥ sequential position t_2:

- the last monitored period is considered to be the best one and the worst period is considered to be the first period in the sequence. It can be deduced from this that the monitored project has a favourable influence on the development of the locality (the territorial unit), based on its description by the given assessment criteria, which means that the project has a low risk.



In this case and in other cases, the function of the "success" of the locality development f(t), t = 1, 2, …, T, can be approximately expressed, for example, by means of the Newton's interpolation polynomial:

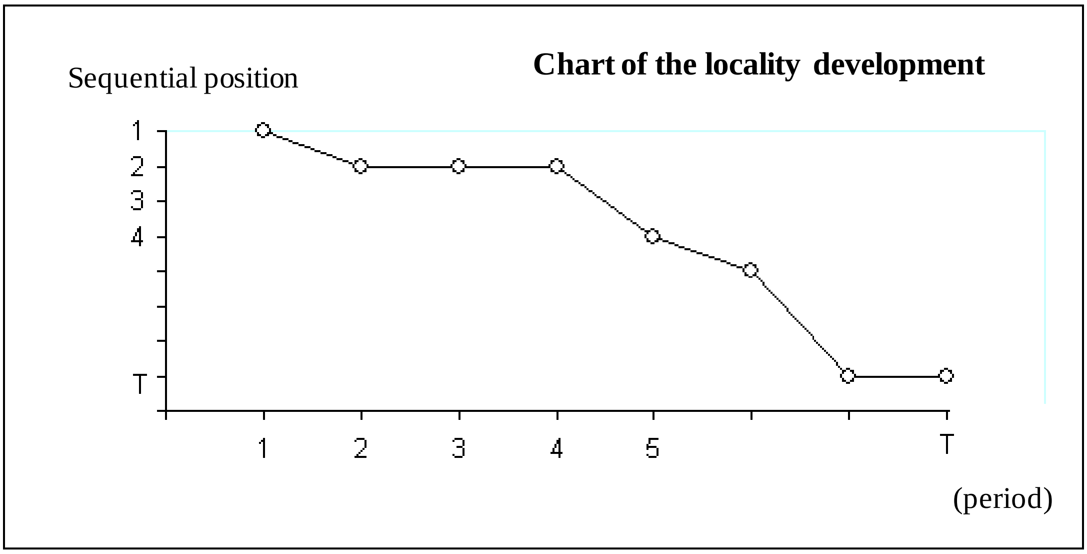
$$f(t) = y_1 + A_1 (t-1) + A_2 (t-1)(t-2) + A_3 (t-1)(t-2)(t-3) + \ldots$$
$$\ldots + A_T (t-1)(t-2) \ldots (t-T),$$

where y_1 is the sequential position of the first period and A_i, i =1, 2, …, T are calculated constants

b) monotonous decrease of success of the locality development

For each pair of periods t_1, $t_2 \in RO$, $t_1 < t_2$, it is true that: the sequential position t_1, ≤ the sequential position t_2:

- we consider the first period to be the best one and the last period to be the worst one in the sequence of periods. We can presume that this is the manifestation of the deteriorating impact of the project on the locality development and therefore it can be assumed that a measure to change this trend will be sought (or simulated) due to the considerably high risk of the project.

