THE OPTIMIZATION OF A PROJECT PORTFOLIO DEVELOPMENT UNDER RISK

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Abstract

The paper is focused on a project portfolio development under risk, where low-quality of this development can lead to catastrophic consequences on corporate performance and long-term prosperity. In the first part of this article the shortcomings of project portfolio development and management are specified. Further the article covers a development of the portfolio. In the phase of the portfolio development the article highlights a key link to corporate strategy, specification of resource constraints, multi-criteria approach to the evaluation of projects with respect to the balance of the portfolio. Emphasis is put on the evaluation of all projects in the most common scenario and future development scenarios, respectively, all which improves the comparability of evaluation of projects.

The goal of the third part of the article is to specify the problem of the project portfolio optimization under risk (optimal allocation of scarce resources). The first approach is based on deterministic equivalents of stochastic optimization using bivalent programming (multi-criteria optimization and single-criterion optimization); the second approach is based on Monte Carlo simulation. Applying the second model approach is illustrated with an example.

Key words: Project Portfolio Development. Simulation Monte Carlo. Portfolio Optimization. Efficient Portfolio. Efficient Frontier.

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Introduction

The experience and knowledge of economic practice show significant disadvantages in project portfolio management of investment projects that are in a form of investment, research or other programs. These shortcomings are pointed e.g. by 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). As a result, there can be wrong investment decisions with more or less significant negative impact on corporate performance and business prosperity.

The process of project portfolio development can be formalized, put into the regulatory framework (Sanval, 2007). For optimization it the deterministic equivalents of stochastic optimization using utility function can be used (more about utility function Fotr & Švecová et al., 2010, pp. 163 – 195). A suitable approach is also stochastic optimization using Monte Carlo simulation (more about the simulation see e.g. Mun, 2010, pp. 85 – 90).

1 Character of Project Portfolio Development

Typical tasks of project portfolio development be characterized as **research projects** (research and development of new products, technologies, processes, etc.), or **investment projects** (extensions, reconstruction of production facilities, innovative production technology, introduction of new products, innovations, information systems, etc.). Implementation of each project requires investment of certain resources and therefore the problem of the portfolio development is simultaneously a **resource allocation problem** (usually limited resources). If we follow maximization or minimization of certain characteristic of the portfolio during its development, then it is an optimization task in the form of optimal resource allocation.

Project portfolio development has usually some common elements, which include especially:

- **Multicriteria character** of task, because more targets are usually observed simultaneously, which achievement levels are expressed through the individual evaluation criteria.
- The **uncertainty** of some variables affecting the projects results and hence their success, so the projects are risky.
- The **limited resources** leading to the individual projects were not assessed in isolation, since the acceptation of a certain project reduces available resources for other projects. Scarcity also raises the need for optimization tools.
- **Dependence between projects**, which should be respected. The dependence of the portfolio can have either the character of statistical dependence (direct or indirect dependence with varying intensity expressed with correlation coefficients of pairs of investment projects) or a certain type of functional dependence (e.g. a project can be included into the portfolio only in case another particular project was also included).

2 Shortcomings of Project Portfolio Development in Economic Practice

Development and management of the portfolio of projects, which is in a form of investment program, research program, etc.; is accompanied by many shortcomings, from which the most serious are as follows[1]:

- **Absence of projects contribution to reach strategic corporate objectives**, which usually operates with only one criterion for selecting projects to the portfolio, usually of a financial nature, and neglect the non-financial criteria.
- Projects are **evaluated** and included into the portfolio **independently**, irrespective of their mutual relations, whether deterministic or stochastic nature.
- **Avoiding** harsh decisions leading to **rejection** of certain projects.
- The portfolio consists of **too many projects**. It is caused by excessive investment in smaller incremental projects and lack of focus on riskier growth and innovation projects.
- The portfolio contains **inappropriate projects** with little or no benefit for the company.
- The **different level of risk** of individual projects **is not respected**.
- The portfolio is often **unbalanced**.
- Significantly **decentralized approach**, where the company portfolio is created based on the best projects from different business units, divisions, etc. However, this approach usually does not lead to the optimal portfolio structure at the corporate level.
- Portfolio development is mainly of **intuitive nature** without the application of analytical tools based on quantitative data.
- The projects portfolio is not explicitly documented and controlled.
- The political nature[2] of portfolio development process may often have negative effects. Instead of rational decision-making process a low transparent process of promotion of local interests, compromising, the use of force, etc often takes place.

