VOLUME 3, 2011

ISSN 2045-3345

PROJECT PORTFOLIO DEVELOPMENT UNDER RISK AND ITS OPTIMIZATION

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ABSTRACT

The article focuses on the problems of the project portfolio development under risk. It is precisely the poor-quality development of this portfolio that may have an even catastrophic impact on company efficiency and long-term prosperity. The first part is devoted to the shortcomings of project portfolio development and management and the specific features of project portfolio development. It further mentions project portfolio development itself. In the phase of portfolio development, emphasis is placed on a key connection to the company strategy, specification of the resource limitations, multi-criteria approach to project evaluation with an appeal to portfolio balance. Stress is put on the evaluation of all of the projects in a common scenario or scenarios of future development, which improves the comparability of the project evaluations. The aim of the article is to specify the role of the optimization of project portfolio development under risk (optimal allocation of limited resources). In the article, two approaches are mentioned: the first arises from the deterministic equivalents of stochastic optimization using bivalent programming (multi-criteria and mono-criterion optimization), whereas the second is based on Monte Carlo simulations. The implementation of the second model method is then illustrated using an example.

JEL CLASSIFICATION & KEYWORDS

■ C15 ■ D81 ■ M21 ■ PROJECT ■ PORTFOLIO DEVELOPMENT ■ RISK ■ OPTIMIZATION

INTRODUCTION

The distinct shortcomings in investment project portfolio development in the form of research, investment, development or other programmes have been indicated by for example (Kendall & Rollins, 2003, pp. 23 – 55; Kodukula, 2007, pp. 1-11 – 1-13; Koller, 2005; Pennapacker & Retna, 2009, pp. 30 – 98; Sanval, 2007, pp. 4 – 15). The consequence of these shortcomings then can be mistaken investment decisions with more or less distinct negative impacts on company efficiency and long-term business prosperity. As is presented by e.g. (Sanval, 2007), the process of project portfolio development can in a certain way be formalised, i.e. placed in a normative framework.

For the actual optimization, it is possible to utilise more methods, for instance deterministic equivalents of the task while using the function of profit (the function of profit has been discussed in more detail by Fotr & Švecová et al., 2010, pp. 163 – 195). An appropriate method is also a stochastic optimization with the use of Monte Carlo simulation (this simulation is discussed e.g. by Mun, 2010, pp. 85 – 90).

Characteristic Features of Project Portfolio Development

The typical tasks for variant portfolio development include particularly research projects (research and development of new products, technologies, processes, etc.) and investment projects (the extension or reconstruction of production capacities, innovation of production technologies, introduction of new products, innovation of information systems etc.). The implementation of every project requires the investment of certain resources, and therefore the task of portfolio development is simultaneously a resource allocation task (these resources are usually limited). If in portfolio development we observe the maximization or minimization of certain characteristics of the portfolio, it is then an optimization task in the form of the optimal resource allocation.

Project portfolio development usually has some common features, including primarily:

The multi-criteria character of a task, because more aims are usually observed; their level of achievement is expressed through the individual evaluation criteria. The evaluation criteria could be both of a quantitative nature (for example economic impacts in the form of a purely contemporary value, the profitability of the capital invested, but e.g. also the achievement of a certain market share or pace of market growth) and a qualitative form (for instance in the form of the achievement of certain competitive advantages, impacts on the company image, etc.).

Scarcity of resources, which leads to individual projects not being assessed in isolation, because the acceptance of a specific project reduces the resources available for the other projects. Such resources include predominantly financial means, production capacities, qualified employees, etc. The scarcity of resources then evokes also a need for optimization instruments, which allow the maximization (e.g. the pure contemporary value) or minimization (e.g. project risk) of a certain criterion of the evaluation in respecting these limitations.

Some of the projects competing for inclusion in the portfolio could be mutually dependent, and it is therefore necessary to respect this dependence. The dependence of the portfolio can have the character of either statistical dependence (a direct or indirect dependence with a different intensity expressed by the correlation coefficients of the pairs of investment projects) or a certain type of functional dependence (e.g. a certain project can be included in a portfolio only if another specific project has also been included there).

