Risk-Oriented Decision Making During Integrated Investment Management under Uncertainty

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***Abstract*—**The model of decision-making during integrated investment management under uncertainty, which enables to distribute capital between real and financial investment, is stated. The problem solution method, which allows supporting decisions in distribution and monitoring stage, is proposed. The model and its solution method enable to manage real investments and security portfolio simultaneously allocating all available resources.

***Keywords*—**investment management, decision making, real investment, financial investment, unsuccess risk.

I. Introduction

Investment decision making is an important process because its results directly impact on development and financial condition of investment activities subject and on the economy of the all country.

Investments include assets, specific deposits, shares, stocks and other securities, technologies, machinery and equipment, credits and all other types of property and property rights, intellectual values etc. But according to the investment goal there are two types of investment: real and financial (security portfolio) investments. Real investment belongs to short-term processes and financial investment can be short-term or long-term.

It is necessary to take into account that financial capital making and turnover are conditional on real capital functioning. So it is necessary for investor to distribute capital among real and portfolio investment to manage these two types of investment simultaneously to increase investment effectiveness. This approach enables to manage investment risks using diversity.

A lot of works are devoted to real investment and financial investment separately.

In [1] Project Definition Rating Index (PDRI) was proposed for project state analysis in the pre-project planning phase by the Construction Industry Institute. The PDRI is used to collect information of the pre-project planning practices in the industrial and building industry. The PDRI for industrial projects is a weighted matrix with 70 scope definition elements grouped into 15 categories and further grouped into three main sections. In [2] the PDRI for building projects was proposed, it has 64 scope definition elements and 11 categories grouped into three sections.

In [3]-[5] dependence between actual project costs and duration deviation from planned values and PDRI is investigated using regression model. In [5] artificial neural networks were proposed for prediction the dependence and the results of artificial neural networks usage were compared with regression model. In [6] artificial neural networks (perceptrons) and their ensembles were investigated for project success modeling.

A lot of classic papers (portfolio theory) by H. M. Markowitz, W. F. Sharpe, J. Tobin were devoted to the security portfolio management problem. In [7] the approach to management of the security portfolio, based on application of the theory of fuzzy sets, was presented. In [8] the approach to the security portfolio management based on D-scores of Russman was modified.

The purpose of this paper is to integrate two main types of investment into the complex investment management problem.

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II. THE MODEL OF DECISION-MAKING DURING INTEGRATED INVESTMENT MANAGEMENT UNDER UNCERTAINTY

Taking into account dependence between real and financial investment the investment decision-making problem should be determined as an allocation of the capital among real investments and security portfolio in such a way that capital is invested in real investment if the investment of the capital, which is required for investment project execution during the necessary investment period of time, is more effective with an allowance for risk than the investment of the same capital for the same period of time in investment (security) portfolio.

Besides that the short-term investment decision-making problem rises as a result of the long-term problem solving. The short-term problem is caused by a real investment fund utilizing way: the capital is utilized during a full investment period, not only in its beginning. Therefore temporary free capital can be used for portfolio investment for short periods of time. The investor should make a decision if it is effective with an allowance for risk to invest temporary free capital in portfolio during the period of its availability.

Investment efficiency with an allowance for risk is estimated by experts based on efficiency and risk measure of investment process. These real and portfolio investment measures can be compared because of the equal capital and investment period.

Decision making during integrated investment management should be done in both short and long periods of time:

– in long period of time capital should be allocated between real investments and security portfolio investments;

– in short period of time capital should be allocated between security portfolio investments and standard allocation of temporarily free resources (for example, deposit).

Let Q be total number of investment directions: Q real investment projects and Q alternative security portfolio investments. T is a maximum real investment duration (considering all i = 1…Q projects).

$U = (U_1, U_2, \ldots, U_T)$ is a vector, which elements determine current control action in point of time $t = 1, 2, \ldots, T$. Each element of this vector is a vector U_t, which can be determined as:

$$U_t = (U_1^t, \ldots, U_Q^t, U_{Q+1}^t, \ldots, U_{2Q}^t),$$

where $U_1^t, \ldots, U_Q^t$ – control action on every $i = 1 \ldots Q$ real investment project in point of time t ($U_1^t, \ldots, U_Q^t = \{0, 1\}$). Instead of a real investment project a standard allocation of temporarily free resources can be considered, but these free resources should be used in a real investment in a period of time;

$U_{Q+1}^t, \ldots, U_{2Q}^t$ – control action on every $i = Q+1 \ldots 2Q$ security portfolio investment in point of time t ($U_{Q+1}^t, \ldots, U_{2Q}^t = \{0, 1\}$).