3 The Process of Project Portfolio Development

3.1 The Specification of Normative Framework of Portfolio Development

An effective project portfolio development process requires a normative framework. This normative framework should mainly include requirements on the specification multi-criteria

[1] Some of these shortcomings are pointed out by source books 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).

[2] For example a research (see Kendall & Rollins, 2003, p. 253) led to the fact, that at 40 % of incremental projects and 90 % of discontinuous innovation, the portfolio's decision-making politicization caused failure to meet their goals.

evaluation of projects, resource constraints, the portfolio balance and the creation of the common scenario.

Processing the multi-criteria evaluation needs to establish sets of criteria, weights, set a rating scale for evaluation of projects, specify the transformation criteria into a non-dimensional expression and set the relationship to calculate the overall ranking of projects (Fotr & Švecová et al., 2010, pp. 178 -186).

Companies usually have a larger number of projects than available **resources** for implementation. Therefore these resources should be specified in terms of their types and their available quantities should be determined. Basic types of resources are financial (capital) resources, human resources and other sources.

A prerequisite for achieving the project portfolio balance is a **categorization of projects**, which will then allow allocating limited resources to individual groups of projects and assessing the overall profitability of projects within each category. E.g. projects can be divided into development projects of strategic character oriented to expansion, renewal projects, rationalization projects or mandatory projects.

In order to increase the comparability of results a **common scenario** the important external factors common to all or at least for most projects shall be developed.

3.2 Project Portfolio Development

The process of selecting projects in the portfolio itself includes three activities. These are benchmark allocation of scarce resources across the projects categories, creation of portfolios within each category of projects and activities aimed at achieving balanced portfolio, combined with possible reallocation of resources among to the project categories. These activities do not constitute a direct sequence but are repeated in the cycle until a final portfolio of sub-portfolios formed according to the categories of projects is reached.

A benchmark resource allocation to project categories is the first step of portfolio composition and affects its balance. Limited resources are divided among different categories of projects, mostly using a non-formalized approach based on experience and knowledge.

The optimization approaches based on bivalent models or stochastic programming, based on the results of multi-criteria evaluation of projects are used to **develop portfolios across project categories**.

A formalized optimization procedure does not lead to the **aggregate portfolio balance**. A non-formalized approach based on experience, expert analysis and support analysis should rather be used instead. Gradual modifications of sub-portfolios have a character of elimination of some projects and their replacement by other projects or reallocation of resources across individual projects.

3.3 Optimization of Portfolio

The project development under risk is a challenge of managerial practice, the following sections focuses on two types of project portfolio optimization problems under risk. The first approach is based on deterministic equivalents of stochastic optimization; the second approach is based on Monte Carlo simulation. The deterministic equivalents of stochastic models are used for simpler types of jobs.

3.3.1 Deterministic Equivalents Stochastic Optimization Problems

Types of deterministic equivalent in stochastic optimization tasks will vary to certain extent according to two characteristics. The first relates to the nature of the optimization in terms of evaluation criteria number, i.e. whether it is a **multi-criteria optimization or a single-criterion one**. The second characteristic is then related to the optimization model variables that have the character of **random variables**. These variables can be coefficients of a criteria function, coefficients of constraint variables or in the right side constraints. The most common and relatively simple are tasks with randomly varying coefficients of criteria functions.

