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Fuzzy Optimization Models for Project Portfolio Rolling Planning Taking into Account Risk and Stakeholder Interests

Lev Solomonovich Mazelis*
Vladivostok State University of Economics and Service, Gogolya Street, 41, Vladivostok, 690014, Russia

Konstantin Sergeevich Solodukhin
Vladivostok State University of Economics and Service, Gogolya Street, 41, Vladivostok, 690014, Russia

Aleksandr Dmitrievich Tarantaev
Vladivostok State University of Economics and Service, Gogolya Street, 41, Vladivostok, 690014, Russia

Abstract

Some modified fuzzy multiperiod optimization models are proposed to support decision-making when selecting a project portfolio within an institution's strategic development program allowing for rolling planning of a project portfolio taking into account stakeholder interests and risks. Stakeholder interests are taken into consideration when setting strategic goals. Risk assessment is carried out in accordance with H. Markowitz portfolio theory using a scenario-based approach. A measure of portfolio risk is the fuzzy dispersion of its general specific utility. The developed models differ from the previously proposed fuzzy multiperiod models in possible revision of the composition of the previously selected project portfolio at every step depending on the already achieved results and changes in external and internal conditions. Another important difference is the introduction of additional fuzzy resource constraints for each time period, which are also revised at each step. In addition, constraints on fuzzy discounted costs are introduced and recalculated. Possible division of periods into subperiods is also taken into consideration. Also, at each step, fuzzy project costs are revised per period depending on whether the project is already included in the development program or not. The use of the proposed models is demonstrated based on the example of a university. Further research trends in this area are defined.

Keywords: Program for an institution's strategic development; Project portfolio; Corporate social responsibility; Stakeholder demands; Utility function; Scenario-based approach; Fuzzy model; Optimization model; Multiperiod model.

1. Introduction

The main tool in the implementation of the strategy of any institution is its investment program consisting of a defined set (portfolio) of projects competing for shared resources. One can say that a project portfolio is the translation of the company's general strategy into the project level (Kendall and Rollins, 2003).

Methods and models used in selection of projects for a portfolio play an important role in the portfolio formation. Most economic and mathematical methods of project selection are based on the use of various financial indicators of potential projects. However, financial indicators are not always key ones both in terms of successful implementation of a project and in terms of achievement of strategic goals by an institution (Gergert and Pronyushkin, 2013). Putting excessive emphasis on short-term economic or financial value when assessing projects and portfolios may jeopardize the achievement of a long-term strategic value (Cooper *et al.*, 2001; March, 1994; Voss and Kock, 2013).

The rapid development of the corporate social responsibility concept has led to the wide use of its principles in the formulation of the institution's strategic goals. In its turn, this makes it necessary to take into account the relevant social criteria in project assessment and selection (Khalilzadeh and Salehi, 2017).

The modern CSR (corporate social responsibility) concept was developed from works related to the concepts of legitimacy and legitimation. The demonstration by a firm of its responsiveness to the demands of the external environment regarding its attitude towards its staff, production sustainability, etc. is, in fact, related to its desire (or need) to remain legitimate (Blagov, 2006). As a consequence, the management of a firm, seeking to prove its social responsibility (to confirm its legitimacy), have to ensure nonviolation of the interests of many individuals and groups from the firm's network, who are interested in its activities (its stakeholders). The ideological basis of the CSR concept is the stakeholder theory (Tambovtsev, 2008).

Institutions invest in projects to create value. One of the key goals of project management in terms of project portfolio is to maximize this value throughout the portfolio. However, the value is not a fixed entity, but it varies depending on how it is perceived by each stakeholder (Ang and Killen, 2016). Value is interpreted and evaluated differently by different stakeholders who can affect decision-making (Brunsson, 2007). For example, the types of values at which leaders and stakeholders aim may vary depending on the institution's strategies and goals (Winter and Szczepanek, 2008). In this regard, special in-depth case studies appear, aiming at understanding how different stakeholders perceive and express value and how value is identified in project portfolios (Ang and Killen, 2016).

*Corresponding Author

This work is a continuation of the authors' works on the optimization of the institution's project portfolio within its investment development program taking into account risk, corporate social responsibility, and stakeholder interests. The previously developed models can be divided into three groups.

