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Multi-Period Models for Optimizing an Institution's Project Portfolio Inclusive of Risks and Corporate Social Responsibility

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Abstract: The article proposes specific multi-period optimization models for supporting making decisions in selecting a project portfolio as part of the program for an institution's strategic development. The allowance for risks is made under the portfolio theory by H. Markowitz using the scenario-based approach. For the target function the author uses a general per-unit utility function whose arguments are levels of attainment of the institution's strategic objectives as a result of implementing the project across periods with allowance for the significance of objectives and the size of present expenditures on the project, as well as the overall volume of necessary resources. It is expected that the utility of the project will depend on the way increases in the levels of attaining strategic objectives unfold across the periods, while different objectives would preferably require a different pace of increase in their levels. It is also expected that different structures for investing resources across periods will be distinguished in preference. The institution's corporate social responsibility is brought out when objectives are set inclusive of the interests of all the parties interested.

Key words: Program for an institution's strategic development · Project portfolio · Corporate social responsibility · Utility function · Scenario-based approach

INTRODUCTION

One of the major objectives of strategic management in an institution is putting together a program for strategic development. And implementing a development program is a no less important and, as experience shows, complex task.

Implementing a development program comes down, in the end, to effecting a certain number of projects for reconstruction and development (strategic activities), the result of implementing which is the attainment (to a certain degree) of the institution's strategic objectives. In this regard, existing limitations on resources (including time) engender the need of resolving the issue of the beforehand selection of projects. In selecting projects, of no less importance than resource limitations should be assessments of all possible consequences of and risks arising as a result of these limitations, especially amid rising levels of uncertainty.

An approach that is inclusive of the need of using the principles of corporate social responsibility in working out strategic plans for activity [1], including strategic objective maps for objectives [2, 3], makes it possible to consider the levels of attaining objectives, which were attained as a result of implementing projects, as the utility of these projects. As a result, the need of the artificial inputting of indicators which reflect the social significance of projects goes away ([4]).

Main Part: This work [5] proposes one-period models for optimizing the project portfolio as part of the investment program for development inclusive of the corporate social responsibility of an institution that follows stakeholder management practices as a discrete institutional alternative (through the example of a university). In decision making, the models are inclusive, beside economic indicators and risks, of the utility of projects for the institution's stakeholders.

In this work, one-period models are summarized across several time periods due to that the pace of attaining different strategic objectives has different gradations of value for the institution.

Thus, the article addresses the objective of optimizing the program for the institution's development inclusive of corporate social responsibility and limitations

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on resources, investment volumes, as well as risks. We'll still consider this objective as one related to portfolio investment [6, 7].

Let the institution have N projects $P_1, P_2,...,P_N$, which influence K strategic goals G_1, G_2, G_K.

The article [3] proposes an approach to putting together a strategic objective map for the institution, which eliminates the inequality of groups of interested parties, which is laid down in the "classic" version of the *balanced scorecard* by R. Kaplan and D. Norton. We'll assume that $G_1, G_2,...,G_K$ are objectives of the upper level of the strategic map (objectives of the "stakeholder" perspective), the attainment whereof is immediately related to satisfying the requests of stakeholders. These objectives can be considered independent since there are no direct cause-and-effect linkages between them (such linkages are at the level of perspectives below). When setting goals, differences in the interests of stakeholders are taken into account [8, 9].

It's assumed that objectives differ in significance (importance) from the standpoint of their impact upon the institution's mission. The weights of objectives $w_1, w_2,...,w_k$ can be determined using the method examined in the same article.

We need, with allowance for resources the institution possesses, risks associated with the projects and the projects' utility, to form an optimum portfolio for these projects.

For modeling internal and external conditions, we'll use the scenario-based approach: we'll examine L scenarios for possible changes in the internal and external environment $S_1, S_2,...., S_L$ where $p_1, p_2,...., p_L$ are the probabilities of these scenarios.

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

- The levels of attainment of objectives $A_n^l = \left(a_{n1}^l, a_{n2}^l, \ldots a_{nK}^l\right)$ in implementing the project as part of the scenario S_l;
- The volume of resources necessary for implementation B_n.

Let's assume that investing resources as part of the project is effected unevenly over T time periods, i.e. $B_n = \sum_{t=1}^{T} B_n^t$.