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 (1) and sets of resource constraints (2).

$$\sum_{j=1}^{n} E\left[U\left(x^{j}\right)\right] \cdot y_{j} \tag{1}$$

$$\sum_{j=1}^{n} a_{kj} \cdot y_{j} \leq L_{k} \tag{2}$$

$$E\left[U\left(X^{j}\right)\right] = \sum_{i=1}^{m} v_{i} \cdot E\left[u_{i}\left(x_{i}^{j}\right)\right] \tag{3}$$

where a_{kj} – consumption of the k^{th} resource to the j^{th} project ($k = 1, 2, \ldots, p$),

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

y_j – bivalent variable acquiring the values 1 (j^{th} project is included in the portfolio) or 0 (j^{th} project is not included in the portfolio),

v_i – weight of the i^{th} criterion,

$E\left[U\left(X^{j}\right)\right]$ – mean of total utility of each project according to equation (3),

$E\left[u_{i}\left(x_{i}^{j}\right)\right]$ – means of utility level of each project due to individual criteria.

Analogically a model for bivalent programming for single-criterion character of problem can be derived. Other types of tasks can be included to maximize the probability of exceeding the target value of criteria or problem with randomly varying restrictions.

3.3.2 Stochastic Optimization using Monte Carlo Simulation with an Example

For more complex optimization problems an analytical solutions of stochastic bivalent programming is usually difficult. However, the optimization programs based on Monte Carlo simulation (a simulation of such deals Mun, 2010, pp. 85 - 90) can be successfully used.

The application of simulation is illustrated by an example of a company that produces the investment portfolio for a total of 12 prepared investment projects. This portfolio should provide the highest growth of value of the firm measured by the net present value while respecting the two scarce resources (capital budget size of CZK 560 million and a number of available workforces of 240). Number of model variables is then given by the number of projects potentially included into the portfolio. Parameters of criteria function and source constrains for each project are summarized in Table 1. The last row of the Table 1 indicates how much the available resources would be overdrawn.

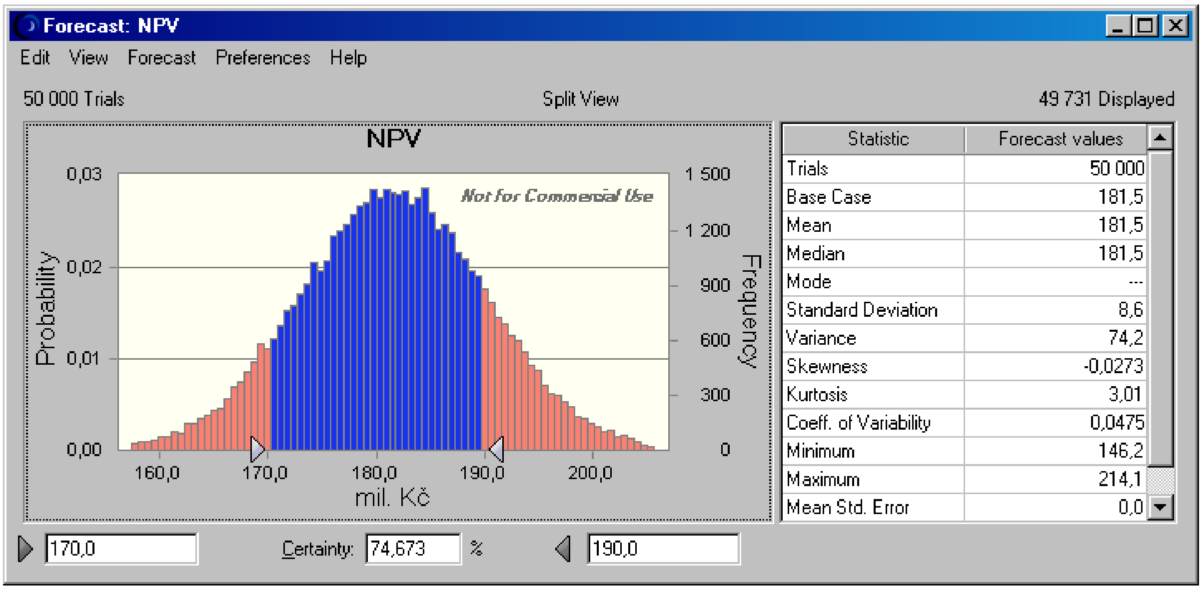
Tab. 1: Characteristic of Investment Projects