The uncertainty of some quantities influencing the results of the project, and thus also its successfulness, so that it is a risky project. This uncertainty can also affect various aspects: the impacts of the projects in terms of the individual evaluation criteria, resource demands, size of the limited resources etc.

If the task of portfolio development is formulated in the form of a bivalent programming model, then these are the variable coefficients in a criteria function, coefficients of constraint variables or in the right side constraints.

Shortcomings of Project Portfolio Development

Project portfolio development and management are accompanied by many shortcomings. These shortcomings have been indicated by e.g. the references (Kendall & Rollins, 2003, pp. 23 – 55; Kodukula, 2007, pp. 1-11 – 1-13; Koller, 2005; Pennapacker & Retna, 2009, pp. 30 – 98; Sanval, 2007, pp. 4 – 15). The most serious include:

Projects are evaluated and included in the portfolio independently of one another without respecting their mutual ties (these ties can have a deterministic or stochastic character).

The connection of the projects to the strategic company aims is missing. It is usual to work with one criterion when selecting projects for a portfolio (mainly of a financial character) and neglect the other criteria of a non-financial character.

The portfolio comprises too many projects. The cause is overinvestment in smaller incremental projects and an insufficient focus on riskier growth and innovation projects.

The portfolio comprises unsuitable projects with little or no benefit for the company.

Hard decisions leading to the rejection of certain projects are avoided. It is usually caused by a lack of equipment of the projects with the necessary resources with a negative impact on the achievement of their planned results.

The different level of risk of the individual projects is not respected.

The portfolio is often unbalanced, which manifests itself e.g. in too low a representation of research projects, a significant number of short-term projects at the expense of long-term projects, in the predominance of distinctly risky projects over low-risk projects etc. Such a portfolio often does not reflect the most important company assets and strategic value resources.

The approach to company portfolio development is distinctly decentralised, with the portfolio usually being developed on the basis of the best projects of the individual divisions, business units, sections, etc., which however as a rule does not lead to the optimal portfolio at the corporate level.

The portfolio is developed predominantly intuitively without the application of analytical tools based on quantitative data.

Impacts can be negative also in the case of the oftentimes political character of the portfolio development process. Instead of a rational decision-making process, it is rather a not very transparent process of promoting local interests, compromising, utilising force (see Sanval, 2007) etc. For instance, one research project (see Kendall & Rollins, 2003, p. 253) led to the conclusion that with 40 % of incremental projects and with 90 % of discontinuous innovations the politicisation of the decision making on the portfolio was the cause of their not meeting their aims.

The project portfolio is not documented and explicitly managed.

The Process of Project Portfolio Development

Specification of the Normative Framework of Project Portfolio Development

Efficient project portfolio development requires the establishment of a certain normative framework. The components of this normative framework should be predominantly requirements related to the specification of the multi-criteria evaluation of the projects, resource constraints, the portfolio balance and the creation of a common scenario.

The implementation of multi-criteria evaluation requires establishing sets of criteria, weights of the criteria, selecting the project assessment scales, specifying the criterion value transformation on a non-dimensional expression (e.g. an interval of 0 to 1, or 0 to 100) and establishing the relation for the calculation of the total project evaluation usually in the form of a weighted total of the partial assessments of the projects with respect to the individual criteria (see Fotr & Švecová et al., 2010, pp. 178 – 186). In establishing the sets of criteria, it is suitable to take into consideration both the elimination criteria and the evaluation criteria. The elimination criteria serve for selecting the unacceptable projects and could have a formal character (for instance missing documentation) or a factual character (for example an insufficient level of pure contemporary value), whereas the evaluation criteria serve for the actual assessment of the projects and should reflect the strategic aims of the company. The established sets of criteria and their weights do not have permanent validity. If there are more distinct changes of the business environment (e.g. a crisis erupts), or in changes of company strategy, these sets need to be updated.