The model of decision-making during integrated investment management under uncertainty consists in finding such a control strategy U from feasible solution set Ω with initial state x_0, which maximizes profit derived from real and financial investments during period of time T and minimizes unsuccess risk of the investment process. The investment process is characterized by object state vector x considering uncertainty ϖ. The model can be mathematically stated as:

$$\underset{\varpi}{M} \sum_{t=0}^{T} B(U_t, x_t, \varpi) \rightarrow \max_{U \in \Omega}, \tag{1}$$

$$\max_{t=0 \ldots T} \underset{\varpi}{M} \{R(U_t, x_t, \varpi)\} \rightarrow \min_{U \in \Omega}, \tag{2}$$

$$\Omega : x_{t+1} = x_t + f(\hat{x}_t, U_t) + w_t, \tag{3}$$

$$U_i^t \oplus U_{Q+i}^t = 1 \tag{4}$$

$$U_1^t, ..., U_{2Q}^t = \{0,1\}, \tag{5}$$

$$S_i^r = S_i^f, \tag{6}$$

$$T_i^r = T_i^f \tag{7}$$

where B (U_t, x_t, ϖ) – profit from investment, which is characterized by control action U_t, control object state x_t and uncertainty ϖ, in point of time t;

R (U_t, x_t, ϖ) – risk of investment, which is characterized by control action U_t, control object state x_t and uncertainty ϖ, in point of time t;

$M\{\ldots\}$ – mathematical expectation;

$\hat{x}_t$ – predicted investment state: real investment costs, real investment duration, unsuccess risk of real and financial investment, financial investment profitability.

Equations (1)-(2) define optimization problem. Equations (3)-(7) define model constraints.

Control action defines if it is necessary to invest the same capital in real project or security portfolio for the same period of time (only one variant for each capital amount $i = 1\ldots Q$). This condition is presented by (4)-(7).

The presented model of decision-making during integrated investment management under uncertainty is a dynamic programming problem model and belongs to the problem class of optimal stochastic control in finite horizon.

Uncertainty ϖ is defined by vector of random disturbances which impact on the system. Vector ϖ consists of the following elements:

– ϖ^1 – vector of random disturbances provided by predicted ($\xi^1{}_i$) and actual real investment unsuccess risk value deviation;

– ϖ^2 – vector of random disturbances provided by predicted ($\xi^2{}_i$) and actual investment costs value deviation;

– ϖ^3 – vector of random disturbances provided by predicted ($\xi^3{}_i$) and actual investment duration value deviation;

– ϖ^4 – vector of random disturbances provided by predicted ($\xi^4{}_i$) and actual financial investment unsuccess risk value deviation;

– ϖ^5 – vector of random disturbances provided by predicted ($\xi^5{}_i$) and actual financial investment profitability value deviation;

– ϖ^6 – vector of random disturbances provided by inaccuracy in expert scores ($\xi^6{}_i$) of real investment projects priority.

It is necessary to predict the following investment metrics to solve the stated problem: real and financial investment unsuccess risk, actual real investment costs and duration deviation from planned values, financial investment profitability.

III. The Method of Integrated Investment Management Decision Making

The method of integrated investment management decision making is intended for the problem solving defined by the model (1)-(7). This method uses an iterative scheme which consists of two components intended for optimal control action synthesis: prediction of the investment metrics and dynamic optimization of decisions based on prediction results.

At the first stage all projects available for real investment and all securities available on the stock market should be defined. Then preliminary project selection should be done. The total costs of the selected projects should not be more than available capital. The selected projects should be the most competitive of all available projects. For this purpose the PDRI of all available projects should be estimated by the group of experts. The estimations of individual experts should be adjusted by the Dephi method.

If there is large amount of available projects, experts can be divided into the groups by their speciality. Projects for these groups should be selected using clusterization algorithms. Density tracking self-organizing maps should be used for cluster analysis. The process of selection should be done based on iterative procedure. On every iteration the number of projects should be decreased. This process is similar to genetic algorithms [9].