The first group of models (Mazelis and Solodukhin, 2012;2013;2014;2015; Mazelis *et al.*, 2016) is based on the approach that takes into consideration the use of corporate social responsibility principles in developing strategic action plans (Maltseva, 2009a) including strategy maps (Maltseva, 2009b; Solodukhin, 2009) which makes it possible to consider the goal achievement levels reached during the implementation of projects as the utility of these projects.

The approach which implies taking into account the compliance of a project with the company's various goals when it is decided whether it should be included in the portfolio or not is rather widespread. For example, in the work (Anshin and Manaikina, 2015) projects are selected into the portfolio based on the compliance of the planned project results and the company's strategic goals in sustainable development. The matter of compliance of the company's goals with project goals was also considered in the works (Anshin *et al.*, 2008; Archibald, 1988; Avdoshin and Lifshits, 2014; Jonas, 2010; Lord, 1993; Meskendahl, 2010; Srivannaboon, 2006; Srivannaboon and Milosevic, 2006; Yu *et al.*, 2012) These and other works have also suggested various approaches to quantification of compliance of projects with strategic goals. In this regard, one should note the work (Anshin, 2015) in which the compliance of goals with projects is implemented through a sequence of steps: goal — link of the value chain — strategic result — project. The author suggests indicators of compliance of goals with the portfolio, indicators of integrated evaluation of goal achievement, and methods used to calculate them.

This approach is alternative to the one which implies the use of additional indicators to express the stakeholder value of the project, e.g. social significance and national significance (Lihosherst, 2015; Lihosherst *et al.*, 2015; S. and Terentyeva, 2009; Volgina *et al.*, 2016). The third group models consider possible changes in the relationship between the institution and its stakeholders as project implementation effects (Kozlitina and Solodukhin, 2015; Kozlitina, 2016; Kozlitina and Solodukhin, 2016; Mazelis *et al.*, 2017).

Among the project portfolio formation models, fuzzy models play a special role. Using the fuzzy set approach, one can take into account the inaccuracy of early project assessment when no accurate information on financial flows and resource costs is available, as well as provide an expert evaluation of nonfinancial indicators of the project in linguistic scales (Avdoshin and Lifshits, 2014). Fuzzy inference rules can be specified to identify changes in the characteristics of the relationship between the institution and the stakeholders through the implementation of a project (Mazelis *et al.*, 2017). Fuzzy models of project portfolio optimization with fuzzy objective functions and fuzzy constraints provide various solutions for different exogenously set satisfaction degrees (Anshin *et al.*, 2008).

The aim of this work is to develop modified fuzzy multiperiod models of project portfolio optimization allowing for rolling planning of a project portfolio taking into account stakeholder interests and risks.

2. Models

The matter of optimization of an institution's development program is considered taking into account stakeholder interests and constraints on resources and investment, as well as risks.

There are *N* projects $P_1, P_2, \ldots, P_N$ which affect *K* strategic goals $G_1, G_2, \ldots, G_K$ of the institution.

It is assumed that $G_1, G_2, \ldots, G_K$ are the goals pertaining to the top level of the strategy map ("stakeholder" perspective goals (Solodukhin, 2009), the achievement of which directly relates to the satisfaction of stakeholder demands.

To determine the fuzzy weights of the strategic goals, $w_1, w_2, \ldots, w_K$ experts may be offered a certain linguistic scale (term set of the linguistic variable "Weight of *k*-goal") with given membership functions. The obtained expert evaluations are then summarized and normalized. Strategic goals can also be ranked through fuzzy analytic hierarchy process (Emrouznejad and Ho, 2017; Van and Pedrycz, 1983) and fuzzy inference method (Novak *et al.*, 2016).

It is necessary to create an optimal project portfolio taking into account the resources available to the institution, the risk and utility of these projects.

L scenarios of possible changes in the internal and external environment $S_1, S_2, \ldots, S_L$ are being considered, where $p_1, p_2, \ldots, p_L$ are the fuzzy probabilities of these scenarios.

Each of the P_n projects is characterized by the following indicators:

- levels of goal achievement $A_n^l = \left(a_{n1}^l, a_{n2}^l, \ldots a_{nK}^l\right)$ during project implementation within the scenario S_l;
- amount necessary for the implementation of resources B_n.

Let us assume that resources are invested in the project in unequal installments over T time periods, i.e. $B_n = \sum_{t=1}^{T} B_n^t$. In a fuzzy case, B_n^t and, therefore, B_n are defined as fuzzy numbers.