Companies usually work on a greater number of projects than the resources available allow them to implement. Considering that, it is necessary to specify these resources in terms of their types and determine their available quantities. The basic types of resources are financial (capital) resources, human resources and other resources (e.g. production capacity, capacity of the equipment, non-material resources etc.). During the actual portfolio development, it is then necessary to distinguish between so-called hard and soft constraints. Hard constraints are often given by the business environment (e.g. the inability to acquire another bank loan) and therefore are difficult to change. The situation is different with soft constraints, which are often given by the internal factors like managerial decisions (e.g. financial means allotted to certain groups of projects, business units etc.) and therefore are easier to change.

Project portfolio development only on the basis of the evaluation of the overall benefits of the projects (the results of multi-criteria evaluation) while respecting scarce resources should lead to a distinctly unbalanced portfolio in terms of the types (categories) of projects included. The prerequisite for achieving balance of the project portfolio is a certain project categorisation, which then makes it possible to allocate limited resources to the individual project groups and to judge the overall suitability of the projects within the individual categories. For instance, projects can be divided into development projects of a strategic character, orientated on expansion; renewal projects; rationalisation projects, orientated for instance on cost saving; or mandatory projects, forced for instance by a change in legislation.

A higher comparability of the results of the individual projects may be facilitated by the preparation of a certain common (basic) scenario of the values of the significant external factors, common for all or for the majority of the projects. This shared scenario can weaken to a certain extent also the distortion arising from over optimism of the project developers, which is manifested by an overestimation of the project profits and underestimation of the project costs. What could also be useful is the development of a common warning (cautionary) scenario, based on highly pessimistic, although realistically possible, assumptions of the development of key factors influencing the results of the projects. Apart from the common scenario, it is necessary to specify also the discount rates of the projects depending on the company's capital expenses and differing riskiness of the individual project groups.

Project Portfolio Development

The actual process of project selection for the portfolio includes three activities, which comprise a benchmark allocation of the limited resources across the individual project categories; project portfolio development within the individual project categories; activities focused on achieving a balanced portfolio, combined with a possible reallocation of the resources among the project categories. These activities do not comprise a direct sequence but repeat cyclically until the final portfolio consisting of sub-portfolios according to the project categories is reached.

A benchmark resource allocation to project categories is the starting point of decision making on the composition of the portfolio and affects its balance. The principle lies in that scarce resources are divided among the individual project categories, mainly by a non-formalised method based on experience and knowledge. However, it is useful to predefine the factors influencing this allocation and then document the results of the orientation allocation in writing. For the support of this allocation, it is possible to utilise also a multi-criteria evaluation like with the system of financial means allocation in three categories of transport projects (roads, railways and waterways) in the CR (see Fotr & Hájek, 2005, pp. 228 – 334).

Project portfolio development by project category utilises optimization methods based on the models of bivalent, or stochastic, programming on the basis of the results of multi-criteria evaluation of the projects.

The outcome of the previous steps is such a company portfolio that is balanced in terms of the individual project categories for which sub-portfolios were created. That does not however guarantee overall balance of the portfolio from other perspectives, such as the share of long-term and short-term projects, low- and high-risk projects, projects oriented on the current and new markets, etc. It is not possible to reach balance of the overall portfolio through a formalised optimization procedure, but rather in a non-formalised way based on experience, expert opinions and supporting analyses. Gradual adjustments of sub-portfolios then have the character of eliminating certain projects and replacing them with other projects or of reallocating resources across the individual project categories. The final outcome of this process is the determination of the projects which shall acquire financing and be included in the company-wide portfolio, rejected projects and projects that will be postponed.

Portfolio optimization

Project portfolio development under risk is a challenge of managerial practice. The following sections focus on the two types of tasks of project portfolio optimization under risk, namely on the deterministic equivalents of the stochastic models and further on the use of stochastic optimization based on Monte Carlo simulation. The deterministic equivalents of the stochastic models are utilised with simpler types of problems.