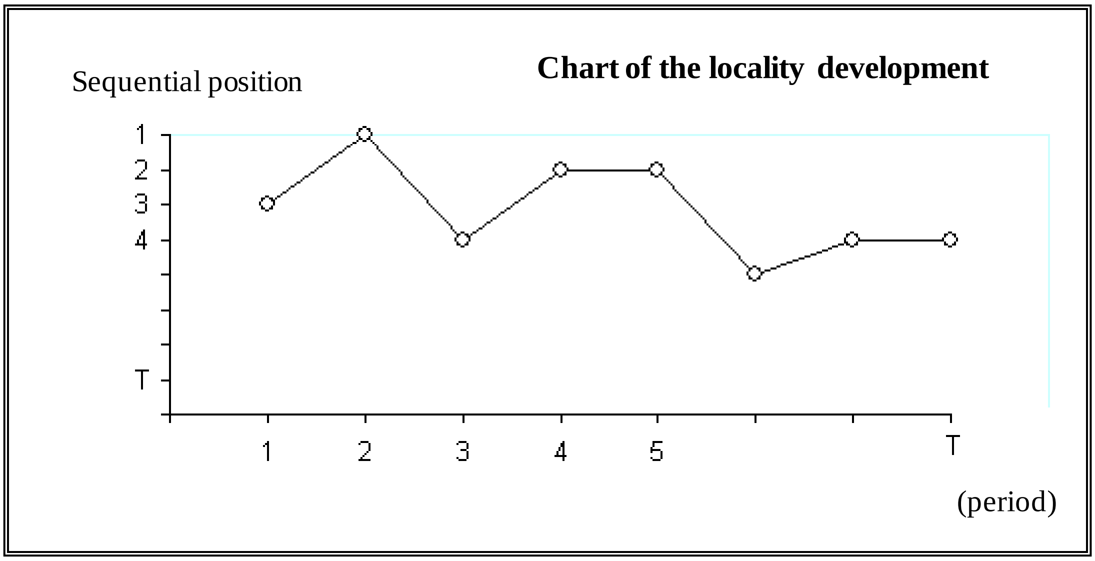


c) extremal course of success of the locality development

- if there is a maximum in the course, then this corresponds to the situation, in which there was a monotonous growth of success of the locality development until this extreme, which was then followed by monotonous decrease of success. It can be expected that the deteriorating situation will eventually bring about problems mentioned in item b). The same applies, by analogy, to the minimum.

d) non-systemic course of success of the locality development

- nothing more detailed can be said about this situation, in which the locality development may have several local extremes; more detailed knowledge can be probably gained from analysing and experimenting with the set of assigned assessment criteria and from simulating a combination of measures.



The obtained courses can be the basis of an ex-ante analysis of the deviations of the locality development from the plans in the simulation of the consequences of the choice of a certain project, a basis of an analysis aimed at finding out how these deviations occur, what development would follow without any intervention, how it is possible to eliminate the deviations, etc. The proposed method thus makes it possible to represent, in a simple graphic manner, the "success" of the locality development in individual time segments as well as over the entire monitored period as an inverse expression of the project risk degree – if the "success" is rising, the "risk degree" of the project is decreasing.

As it has been stated, the assessment criteria characterise, in time segments, the requirements and effects brought about by implementation of a certain project, which influences the locality concerned over the period of development. The goals and assessment criteria are expressed in the "language of the problem" on which a decision is to be made. For different problems (different types of infrastructure projects), different "languages" are used. However, the formal procedure is identical.

6. Conclusion

The basis of assessment of the investments in transportation projects is the general principle of comparison of costs and benefits. This principle can be applied through various methods and indicators, often in special modifications and versions, determined, for example, by the purpose of the assessment and the specific requirements of financial institutions.

Another factor is the uncertainty in the estimates of future developments. The calculation of the values of the criterial function often needs to be based on assumptions or estimates, which may influence the resultant assessment, or the result can be burdened with uncertainty. The purpose of a sensitivity analysis is to identify the variables, which influence the assessment result the most. The sensitivity of a variable can depend on its size, weight and on the possibility of deviation from the mean value. A sensitivity analysis provides the first idea about the possible risks of a project. It is a basis for the subsequent project risk exposure quantification, which relies on the obtained probability distribution of the project's criterial function and the characteristics of this distribution, if this criterial function is known. The first part of the paper deals with the possibilities of this project risk exposure quantification.

The second part of the paper deals with the project risk exposure quantification when the project's criterial function is unknown; this kind of project risk exposure quantification is based on the expert quantitative assessment of risk factors – contingencies, which have an unfavourable impact on the project's goals. The significance of the risk factors is most often assessed according to two aspects – the probability of occurrence of the risk factor and the intensity of the negative impact of the factor on the project's benefits, when the factor occurs. The purpose of the quantification is to minimise the risk of project failure – to identify the least risky variant of the project. Quantitative assessment of the significance of risk factors can be used:

- to express the isolines of the same risks (to divide the risk factors into groups with different significance; usually, three groups of factors will be analysed: the risk is unacceptable; the risk is conditionally acceptable; the risk is acceptable);
- to arrange the risk factors in the order from the most significant factors to the least significant ones; this is then the basis for the resultant assessment and for recommendations on the assessed variants;
- to identify the overall risk of the project (variants).

The third part of the paper deals with the proposal for a method of multicriterial assessment of a locality (a territorial unit), respecting the development over time. Its benefit consists in including the time factor in the multicriterial decision-making procedures. The proposed method makes it possible to represent, in a simple graphic manner, the "success" of the locality development in individual time segments as well as for the whole monitored period as a characteristic inverse to the project's degree of risk. It can be the basis used to analyse the deviations of the real locality development from the plans when certain measures are taken; it can be the basis used to analyse how these deviations occur, what developments would follow without any intervention and how it is possible to eliminate the deviations, etc.

The characteristic feature of the above-mentioned project risk exposure quantification methods is the effort to combine the exact procedures and model tools with the knowledge and experience of the solvers of these problems. From a certain point of view, this feature also determines the possibilities and limits of the risk exposure quantification for transportation projects.

Recently, available commercial software has significantly supported practical implementation of project risk exposure quantification. Other problems and recommendations for implementation of risk analysis in non-financial and financial organisations are contained in [31], [32].