In each period, there is an increase in the levels of achievement of relevant goals. Thus, there appear sequences $\left(a_{nk}^{l1}, a_{nk}^{l2}, \ldots, a_{nk}^{lT}\right), \sum_{t=1}^{T} a_{nk}^{lt} = a_{nk}^{l}, k = 1, \ldots, K, n = 1, \ldots, N, l = 1, \ldots, L$. Numbers a_{nk}^{lt} can also be fuzzy.

It is assumed that the utility of a project depends on the growth rate of the achievement of strategic objectives as a result of its implementation. But not all goals require a rapid growth of the level of their achievement. For some goals, a slow growth may be more "profitable".

It is assumed that different structures of resource investment per period differ in their preference due to the fact that the cost of resources and their availability can differ in different periods. In this regard, for each project P_n $(n = 1, \ldots, N)$, at a given fuzzy discount rate, it is possible to calculate fuzzy values of discounted costs per period B'^t_n (if periods, in their turn, consist of subperiods) and the fuzzy value of the total discounted costs B'_n ($B'_n = \sum_{t=1}^{T} B'^t_n$).

Thus, for each goal G_k within project P_n, during the implementation of scenario S_l, there is a set $\left(a_{nk}^{l1}, a_{nk}^{l2}, \ldots, a_{nk}^{lT}, B'_n\right)$ which determines $\tilde{u}_{nk}^{l}$, and the specific utility of project P_n in relation to goal G_k during the implementation of scenario S_l.

The general specific utility $\tilde{u}_n^l$ of the project P_n during the implementation of the scenario S_l is calculated as follows:

$$\tilde{u}_n^l = \sum_{k=1}^{K} w_k \tilde{u}_{nk}^l \quad (1)$$

The method for the specification of membership function $\tilde{u}_{nk}^l$ was proposed in the work (Mazelis et al., 2016).

Goal achievement levels in each period and, consequently, general specific utilities $\tilde{u}_n^l$ will be considered as fuzzy random values depending on a number of factors, which are time functions. Fuzzy dispersions of general specific utilities will be used as measures of risk $D\tilde{u}_n^l$.

Let us define binary variable y_n, taking values 0 and 1, as follows:

- y_n = 0, if project *n* is not included in the development program;
- y_n = 1, if project *n* is included in the development program.

The following scheme is used for creating an optimal portfolio:

For each N project in question, the costs in each *T* time period in question are fuzzily determined, and fuzzy discounted costs are calculated for the project.

The fuzzy weighting coefficients K of top level strategic goals are determined.

A set of fuzzy scenarios $S_1, S_2, \ldots, S_L$ is determined and the probability of each of them $p_1, p_2, \ldots, p_L$ is fuzzily assessed.

For each scenario, for each project, its fuzzy specific utility in relation to each goal is determined, and the fuzzy general specific utility of the project using formula (1) is calculated.

The fuzzy expectation of the utility of project *n* is found:

$$m_n = E(\tilde{u}_n^l) = \sum_{l=1}^{L} \tilde{u}_n^l p_l \quad (2),$$

as well as fuzzy elements of the covariance matrix of specific utility of projects *i* and *j*:

$$v_{ij} = \sum_{l=1}^{L} (\tilde{u}_i^l - m_i)(\tilde{u}_j^l - m_j) p_l \quad (3)$$

The upper limit for available resources B_0 is fuzzily specified.

Portfolio utility $m_{port}=\sum_{i=1}^{N} y_i m_i$, portfolio risk $\sigma_{port}^2=\sum_{i,j=1}^{N} y_i y_j v_{ij}$.

Model 1. The institution's development program is formed based on the maximum expected specific utility under constraints on the program risk magnitude and the amount of resources required for the program implementation:

$$\begin{cases} \sum_{i=1}^{N} y_i m_i \to \max, \\ \sum_{i,j=1}^{N} y_i y_j v_{ij} \le \sigma_0^2, \\ \sum_{i=1}^{N} y_i B_i' \le B_0. \end{cases} \quad (4)$$

Model 2. The institution's development program is formed based on the minimum program risk under constraints on the amount of resources required for the implementation of the program, and the expected specific utility magnitude:

$$\begin{cases} \sum_{i,j=1}^{N} y_i y_j v_{ij} \to \min, \\ \sum_{i=1}^{N} y_i m_i \ge m_0, \\ \sum_{i=1}^{N} y_i B_i' \le B_0. \end{cases} \quad (5)$$

Let us introduce additional fuzzy resource constraints for each time period into the model. Let B'^t_0 be fuzzy upper constraints in period t on total discounted costs for all projects included in the development program. Then the optimal portfolio formation models change as follows.