Deterministic Equivalents of Stochastic optimization Problems

The types of deterministic equivalents of stochastic optimization problems will differ to a certain extent depending on two characteristics. The first concerns the nature of the optimization in terms of the number of assessment criteria, i.e. whether it is a multi-criteria or mono-criterion optimization. The second characteristic is then related to the optimization model variables, which have the nature of random variables. These variables could be coefficients of the criteria function, coefficients of constraint variables or in the right side constraints. The most frequent and relatively simplest are then the tasks with randomly variable coefficients of the criteria function.

Knowledge of the mean values of the component utilities then makes it possible to determine the mean value of the aggregate profit of every project (1) as a total of the mean values of the overall profits of the individual projects contained in the portfolio:

$$E[U(X^j)] = \sum_{i=1}^{m} v_i \cdot E[u_i(x_i^j)] \qquad (1)$$

Deterministic equivalents of project portfolios optimization problems under risk can generally be formulated as problem of bivalent programming with criteria formulation based on the concept of multi-criteria utility function under risk (2) and sets of resource constraints (3):

$$\sum_{j=1}^{n} E[U(x_j)] \cdot y_j \qquad (2)$$

$$\sum_{j=1}^{n} a_{kj} \cdot y_j \le L_k \qquad (3)$$

where

a_{kj} = consumption of the k^{th} resource to the j^{th} project (k = 1, 2,…, p),

L_k = available amount the k^{th} resource,

y_j = weight of the i^{th} criterion,

$E[U(X^j)]$ = mean of total utility of each project according to equation (1),

$E[u_i(X^j_i)]$ = mean of utility level of each project due to individual criteria.

Analogously, also the model of bivalent programming for a mono-criterion character of a problem can be derived. It is possible to include among the other types of problems the maximization of the likelihood of surpassing the target value of a criterion or a problem with randomly variable restrictions.

Stochastic optimization Using Monte Carlo Simulation with an Example

With the more complex optimization problems, an analytic resolution of stochastic bivalent programming is usually difficult, but it is possible to use advantageously optimization programs based on Monte Carlo simulation (the simulation has been discussed e.g. by Mun, 2010, pp. 85 – 90).

The resolution of the problem of project portfolio optimization under risk is illustrated using the example of an investment program portfolio which was based on the total of twenty-one investment projects. The assessment of these projects considering the elimination criteria led to the exclusion of five projects, so a total of sixteen projects remained for investment program development. In addition, three of these projects were mandatory, so thirteen projects competed for inclusion in the investment program.

Not all of these projects were however possible to include in the investment program because of the necessity to respect two limitations, on the one hand the amount of financial means available for the implementation of the investment program (capital budget) and on the other hand the number of employees necessary for the preparation of the investment portfolio for implementation.

An overview of the investment projects from which the company investment program is to be created is provided in Table 1. For each project, the following are listed in the table:

- The overall evaluation as the result of the multi-criteria evaluation of the project considering the array of criteria selected. The projects were assessed both in economic and non-economic terms; the greatest weight among the economic criteria went to the net present value (NPV); among the non-economic criteria the accord of the individual investment projects with the company strategy, coverage of the most important areas of the business, impacts on the environment etc. were judged.
- The mean NPV as an optimization criterion for investment program development and its standard deviation as the level of risk. Since within the preparation and evaluation of the individual investment projects they were analysed for risk using Monte Carlo simulation, the division of the likelihood of the NPV of the individual projects and their statistical characteristics are available.
- The mean value of the investments costs (IC) and their standard deviation. These characteristics have been determined for each project based on expert-set subjective divisions of the likelihood of the investment costs of each project.
- The number of employees necessary for ensuring the project after its implementation.
- Investment decisions containing the bivalent decision-making variables attaining only the value of 1 (the given project is included in the investment portfolio) or 0 (the project is not included in the portfolio).