In that regard, each period sees an increase in the levels of attainment of corresponding objectives. Thus, we get the sequences.

$$\left(a_{nk}^{l1}, a_{nk}^{l2}, \ldots, a_{nk}^{lT}\right), \sum_{t=1}^{T} a_{nk}^{lt} = a_{nk}^{l}, k = 1, \ldots, K, n = 1, \ldots, N, l = 1, \ldots, L$$

In one-period models, the utility of the project P_n in implementing the scenario S_l was construed as an integral indicator that characterized the level of attainment of all the objectives inclusive of their significance:

$$u_n^l = \sum_{k=1}^{K} w_k a_{nk}^l \quad (1)$$

In that regard, the notion of the per-unit utility of the project P_n was introduced in effecting the scenario S_l, which was calculated using the formula:

$$\tilde{u}_n^l = \frac{u_n^l}{B_n} \quad (2)$$

In multi-period cases, the project's utility will, apparently, depend on the way increases in the levels of attainment of objectives unfold across the periods.

Let's assume that, for instance, T=2 and the level of attainment of a certain objective under a certain structure for investing resources rises the following way: (0,2; 0,6). Let's now assume that under a different structure for investing resources (but with the same volume of those) the level of attainment of this objective rises differently: (0,5; 0,3). It's apparent that consequences for the institution (and, consequently, the utility of the corresponding project) will be different in each of the cases. In this regard, for some strategic objectives a rapid increase in the level of attaining them would be more "profitable", while for other objectives a slow increase can be more preferable.

On the other hand, different structures for investing resources across periods also can differ in preference due to that in different periods there can be differences in the cost of resources and in how hard it is to get access to them. In each specific case, this can be allowed for in a formula used to discount expenditures on the project. As a result, each project P_n (n = 1,...,N) is conformed to by not only the volume of necessary resources B_n, but the size of present expenditures B'_n. Note that the set of possible structures for investing resources across periods and, consequently, the set of possible values for B'_n are finite due to that each project is a set of a certain number of specific strategic activities with given implementation durations and budget.

Thus, each objective G_k within the project P_n in implementing the scenario S_l has the set $\left(a_{nk}^{l1}, a_{nk}^{l2}, \ldots, a_{nk}^{lT}, B'_n\right)$ by which we'll now determine $\tilde{u}_{nk}^{l}$, which is the per-unit utility of the project P_n with reference to objective G_k in implementing the scenario S_l. In this regard, the general per-unit utility of the project P_n in implementing the scenario S_l can be found the following way:

$$\tilde{u}_n^l = \sum_{k=1}^{K} w_k \tilde{u}_{nk}^l \quad (3)$$

Let's take a detailed look at the procedure for determining the quantity $\tilde{u}_{nk}^{l}$ by the set $\left(a_{nk}^{l1}, a_{nk}^{l2}, \ldots, a_{nk}^{lT}, B'_n\right)$. It's based on constructing a T+1-dimensional plane, which is an approximation (with the accuracy required) of the graph of the function $\tilde{u}_k = \tilde{u}_k(x_1, x_2, \ldots, x_T, z)$, which is considered as the function of utility: $\tilde{u}_k \in [0,1]$, $x_t \in [0,1]$, $t = 1,\ldots, T$; the interval of changes in the variable z is governed by limitations on resources.

A universal method for constructing such planes for utility functions of an arbitrary number of variables (criteria) under any interrelations between criteria is considered below [10]. The rationale behind the method is generating, via a certain algorithm, questions of a certain form for surveying experts, determining the values of the function at corresponding points based on the experts' answers and calculating the values of the function at any given point in the function domain. The process of constructing such planes can be automated.

Once the plane for the objective G_k is constructed, one can determine the quantities $\tilde{u}_{nk}^{l}$ across all N projects for all L scenarios as the value of the function at corresponding points. Thus, all in all, one needs to construct K planes (for each objective) and find the K. N. L of the quantities $\tilde{u}_{nk}^{l}$.