Model 3.

$$\begin{cases} \sum_{i=1}^{N} y_i m_i \to \max, \\ \sum_{i,j=1}^{N} y_i y_j v_{ij} \le \sigma_0^2, \\ \sum_{i=1}^{N} y_i B'^1_i \le B'^1_0, \dots, \sum_{i=1}^{N} y_i B'^T_i \le B'^T_0. \end{cases} \quad (6)$$

Model 4.

$$\begin{cases} \sum_{i,j=1}^{N} y_i y_j v_{ij} \to \min, \\ \sum_{i=1}^{N} y_i m_i \ge m_0, \\ \sum_{i=1}^{N} y_i B'^1_i \le B'^1_0, \dots, \sum_{i=1}^{N} y_i B'^T_i \le B'^T_0. \end{cases} \quad (7)$$

The formulated models for the formation of an optimal project portfolio of an institution's development program represent fuzzy Boolean quadratic programming problems. These problems are reduced to crisp Boolean quadratic programming programs by means of the techniques described in the works (Anshin *et al.*, 2008; Dubois and Prade, 1988; Wang and Hwang, 2007) and can then be solved by means of standard methods. The crisp optimization problems corresponding to fuzzy problems (4) and (5) are given in the work Mazelis *et al.* (2016). The crisp optimization problems corresponding to fuzzy problems (6) and (7) are formulated the same way.

For each project portfolio, which is a solution of crisp optimization problems, its fuzzy risk, fuzzy value, and fuzzy budget are calculated. The obtained fuzzy characteristics of a portfolio, if necessary, can be reduced to crisp ones by means of defuzzification.

Models (6) and (7) allow for review of the portfolio composition at each step depending on the already achieved results and changes in external and internal conditions. The need to revise the composition of the project portfolio is related to the fact that, under the new conditions, the fuzzy weights of goals as well as the scenarios being considered may change (their number and probabilities). Moreover, fuzzy specific utility of projects may also change relative to each goal. Accordingly, fuzzy general specific utilities of projects change as well. Fuzzy discounted costs of projects also changes, both for projects which are being implemented (due to the clarification of various parameters of the external and internal environment, possible change of prices for resources, changes of fuzzy discount rate and alignment of costs to the new point in time) and for those not yet included in the development program (for the same reasons).

As a result, a situation may occur where it would be more reasonable to cancel some projects. The resources which in this case become available allow the projects not selected for the program previously to be included in it.

It is therefore proposed to carry out an analysis and build an optimal portfolio based on the above mentioned scheme at each step (at the beginning of each of the T time periods). Note that it is possible to vary the planning horizon. It is possible to reduce the number of time periods by one at each step. However, the number of time periods may stay the same; then the planning is "rolling".

3. Results

The use of the crisp and fuzzy multiperiod models, previously developed by the authors, including the crisp rolling planning models, was demonstrated based on the university practices. The use of the same basic example made it possible to compare the models and demonstrate their benefits, as well as the peculiarities of using fuzzy tools more clearly. In this regard, this work uses the same example for testing the new models.

Thus, the three strategic goals with normalized fuzzy weights <0.15, 0.22, 0.41, 0.57>, <0.08, 0.13, 0.29, 0.43> and <0.31, 0.39, 0.65, 0.86>, respectively, are considered (let us remind that trapezoidal fuzzy numbers are used in calculations).

In addition, three scenarios of possible changes in the internal and external environment (pessimistic, realistic, and optimistic) with normalized fuzzy probabilities <0.11, 0.23, 0.33, 0.57>, <0.38, 0.50, 0.72, 1.00> and <0.04, 0.09, 0.17, 0.29>, respectively, are considered.

Let us also consider the same nine strategic activities (projects), which, if implemented in two periods (two years each), will contribute to the achievement of the selected goals.