The fuzzy analytic hierarchy process (FAHP) [10] is proposed to be used for project estimation and selection. At every stage N_i projects should be selected. N_0 projects should be selected using FAHP and other $N_i - N_0$ projects should be selected using roulette selection mechanism based on principles of genetic algorithms [9].

At the second stage unsuccess risk, expected duration and costs deviation from planned values should be estimated, using methods of real investment unsuccess risk prognostication and prognostication of actual real investment results deviation from planned real investment results [11].

Projects are considered as successful if their actual costs and duration don’t exceed planned values:

$$CI = \frac{AC - PC}{PC} \le 0; \tag{8}$$

$$DI = \frac{AD - PD}{PD} \le 0, \tag{9}$$

where AC and AD – actual costs and duration of project;

PD and PC – planned costs and duration of project;

CI, DI – costs and duration index.

Unsuccess risk is unsuccess project class belonging probability. Method of real investment unsuccess risk prognostication [11] predicts this probability based on data which defines project characteristics and artificial neural networks ensembles using AdaBoost method.

The method of prognostication of actual real investment results deviation from planned real investment results [11] is based on data that defines project characteristics, Kohonen self organizing maps, neural networks and NeuroEvolutionary Algorithm.

The modified investment portfolio management method based on D-scores of Russman [8] should be used for portfolio optimization to determine security portfolios that should be used as alternative for real investment. This method allows to manage investments more efficiently on unstable stock exchange. In the modified method genetic algorithm is used for the portfolio optimization problem solving: genes in chromosome encode portfolio structure. Yield increase range and system motion path to the goal are used for estimation using the fuzzy group method of data handling.

To use the modified investment portfolio management method based on D-scores of Russman for the method of integrated investment management decision making it is necessary to estimate planned profitability. The Delphi method should be used for this purpose.

After all metrics are predicted it is necessary to evaluate control actions based on dynamic programming method, allocating all available capital in real and financial investment. Using main criterion method optimization problem (1)-(2) can be transformed to optimization problem (1) with constraint:

$$DI = \frac{AD - PD}{PD} \le 0, \tag{10}$$

So the method of integrated investment management decision making solves the model of decision-making during integrated investment management under uncertainty as optimization problem (1) with constraints (3)-(7), (10).

After this stage all projects and security portfolios should be monitored during period of time T. If there are free temporary available resources it is necessary to allocate these resources using model (1) with constraints (3)-(7), (10).

IV. Experimental Investigation of Integrated Investment Management

In the previous papers [8], [9] the efficiency of the proposed methods usage individually for real investment and security portfolio management was investigated.

For experimental investigation of the presented approach historical data were used.

These data are collected from building and industrial project execution and are used as a real investment data source. The real investment data consist of PDRI, planned project duration, planned project costs, unsuccess class, actual project duration and actual project costs.

The other part of the data consists of the Ukrainian stock exchange trade performance. These data characterize security prices on the Ukrainian stock exchange during last 10 years.

The decision support system for investment management process was developed using programming language C++.

During experimental investigation of integrated investment management approach the integrated investment management decision making method was compared with individual real and financial investment management when capital is initially separated for these two types of investment. Investment period was set equal to 4 years. The proposed approach allowed to increase profitability for 14,3 %. Using this method 55 % of capital was allocated in financial investment and 45 % in real investment.

V. Conclusion

In this paper risk-oriented decision making approach to integrated investment management was presented. Using this approach real and financial investments can be managed simultaneously.

The model of decision making during integrated investment management under uncertainty was presented. This model can be used for allocating capital between projects, security portfolios and standard allocation of temporary available resources which should be used for financial investment. The model is a dynamic programming problem model and belongs to the problem class of optimal stochastic control in finite horizon.

The method of integrated investment management decision making which is intended for solving the problem defined by the described model was presented. This method uses main criterion method for solving the model problem. It is based on the method of prognostication of actual real investment results deviation from planned real investment results, on the method of real investment unsuccess risk prognostication and on the modified investment portfolio management method based on D-scores of Russman.

Application efficiency of the proposed approach is confirmed by the implementation results.

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