We'll consider the levels of attaining objectives in each period and, consequently, the general per-unit utilities $\tilde{u}_n^l$, as chance quantities which depend on a number of internal and external factors which are functions of time. For the measure of risk we'll use, following H. Markowitz [6], the dispersions of the general per-unit utilities $D\tilde{u}_n^l$, which characterize the sizes of the spreads of the possible values of the general per-unit utilities about their mathematical expectations.

We'll determine the binary variable y_n, which takes the values 0 and 1, as follows:

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

The article proposes the following scheme for conducting analysis and constructing an optimum portfolio:

- For each of the N projects examined determine expenditures within each of the T time periods examined and calculate the present expenditures on the project.
- Determine the weight coefficients K of the strategic objectives of the upper level.
- For each of the objectives construct a plane, which is an approximation of the graph of the per-unit utility function, considered as a function of T+1 variables (criteria), where the first T criteria are a possible increase in the level of attainment of objectives in each of T periods and the last criterion is the present expenditures on the project, which facilitates increase in the level of attaining objectives.
- Define the set of scenarios S_1, S_2,...S_L and assess the probability of each of them p_1, p_2,...p_L with $\sum_{l=1}^{L} p_l = 1$.
- For each scenario in each project determine its per-unit utilities with respect to each objective (using the planes constructed) and using a formula (3) calculate the per-unit utility of the project.
- Find the mathematical expectation for the project n:

$$m_n = E(\tilde{u}_n^l) = \sum_{l=1}^{L} \tilde{u}_n^l p_l. \quad (4)$$

and the elements of the covariance matrix of the per-unit utilities of the projects i and j:

$$v_{ij} = \sum_{l=1}^{L} (\tilde{u}_i^l - m_i)(\tilde{u}_j^l - m_j) p_l. \quad (5)$$

- Set the limitations on resources available.
- The utility of the portfolio $m_{port} = \sum_{i=1}^{N} y_i m_i$; the risk of the portfolio $\sigma_{port}^2 = \sum_{i,j=1}^{N} y_i y_j v_{ij}$.

On the strength of the above assumptions, ratios and notations, the article suggests forming the project portfolio using the following models.

Model 1: The institution's development program is formed by the criterion of the maximum of the expected per-unit utility given limitations on the quantity of the program's risk and the volume of resources necessary for implementing the program:

$$\begin{cases} \sum_{i=1}^{N} y_i m_i \to \max, \\ \sum_{i,j=1}^{N} y_i y_j v_{ij} \le \sigma_0^2,. \\ \sum_{i=1}^{N} y_i B_i \le B_0. \end{cases} \quad (6)$$

Model 2: The development program is formed by the criterion of the minimum of the program's risk given limitations on the volume of resources necessary for implementing the program and the size of the expected per-unit utility:

$$\begin{cases} \sum_{i,j=1}^{N} y_i y_j v_{ij} \to \min, \\ \sum_{i=1}^{N} y_i m_i \ge m_0, \\ \sum_{i=1}^{N} y_i B_i \le B_0. \end{cases} \quad (7)$$

The formulated models for forming an optimum project portfolio of the institution's development program are Boolean quadratic programming problems which can be solved using standard numerical optimization software.

CONCLUSION

On balance, the article proposes multi-period optimization models for supporting making decisions in selecting project portfolios as part of an institution's strategic development program. The institution's corporate social responsibility is brought out when setting objectives inclusive of the interests of all parties interested. The allowance for risk is made under H. Markovitz's portfolio investment theory using the scenario-based approach. For the target function the author uses a general per-unit utility function whose arguments are levels of attaining the institution's strategic objectives as a result of implementing the project across periods inclusive the significance of objectives and the size of present expenditures on the project, as well as the overall volume of necessary resources. It is expected that the utility of the project will depend on the way increases in the levels of attaining strategic objectives unfold across periods, while different objectives will preferably require a different pace of increase in their levels. It is also expected that different structures for investing resources across periods can differ in preference due to that in different periods there can be differences in the cost of resources and in how hard it is to get access to them. The analytical assignment of the target function is based on the universal method of constructing utility functions of an arbitrary number of variables under any interrelations between the variables.

Inferences. The article proposes multi-period models for optimizing the project portfolio as part of the development program inclusive of an institution's corporate social responsibility. In making decisions, in these models allowance is made for - along with economic indicators and risks - the utility of projects for the institution's stakeholders.

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