For each project, the necessary costs were fuzzily determined per period, and fuzzy discounted costs with fuzzy discount rate <0.090, 0.100, 0.100, 0.115> were calculated. The costs were discounted to the initial point in time. Discounting was carried out for four time periods (four years). It was assumed that in each subperiod (year) within a two-year period the costs were the same. The results obtained are shown in Table 1.

Table-1. Project costs (million rubles)

Project №	Period 1	Period 2	Discounted costs (period 1)	Discounted costs (period 2)
1	<8, 8, 8, 8>	<7, 8, 8, 10>	<7.59, 7.64, 7.64, 7.67>	<5.34, 6.31, 6.31, 8.07>
2	<14, 14, 14, 14>	<13, 14, 14, 17>	<13.28, 13.36, 13.36, 13.42>	<9.92, 11.04, 11.04, 13.72>
3	<10, 10, 10, 10>	<5, 6, 6, 8>	<9.48, 9.55, 9.55, 9.59>	<3.81, 4.73, 4.73, 6.46>
4	<10, 10, 10, 10>	<6, 8, 8, 11>	<9.48, 9.55, 9.55, 9.59>	<4.58, 6.31, 6.31, 8.88>
5	<0.3, 0.3, 0.3, 0.3>	<0.15, 0.2, 0.2, 0.3>	<0.28, 0.29, 0.29, 0.29>	<0.11, 0.16, 0.16, 0.24>
6	<4, 4, 4, 4>	<3.5, 4, 4, 5>	<3.79, 3.82, 3.82, 3.83>	<2.67, 3.16, 3.16, 4.03>
7	<4.8, 4.8, 4.8, 4.8>	<4.5, 4.8, 4.8, 5.5>	<4.55, 4.58, 4.58, 4.60>	<3.43, 3.79, 3.79, 4.44>
8	<0.3, 0.3, 0.3, 0.3>	<0.3, 0.3, 0.3, 0.5>	<0.28, 0.29, 0.29, 0.29>	<0.23, 0.24, 0.24, 0.40>
9	<2.5, 2.5, 2.5, 2.5>	<3, 3.5, 3.5, 4.5>	<2.37, 2.39, 2.39, 2.40>	<2.29, 2.76, 2.76, 3.63>

Note that the costs per project in the first period are crisp numbers since it is possible to determine them relatively accurately. However, discounted costs will be represented by fuzzy numbers due to the fuzzy discount rate. For each subsequent period, such "blurriness" will be even greater. When revising the portfolio composition at each step (at the beginning of each period), the "blurriness" of fuzzy project costs will, on the contrary, decrease, as a rule (unless, of course, the uncertainty of the external environment parameters defining project costs increases significantly in the previous period).

The sequences of increments of goal achievement levels per period for each scenario are being fuzzily specified. For each goal, fuzzy values of specific utility are determined. The fuzzy general specific utilities of projects are calculated during the implementation of each scenario, and fuzzy expectations of project utilities. A fuzzy covariance matrix of project specific utilities is built. The relevant data for the example in question are provided in the work (Mazelis et al., 2016).

In order to reduce fuzzy optimization problems 3 and 4 to crisp optimization problems, it is again necessary to specify the satisfaction degrees for the objective function and each constraint. As before, these satisfaction degrees are specified as equal ($\gamma = 0.95$). For a specified satisfaction degree, crisp Boolean quadratic programming problems are formulated and solved.

Table 2 shows some results of the third model application when a university development program is formed based on the maximum expected specific utility under constraints on the amount of program risk and the amount of resources required for the implementation of the program in each period. Various options of dividing the total fuzzy budget into periods were considered.

Table-2. Simulation the formation of a university development program (maximization of expected utility, model 3)