The resource constraints show the available amount of financial means (capital budget of CZK 620 million) and the constraint of the number of employees (250), who are available for the implementation of the investment programme. The demand for the budget and for the number of employees in the next line can easily be determined as the total of the mean values of the investment costs and the number of employees of the projects that have been included in the investment programme (in our case we see that the investment portfolio into which all three projects were included represents an unacceptable version of the investment programme, because the budget has been exceeded by CZK 136.1 million and the limit of the number of employees by 79, as listed in the line 'Overdraft'. The mean net present value of the investment portfolio is CZK 231.7 million and represents the optimization criterion of investment programme development (it is again determined as the total of the mean net present values of the projects included in this portfolio and is the same also with the overall evaluation of the portfolio). Considering that some projects competing for inclusion in the investment portfolio are statistically dependent, it is necessary to respect this dependence in the optimization of the investment programme. The expert judgement of the dependence of the projects in terms of NPV has reached the conclusion that there is a relatively strong dependence between the third and fourth projects, the third and fifth projects (correlation coefficients of a size of 0.75) and mean indirect dependence between the third and fourth projects on the one hand and the tenth and eleventh projects on the other hand (size correlation coefficients – 0.5). The statistical dependencies of the investment costs of the individual projects have been respected in a similar way.

The resolution of the task of the maximization of the mean portfolio value with two resource limitations is an optimal

Table 1: Characteristic of Investment Projects

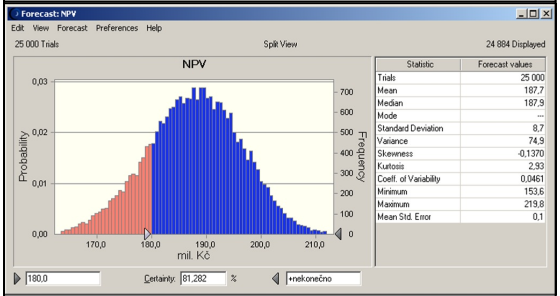
Project	Evaluation	NPV (mil. CZK)	Standart deviation of NPV (mil.CZK)	IC - Investment costs (mil.CZK)	Standart deviation of IC (mil. CZK)	Number of emloyees
Project 1	68	25,4	2,5	41,8	3,9	24
Project 2	36	6,5	1,7	26,9	1,8	13
Project 3	48	34,21	6,75	128,2	4,1	44
Project 4	72	26,42	4,43	95,5	6,8	35
Project 5	75	15,46	1,61	54,2	4,6	26
Project 6	56	10,53	1,92	37,3	3	24
Project 7	45	12,4	1,02	45,8	3,8	17
Project 8	65	22,8	1,86	66,4	4,3	25
Project 9	76	14,98	2,11	48,7	3,3	22
Project 10	82	18,54	5,4	86,1	5,5	40
Project 11	49	15,48	4,03	52,7	4,7	21
Project 12	77	16,96	3,21	41,9	3,1	15
Project 13	53	12,05	2,77	30,6	2,3	23
Resource limit				620		250
Demand				756,1		329
Overcraft				136,1		79
Evaluation of Portfolio	802					
NPV of Portfolio		231,7				

Source: authors (2011)

portfolio with nine projects (with the exclusion of projects 2, 6, 9 and 13). Its maximum mean NPV is CZK 187.7 million, an overall evaluation 581, with CZK 7 million and three employees left unutilised.

The division of the likelihood of the NPV of this portfolio is in Fig. 1. In the best case scenario, the NPV of the portfolio reaches CZK 219.8 million, in the worst case then only CZK 153.6 million. The mean NPV of the optimal portfolio is CZK 187.7 million and its risk expressed by standard deviation has a value of CZK 8.7 million. From the division of the likelihood of the NPV, it arises that with high likelihood (approximately 82 %) its NPV will surpass CZK 180 million (see the data in the *Certainty* field in Fig. 1 below).