Acknowledgement

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University qualification and scientific and academic titles

- He obtained a university degree in the field of economics and power industry management and was awarded the title of engineer (“Ing.”) at the Faculty of Electrical Engineering at the Czech Technical University in Prague in 1978.
- He obtained the scientific title of the Candidate of Economic Sciences in the field of sectoral and inter-sectoral economics at the Faculty of Electrical Engineering at the Czech Technical University in Prague in 1993.
- He obtained the title “Dr.” after completing the postgraduate studies at the Faculty of Information Technology and Statistics at the Economic University in Prague in the field of Econometrics and Operational Research and after defending his postgraduate thesis in 1998.
- He qualified for associate professorship in the field of Technology and Management in Transportation and Telecommunications at the Faculty of Transportation Sciences at the Czech Technical University in Prague in 2000.

After completing Secondary Electrical Engineering School in Kladno and after completing the practical training, I graduated from the Faculty of Electrical Engineering at the Czech Technical University in Prague (CTU) where I majored in economics and power industry management. I worked in the Regional Computer Centre of Universities and in the Department of Automated Control Systems at the Ministry of Education of the Czechoslovak Socialist Republic. In 1981, I started to work at the Fuel and Energy Research Institute, in the department of free research where I worked mainly on the applications of economic-mathematical methods in the utility network industries.

In 1987, I started to work at the Faculty of Electrical Engineering Energy at CTU where I worked in the Department of Economics, Management and Humanities. Here, besides doing the pedagogical work, I participated in the research with a focus on development of the resource basis of the electric power grid and organisational structures of the electrical engineering industry. After the Faculty of Transportation Sciences had been established at CTU, I was teaching there in the daytime and combined studies as an external collaborator. I was also involved there in the Joint European Project “Energy Planning Course”, TEMPUS 3160. Starting from March 1999, I had a full-time job the Faculty of

Transportation Sciences at CTU in the Department of Financing and Economics of Operation. There, I participated in working on the research project VZ23 “Development of the Methods of System Analysis, Algorithms and Statistical Methods for Transportation and Communications” and the research project VZ24 “Automatic Systems in Transportation; Diagnostics of Transportation Systems and Processes”; and now, since 2007, I have worked on the plan MSM 043 “Development of the Methods of Designing and Operating Transportation Networks with Respect to Their Optimisation”. I was the implementer of a project funded by a grant 2031/2004 from the University Development Fund, titled “Preparation of New Subjects: Project in a Team; and Individual Project”; I was the implementer of a project funded by a grant 16012/05 under IGS, titled “Innovation in Teaching Quantitative Methods”. I collaborated with the Economic Faculty of the Technical University in Košice in the International Visegrad Fund (IVF) project, titled “Comparative Study of Approaches in Solving Brownfield Issues in Partner Cities“, International Visegrad Fund, (2004-2005) and a project titled “Eastern Policy of Innovation and Technology Transfer, Capability in Visegrad Countries”, International Visegrad Fund, (2005-2006). In 2007, I was appointed an expert for assessing research projects of the Ministry of Science and Education of the Republic of Serbia. Since 2008, I have been a collaborator of the TATLS project: Trans Atlantic Transportation Science and Logistics Systems, under EU – US ATLANTIS; this involves cooperation between the Czech Technical University in Prague, Faculty of Transportation Science, and Texas University at El Paso, USA. Since 01/01/2009, I have been a collaborator participating in the implementation of the GRUNDTVIG international project, in cooperation with the Economic Faculty of the Technical University in Košice, titled “Education in IT as an Activating Factor for Adults from a Region with an Unemployment Risk”.

From 2001 to August 2004, I held the position of a deputy to a vice dean for science and research; now I am the deputy to the vice dean for the worksite of the Faculty of Transportation Sciences in Děčín. In 2008, I was awarded the Silver Felbr Medal by the Scientific Board of CTU for merit in the development of CTU.

I have held the position of the head of the Department of management of Transportation Processes and Logistics at the Faculty of Transportation Sciences at CTU since 1 September 2004. I am a member of the Scientific Board of the Faculty of Transportation Sciences at CTU and since April 2009 I have been the chairman of the industry-specific board of the postgraduate studies discipline of Technology and Management in Transportation and Telecommunications, the chairman of the Commission for Defending Postgraduate Theses in the Discipline of Technology and

Management in Transportation and Telecommunications, the instructor for postgraduate studies in the discipline of Technology and Management in Transportation and Telecommunications. At the Faculty of Transportation Sciences of Jan Perner at the Pardubice University, I am a member of the commission for defending theses in the discipline of Technology and Management in Transportation and Telecommunications.

At the Faculty of Electrical Engineering at CTU, I work as an external collaborator, holding the positions of an instructor for postgraduate studies in the discipline of Economics and Business Management, a member of a commission for defending postgraduate theses in the discipline of Economics and Business Management and a member of the industry-specific board of postgraduate studies in the discipline of Aviation Transport Operation and Management.

My scientific and pedagogical interests include mainly the application of and elaboration on economic-mathematical methods for optimisation of operation and development of transportation and energy networks, the issues of economics, management, logistics and project management.