Auxiliary bound applied to discounted costs per period (million rubles)		Auxiliary bound applied to project portfolio risk	Numbers of projects included in the portfolio	Project portfolio risk	Expected utility of project portfolio	Total discounted costs of project portfolio (million rubles)
1st period	2nd period					
33.42	27.84	8.05	3, 4, 6, 7, 8, 9	0.117	0.660	30.16
		9.66	1, 4, 5, 7, 8, 9	0.145	0.740	24.72
		12.08	3, 4, 5, 6, 7, 8, 9	0.173	0.797	30.45
		15.78	3, 4, 5, 6, 7, 8, 9	0.173	0.797	30.45
28.64	31.79	8.05	3, 4, 5, 8, 9	0.112	0.660	22.05
		9.66	1, 4, 5, 7, 8, 9	0.145	0.740	24.72
		12.08	3, 4, 5, 7, 8, 9	0.149	0.748	26.63
		15.78	3, 4, 5, 7, 8, 9	0.149	0.748	26.63
38.19	27.84	8.05	3, 4, 6, 7, 8, 9	0.117	0.660	30.16
		9.66	1, 4, 5, 7, 8, 9	0.145	0.740	24.72
		12.08	3, 4, 5, 6, 7, 8, 9	0.173	0.797	30.45
		15.78	3, 4, 5, 6, 7, 8, 9	0.173	0.797	30.45
28.64	35.74	8.05	3, 4, 5, 8, 9	0.112	0.660	22.05
		9.66	1, 4, 5, 7, 8, 9	0.145	0.740	24.72
		12.08	3, 4, 5, 7, 8, 9	0.149	0.748	26.63
		15.78	3, 4, 5, 7, 8, 9	0.149	0.748	26.63

Let us consider the procedure of revision of the university's development program after the first two-year period.

Based on the results of the university's development in the first period and the changes in the internal and external conditions, the fuzzy weights of goals and the fuzzy probabilities of scenarios are revised and normalized. Now, let the normalized weights of goals be equal to <0.19; 0.26; 0.47; 0.64>, <0.12; 0.17; 0.35; 0.50> and <0.23; 0.30; 0.53; 0.71>, respectively, the normalized probabilities of scenarios will be equal to <0.15; 0.27; 0.39; 0.64>, <0.31; 0.41; 0.61; 0.86> and <0.08; 0.14; 0.22; 0.36>, respectively. Generally speaking, the number of scenarios under consideration may also change. However, in this example, as it was in the testing of the corresponding crisp model, the number of scenarios does not change.

One should also revise the project costs per period and reduce them to a new point in time (Table 3). The fuzzy discount rate may change as well (in the example, it is not changed for the sake of simplicity). Table 3 shows the changed costs per project provided they were not selected into the portfolio in the first period. Table 4 shows the changed costs in the second period for the projects which were implemented in the first period (were selected into the portfolio).

Table-3. Project costs after the end of the first period if not implemented in the first period (million rubles)

Project №	Period 2	Period 3	Discounted costs (period 2)	Discounted costs (period 3)
1	<8.5, 8.5, 8.5, 8.5>	<7, 9, 9, 10>	<8.06, 8.11, 8.11, 8.15>	<5.34, 7.10, 7.10, 8.07>
2	<13, 13, 13, 13>	<12, 13, 13, 15>	<12.33, 12.41, 12.41, 12.46>	<9.15, 10.26, 10.26, 12.10>
3	<11, 11, 11, 11>	<6, 7, 7, 8>	<10.43, 10.50, 10.50, 10.55>	<4.58, 5.52, 5.52, 6.46>
4	<10.5, 10.5, 10.5, 10.5>	<5.5, 7, 7, 10>	<9.96, 10.02, 10.02, 10.07>	<4.20, 5.52, 5.52, 8.07>
5	<0.3, 0.3, 0.3, 0.3>	<0.2, 0.25, 0.25, 0.3>	<0.28, 0.28, 0.28, 0.28>	<0.15, 0.20, 0.20, 0.24>
6	<3.8, 3.8, 3.8, 3.8>	<3, 3.5, 3.5, 4.5>	<3.60, 3.63, 3.63, 3.64>	<2.29, 2.76, 2.76, 3.63>
7	<4, 4, 4, 4>	<3.5, 4, 4, 5>	<3.79, 3.82, 3.82, 3.83>	<2.67, 3.16, 3.16, 4.03>
8	<0.3, 0.3, 0.3, 0.3>	<0.2, 0.25, 0.25, 0.4>	<0.28, 0.29, 0.29, 0.29>	<0.15, 0.20, 0.20, 0.32>
9	<2.8, 2.8, 2.8, 2.8>	<3.2, 3.6, 3.6, 4>	<2.66, 2.67, 2.67, 2.68>	<2.44, 2.84, 2.84, 3.23>

Table-4. Project costs after the end of the first period in the second period if implemented in the first period (million rubles)