Figure 1: Probability distribution NPV of the optimal portfolio



Source: authors (2011)

It was not a component of the problem to determine the risk of the portfolio in terms of its NPV. The impact on the optimization of the portfolio was determined by means of tightening or softening the risk of the demands for the risk of this portfolio (measured by the standard deviation of the NPV of the portfolio). In this way, we would have gradually received several so-called efficient portfolios maximising the mean value of their NPV under the given risk expressed as the efficient frontier (Fotr & Švecová et al., 2010, pp. 400 – 407).

For setting the efficient frontier, several optimization problems of maximising the mean NPV of the portfolio were resolved under given resource constraints while gradually softening the portfolio risk demands measured as its standard deviation. In the first optimization, the upper frontier of the risk of the portfolio was CZK 5 million; in the further optimizations, the upper risk frontier was gradually raised by CZK 1 million up to CZK 9 million. The individual efficient portfolios and their characteristics are summarised in Table 2. It is clear from this table that:

- With the increase of the risk of the portfolio, its mean NPV increases (from CZK 103.1 million with portfolio A to CZK 187.7 million with portfolio E).
- The overall evaluation of the portfolio increases (except for the transition from portfolio D to portfolio E, where the evaluation has dropped by 40).
- With the relaxation of the risk demand, the number of projects included in the individual portfolios and with it also the drawing on the limited resources, increases (a strict risk constraint leads to the first three portfolios drawing on only a part of the limited resources).
- With the increasing risk of the portfolio, the incremental growth of the mean NPV per unit of incremental growth of risk (from a value of 40.4 in the transition from portfolio A to portfolio B to 7.1 in the transition from portfolio D to portfolio E). Considering the dropping incremental growth of the mean NPV per unit of incremental risk growth also the slope of the abscissas on the efficient frontier connecting the individual efficient portfolios decreases (see Figure 2).

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- The overall evaluation of the portfolio increases (except for the transition from portfolio D to portfolio E, where the evaluation has dropped by 40).
- With the relaxation of the risk demand, the number of projects included in the individual portfolios and with it also the drawing on the limited resources, increases (a strict risk constraint leads to the first three portfolios drawing on only a part of the limited resources).
- With the increasing risk of the portfolio, the incremental growth of the mean NPV per unit of incremental growth of risk (from a value of 40.4 in the transition from portfolio A to portfolio B to 7.1 in the transition from portfolio D to portfolio E). Considering the dropping incremental growth of the mean NPV per unit of incremental risk growth also the slope of the abscissas[1] on the efficient frontier connecting the individual efficient portfolios decreases (see Figure 2).

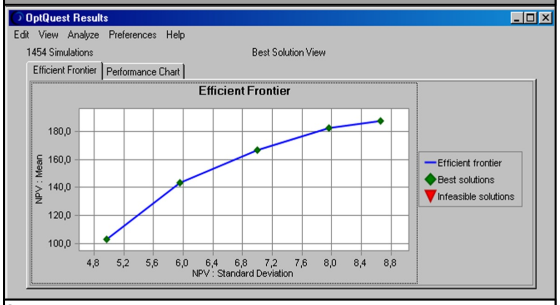
[1] The incremental growth of the mean NPV by unit of the incremental risk growth is a guideline of the individual abscissas for the efficient frontier.

Table 2: The result of stochastic optimization with varying constraints on portfolio risk

Efficient portfolio		Projects not included in the portfolio	NPV Mean	NPV Standart Deviation	ΔNPV / Δ risk	Evaluation	Investment cost	Number of employees
A	$(\sigma \leq 5)$	1-3, 9, 10, 12, 13	103,1	5	–	362	352	148
B	$(\sigma \leq 6)$	2, 3, 10, 12, 13	143,5	6	40,4	506	442	194
C	$(\sigma \leq 7)$	3,10, 13	166,9	7	23,4	619	511	222
D	$(\sigma \leq 8)$	4, 6, 13	182,7	8	15,8	621	593	247
E	$(\sigma \leq 9)$	2, 6, 9, 13	187,7	8,7	7,1	581	613	247