Project	NPV (million CZK)	Standard deviation of NPV (million CZK)	Investment costs (million CZK)	Number of workers
P1	22,30	3,20	31,0	23
P2	5,16	1,62	27,6	12
P3	28,21	6,67	126,8	45
P4	26,32	4,35	96,5	37
P5	15,32	1,53	55,8	25
P6	10,47	1,80	36,8	23
P7	12,30	0,94	44,7	15
P8	23,01	2,75	67,5	26
P9	15,07	2,11	49,0	24
P10	29,47	5,32	85,8	38
P11	20,24	3,91	53,3	20
P12	12,35	3,12	42,3	17
Resource limit			560,0	240
Demand			717,1	305
Overdraft			157,1	65

Source: authors

The solution of the maximization problem of the average portfolio value with two source constraints is an optimal portfolio of 10 projects (excluding projects P3 and P6). Figure 1 shows the NPV distribution function of this portfolio. Mean NPV of optimal portfolio is CZK 181.5 million and the risk expressed by a standard deviation is CZK 8.6 million. At the best case the NPV of the portfolio reaches CZK 214.1 million, in the worst case only CZK 146.2 million. The probability that the NPV of the portfolio will be between 170 and 190 million CZK is nearly 75 % (see figure in the field *Certainty* below in Figure 1).

Fig. 1: Probability distribution NPV of the optimal portfolio



Source: own calculations using Crystal Ball software system for Monte Carlo simulation

Findings portfolio risk due to its NPV was not a part of the job. An impact of gradual tightening or softening the risk of portfolio requirements (measured standard deviation of the NPV of the portfolio) was also tested by the on portfolio optimization. Thus we gradually got a few efficient portfolios maximizing the mean value of NPV at a given level of risk forming the efficient frontier (Fotr & Švecová et al., 2010, pp. 400 – 407).

Five versions of stochastic optimization have been solved with gradually softening requirements on portfolio risk (measured by standard deviation) due to its NPV. The Table 2 summarizes the results of the solution and Figure 2 shows an efficient frontier. The Table 2 shows that with the gradual softening the portfolio risk requirements increases the mean NPV of portfolios. For the first three efficient portfolios, however, their risk constraints do not allow a full use of resources. The last two efficient portfolios lead to the nearly full utilization of scarce resources. The latest efficient portfolio (EP5) leads to maximum mean NPV, this portfolio is identical with the optimal portfolio without limitation the risk, and Figure 1 shows the probability distribution of its NPV.

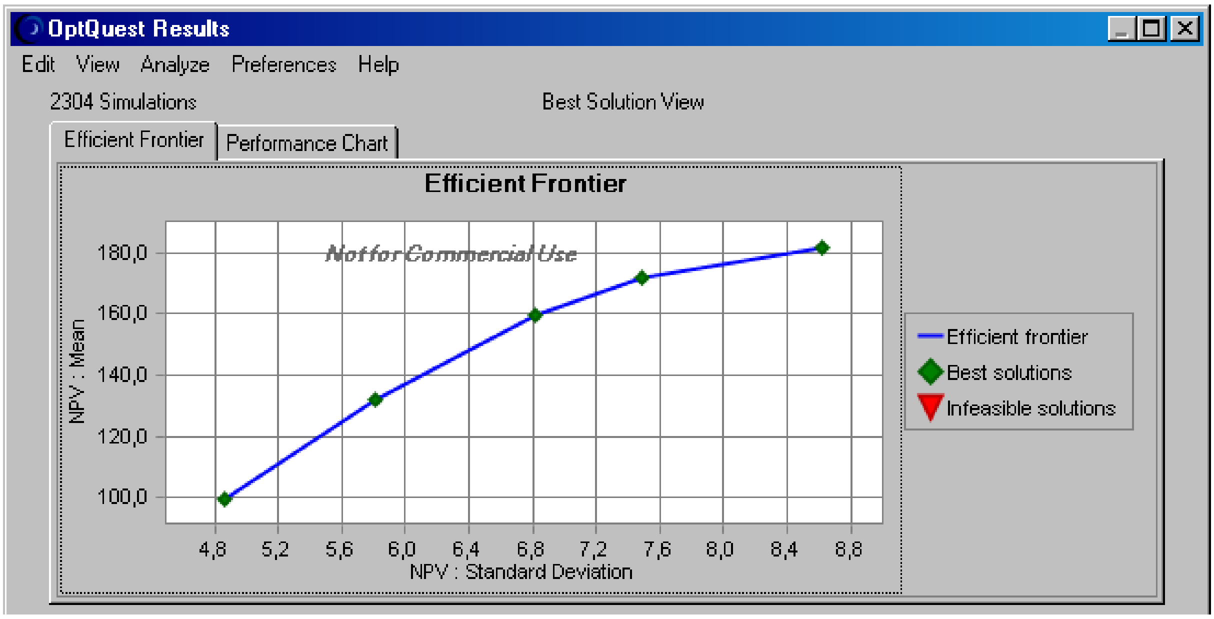
Tab. 2: The results of stochastic optimization with varying constraints on portfolio risk