Project №	Period 2	Discounted costs (period 2)
1	<9, 9, 9, 9>	<8.54, 8.59, 8.59, 8.63>
2	<15, 15, 15, 15>	<14.23, 14.32, 14.32, 14.38>
3	<6, 6, 6, 6>	<5.69, 5.73, 5.73, 5.75>
4	<7, 7, 7, 7>	<6.64, 6.68, 6.68, 6.71>
5	<0.25, 0.25, 0.25, 0.25>	<0.23, 0.24, 0.24, 0.24>
6	<4, 4, 4, 4>	<3.79, 3.82, 3.82, 3.83>
7	<5, 5, 5, 5>	<4.74, 4.77, 4.77, 4.79>
8	<0.4, 0.4, 0.4, 0.4>	<0.38, 0.38, 0.38, 0.38>
9	<4, 4, 4, 4>	<3.79, 3.82, 3.82, 3.83>

New specific utilities of projects are defined for each goal (including progress in goal achievement in the first period), general specific utilities of projects for each scenario and expectations of project utilities are calculated (Table 5), and a new fuzzy covariance matrix of specific utilities of projects is built.

Table-5. Fuzzy general specific utilities of projects after the end of the first period

Project №	General specific utility of project			Expectation of project utility
	Scenario 1	Scenario 2	Scenario 3	
1	<0.027, 0.045, 0.093, 0.156>	<0.042, 0.066, 0.142, 0.223>	<0.047, 0.084, 0.167, 0.259>	<0.021, 0.051, 0.160, 0.384>
2	<0.016, 0.027, 0.061, 0.096>	<0.021, 0.039, 0.084, 0.127>	<0.031, 0.049, 0.111, 0.167>	<0.011, 0.030, 0.100, 0.230>
3	<0.026, 0.048, 0.100, 0.159>	<0.040, 0.069, 0.142, 0.223>	<0.050, 0.085, 0.181, 0.263>	<0.020, 0.053, 0.166, 0.387>
4	<0.054, 0.087, 0.178, 0.290>	<0.065, 0.102, 0.197, 0.317>	<0.072, 0.113, 0.230, 0.355>	<0.034, 0.081, 0.241, 0.585>
5	<0.040, 0.066, 0.127, 0.201>	<0.052, 0.086, 0.180, 0.276>	<0.069, 0.110, 0.215, 0.339>	<0.028, 0.068, 0.207, 0.487>
6	<0.012, 0.020, 0.039, 0.063>	<0.020, 0.032, 0.065, 0.104>	<0.028, 0.047, 0.093, 0.140>	<0.010, 0.025, 0.076, 0.180>
7	<0.022, 0.036, 0.072, 0.112>	<0.037, 0.061, 0.118, 0.186>	<0.048, 0.083, 0.164, 0.253>	<0.018, 0.046, 0.137, 0.322>
8	<0.042, 0.069, 0.134, 0.194>	<0.062, 0.089, 0.182, 0.272>	<0.071, 0.106, 0.213, 0.351>	<0.031, 0.070, 0.211, 0.483>
9	<0.023, 0.035, 0.070, 0.100>	<0.040, 0.059, 0.113, 0.179>	<0.051, 0.076, 0.143, 0.236>	<0.020, 0.044, 0.128, 0.302>

The results of the revision of the university's development program in accordance with the third model are shown in Table 6. A significant reduction in the constraints on costs in the third period is due to the completion of some projects selected in the first period.

Table-6. Simulation the revision of a university development program after the first period (maximization of expected utility, model 3)

Auxiliary bound applied to discounted costs per period (million rubles)		Auxiliary bound applied to project portfolio risk	Numbers of projects included in the portfolio	Project portfolio risk	Expected utility of project portfolio	Total discounted costs of project portfolio (million rubles)
2nd period	3rd period					
30.55	19.95	8.05	4, 5, 6, 7, 8, 9	0.124	0.652	17.54
		9.66	1, 4, 5, 7, 8, 9	0.145	0.707	20.03
		12.08	1, 3, 4, 5, 6, 8, 9	0.176	0.776	24.00
		15.78	1, 3, 4, 5, 7, 8, 9	0.197	0.817	24.77
31.59	23.90	8.05	4, 5, 6, 7, 8, 9	0.124	0.652	17.54
		9.66	1, 4, 5, 7, 8, 9	0.145	0.707	20.03
		12.08	1, 3, 4, 5, 7, 8, 9	0.197	0.817	24.77
		15.78	1, 3, 4, 5, 7, 8, 9	0.197	0.817	24.77
30.55	19.95	8.05	4, 5, 6, 7, 8, 9	0.124	0.652	17.54
		9.66	1, 4, 5, 7, 8, 9	0.145	0.707	20.03
		12.08	1, 3, 4, 5, 6, 8, 9	0.176	0.776	24.00
		15.78	1, 3, 4, 5, 7, 8, 9	0.197	0.817	24.77
35.54	27.84	8.05	3, 4, 5, 6, 8, 9	0.130	0.672	17.69
		9.66	2, 4, 5, 6, 7, 8, 9	0.153	0.717	28.59
		12.08	1, 4, 5, 6, 7, 8, 9	0.169	0.756	23.85
		15.78	1, 3, 4, 5, 6, 7, 8,9	0.225	0.866	28.59