Source: authors (2011)

Figure 2: Efficient frontier



Source: authors (2011)

Every portfolio on the efficient frontier then has the characteristic that:

- At the given risk, it is not possible to achieve a higher mean NPV (e.g. the efficient portfolio C at a given risk of the size of CZK 7.0 million cannot reach a higher mean NPV than CZK 166.9 million).
- At the given mean NPV, it is not possible to achieve lower risk (e.g. the risk of efficient portfolio D with a mean NPV of CZK 182.7 million cannot drop below CZK 8.0 million).

The points above the efficient frontier are a mapping of unacceptable portfolios, which cannot be reached with the given limitations of the optimization model. The points below the efficient frontier then depict inefficient portfolios, whose one or both characteristics can be improved by optimization. For that reason, attention in investment, research etc. project portfolio development should be paid to all of the factors which negatively influence the position of the portfolio in relation to the efficient frontier.

In selecting an investment programme based on some of the efficient portfolios from Table 2 on the basis of a multi-criteria evaluation and the mean NPV, predominantly portfolios C, D and E would come into consideration, but with portfolio C we would have to respect the effects of the alternative use of the free financial means (ca CZK 100 million) and employees (ca 30), namely e.g. by shifting them to another category of the projects. The assessment of projects D and E would also be influenced by the attitude of the entity responsible for the selection of the investment programme towards risk. An entity with a lower willingness to risk would probably select the less risky portfolio D with a higher overall evaluation but a mean NPV of only CZK 5 million lower than with the more risky portfolio E.

As has already been mentioned, the selection of the portfolio for implementation would depend on the attitude of the decision maker (the manager, or upper management of the company) towards risk. In a non-formalised approach, we would first compare the portfolios in terms of the individual aspects (benefit, risk). A formalised evaluation of the portfolios would require determining the importance of the individual criteria in terms of their weights and application of one of the multi-criteria evaluation methods (for more information, see Fotr & Švecová et al., 2010, pp. 178–186). This approach is suitable especially in the case of a greater number of portfolios assessed and a more extensive array of the evaluation criteria, where the non-formalised approach may fail.

It is clear from the text above that the model of bivalent programming in connection with stochastic optimization is a useful tool contributing to increasing the quality of project portfolio development under risk.

Conclusion

Investment project portfolio development is relatively underestimated in economic practice, which often leads to mistaken investment decisions with negative impacts for corporate performance. This development is normally done assuming certainty, i.e. in one possible scenario of future development. In portfolio optimization, the multi-criteria character of the task is seldom respected. The evaluation of the projects usually occurs in isolation without interconnection to the other projects or without including the dependencies between them.

Project portfolio optimization under risk is possible either in the form of deterministic equivalents of the project portfolio optimization problems under risk, or by using stochastic optimization.

In the first approach, either the value of the portfolio in the form of its multi-criteria evaluation or the value of the selected important criterion of the evaluation in compliance with the constraints is maximised. It is further possible to maximise also the likelihood of surpassing the target values of the criterion or optimize the risk with randomly variable restrictions.

The second approach is the application of simulation techniques (Monte Carlo simulation) in a stochastic project portfolio optimization. A reduction of the demanding nature of these methods can be attained by using suitable software tools. The outputs of an optimization based on a simulation are efficient portfolios, i.e. portfolios lying on the efficient frontier. Optimization can be further used for the analysis of the influence of raising the resource limits on the portfolio effects, for maximising or minimising the likelihood of surpassing the target value of the criterions etc.

The utilisation of these instruments for project portfolio optimization under risk definitely does not lower the weight of the manager himself/herself. The key decision of which portfolio to select, namely either in a non-formalised way (based on a portfolio evaluation according to individual criteria), or using the methods of multi-criteria evaluation of alternatives, is then up to the manager.

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