Efficient portfolio	Project not included in the portfolio	Mean NPV (million CZK)	Standard deviation of NPV (million CZK)	Investment costs (million CZK)	Number of workers	increment NPV / increment risk
EP1	4 - 7, 9	99,7	4,9	336	144	
EP2	4 - 10	132,0	5,8	436	188	35,9
EP3	1, 2, 4 - 10	159,5	6,8	495	223	27,5
EP4	1, 2, 4 - 10, 12	171,8	7,5	537	240	17,6
EP5	1, 2, 4, 5, 7- 12	181,5	8,6	554	237	8,9

Source: own calculations using the OptQuest software for stochastic simulation

The Table 2 also shows that the incremental growth of mean NPV per unit of incremental growth of risk declines with increasing risk of an efficient portfolio (see last column in Table 2). This fact is confirmed by the chart of efficient portfolios in the form of efficient frontiers in Figure 2, the tangent of lines connecting each of efficient portfolios decreases from left to right.

Fig. 2: Efficient frontier



Source: own calculations using the OptQuest software for stochastic simulation

The choice of the portfolio would now depend also on the risk awareness of the decision maker (manager, respectively top management). In the non-formalized approach we first compared portfolios with each other in terms of different aspects (benefit, risk).

Formalized assessment of portfolios would require setting the significance of individual criteria in terms of their weights and subsequent application of some multi-criteria evaluation methods (see Fotr & Švecová et al., 2010, pp. 178 – 186). This approach is particularly suitable for a large number of valuated portfolios and a larger set of evaluation criteria when non-formalized approach can fail.

The previous text shows that the model of bivalent programming in combination with the stochastic optimization is a useful tool contributing to improving the quality of the project portfolio development under risk.

Conclusion

The portfolio development of investment projects in the economic practice is rather underestimated often leading to wrong investment decisions with negative impacts on corporate performance. This development is usually done assuming a certainty that the only one single possible scenario exists for future developments. Multi-character role is rarely respected in portfolio optimization. The evaluation of projects is usually isolated without linkage to other projects or without the inclusion dependencies between them.

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

In the first approach the value of the portfolio in the form of multi-criteria evaluation or the value of selected major criterion in compliance with constraints are maximized. In addition, one can also maximize the probability of exceeding the target values of the criterion or optimize risk with randomly varying restrictions.

The second approach is to use the simulation techniques (Monte Carlo) in the stochastic portfolio optimization of projects. Gear down of these approaches can be achieved by using appropriate software tools. The output of optimization based on simulation is a set of efficient portfolios, i.e. portfolios lying on the efficient frontier. Optimization can be used for further analysis of the impact of increasing the resource limits on portfolio effects, for maximizing or minimizing the probability of exceeding the target values of criterion etc.

Using these instruments for portfolio optimization under risk certainly does not reduce the weight of manager himself. The key decision of choosing the portfolio lies on them using either non-formalized approach (based on evaluation of portfolio according to the criteria) or using some of the methods for multi-criteria evaluation of alternatives.

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