As already noted, the satisfaction degree γ defines the form of a crisp objective function and the severity of constraints and, therefore, has an impact on the composition of the portfolio and its assessment. The more γ is, the less the blurriness of the fuzzy parameters of the model, i.e. uncertainty, is taken into account.

Table 7 shows the changes in the composition of an optimal project portfolio at different γ (maximization of utility, model 3) with the same fuzzy constraints on the portfolio risk, as well as changes in the discounted costs per period.

Table-7. Simulation the formation of a university development program with different satisfaction degrees (maximization of utility, model 3)

γ	Period	Numbers of projects included in the portfolio	Project portfolio risk projects	Expected utility of project portfolio	Total discounted costs of project portfolio (million rubles)
0.70	1	2, 4, 5, 6, 8, 9	0,116	0.666	29.69
	2	4, 5, 6, 7, 8, 9	0,131	0.671	17.54
0.75	1	1, 3, 5, 7, 8, 9	0,135	0.678	24.72
	2	4, 5, 6, 7, 8, 9	0,130	0.669	17.54
0.80	1	1, 3, 5, 7, 8, 9	0,135	0.678	24.72
	2	4, 5, 6, 7, 8, 9	0,130	0.669	17.54
0.85	1	1, 3, 5, 7, 8, 9	0,135	0.678	24.72
	2	4, 5, 6, 7, 8, 9	0,130	0.669	17.54
0.90	1	3, 4, 6, 7, 8, 9	0,117	0.660	30.16
	2	4, 5, 6, 7, 8, 9	0,129	0.666	17.54
0.95	1	3, 4, 6, 7, 8, 9	0,117	0.660	30.16
	2	4, 5, 6, 7, 8, 9	0,124	0.652	17.54
0.99	1	3, 4, 5, 8, 9	0,112	0.660	22.05
	2	4, 5, 6, 7, 8, 9	0,129	0.667	17.54

If necessary, it is possible to find more accurate values γ at which the composition of portfolios changes. In particular, such values γ include 0.981 and 0.871 (the composition of the portfolio changes in the first period), as well as 0.724 (the composition of the portfolios changes in both periods).

4. Conclusion

The suggested modified fuzzy multiperiod optimization models allow for rolling planning of a project portfolio taking into account risk within an institution's strategic development program. Stakeholder interests are taken into consideration when setting strategic goals. Risk assessment is carried out in accordance with H. Markowitz portfolio theory using a scenario-based approach. In this case, a measure of portfolio risk is the fuzzy dispersion of its general specific utility.

The developed models differ from the previously proposed fuzzy multiperiod models in possible revision of the composition of the previously selected project portfolio at every step depending on the already achieved results and changes in external and internal conditions. Another important difference is the introduction of additional fuzzy resource constraints for each time period, which are also revised at each step. In addition, constraints on fuzzy discounted costs are introduced and recalculated. The calculation of the fuzzy discounted costs takes into account possible division of periods into subperiods. Also, at each step, fuzzy project costs per period are reconsidered depending on whether the project was selected in the portfolio at the previous step or not.

Further research in this area can be carried out in the following directions. Firstly, a fuzzy model can be developed allowing to optimize the distribution of the total budget of an institution's program among periods. Secondly, a procedure of resource reallocation among projects can be suggested, implying that some projects are not excluded from the portfolio, but their funding may be reduced, or they may be temporarily cancelled. Due to the resources which, in this case, become available, other projects of the program can be funded, or new ones can be included in it. Thirdly, taking into consideration the stakeholder interests, the suggested models can take into account possible changes in their relationship with the institution and with each other in different time periods.

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