Efficient Project Portfolio as a Tool for Enterprise Risk Management

Valentin O. Nikonov
Ural State Technical University
"Growth Trajectory" Consulting Company

Enterprise Risk Management Symposium
Society of Actuaries

Chicago, IL

March 28-30, 2007

Abstract

Risks of different types are embedded into every business process and every business activity no matter what the business of the organization. At the same time, today all organizations seeking sustainable growth simultaneously manage a number of projects: endeavors that are even riskier than their usual daily routine. Examples are projects for the development of a new product or service, investment activities, implementation of an information system, entering a new market, re-branding and many others. All projects of an organization constitute a project portfolio.

Since projects are realized within one organization, they are subject to all types of risks that the organization has. At the same time, each project has its own risks that appear from the project's scope and uncertainties.

The project portfolio captures all the risks that the organization is subject to, along with the risks of the projects. These risks interact with and influence each other, and have a strong impact on the project portfolio realization and the organization's overall business performance. That is why a tool for managing project portfolio risks should be an indispensable part of an enterprise risk management system.

A tool for managing an organization's project portfolio risks is introduced in this paper. This tool is based on the approaches of H. Markowitz Portfolio Theory with the main idea of the organization's portfolio risk diversification. The H. Markowitz theory was developed to help an investor build an efficient investment portfolio (portfolio of securities). However today we would hardly find an organization that invests only in the equity market. Organizations invest in securities and at the same time invest in projects of different types.

In the report we introduce a generalization of H. Markowitz theory and apply it to project portfolios (that could contain investments in securities). The idea remains the same: we suggest that analyzing the profitability (utility) and risks of every project in the portfolio is important but insufficient; the correlations of the project's risks and the influence that the project has on risks of other projects and project portfolio should be considered in order to build an efficient project portfolio.

An efficient project portfolio term is introduced in the presentation. The term means a project portfolio that is built in order to achieve the organization's strategic goals with **minimal risks** under the conditions of limited resources.

We also consider a mathematical model for building an efficient project portfolio along with an algorithm based on the model.

In order to create the model, we have to consider a number of tasks that are described in the paper. We present the formalization of the characteristics of a project and specify the differences between project portfolio and portfolio of securities. That makes it clear that the differences between defining and formalizing risks of a security and risks of a project are substantial. A new approach for defining a project risk should be offered. The description of this approach follows; a way to determine a project portfolio risk is also presented.

Based on this approach to quantifying the risks of the projects, we offer a new concept of the interference of projects within a portfolio. The interference can be determined through the creation of a risk matrix of a simultaneous realization of projects.

The description of the model for building an efficient project portfolio, based on Markowitz theory, completes the theoretical part of the presentation. Then the algorithm is introduced along with the results of its approbation in one of Russia's financial institutions.

We believe that the approach described in the paper could help organizations build balanced and efficient project portfolios, thus minimizing the risks. That, in turn, is a necessary condition for achieving strategic objectives and sustainable growth.

1. Introduction

In this paper we introduce an approach to manage the organization's risks which is based on project management methodology, modern portfolio theory (MPT) and risk management techniques.

Nowadays, all organizations that are seeking growth and sustainable competitive advantage need to realize different projects. A project is an endeavor that is unique and limited in time. Examples are projects for the development of a new product or service, implementation of an information system, entering a new market, re-branding and many others.

Innovation and investment activities that have a very strong influence on business performance and yield competitiveness of an organization on a micro level (and economic growth on macro level) are projects by definition. All projects of an organization constitute a project portfolio. Hence risks of a project portfolio should be managed and mitigated.

Since projects are realized within one organization, they are subject to all types of risks that the organization has. At the same time, each project has its own risks that appear from the project's scope and uncertainties.

Project management methodology provides tools for managing one project at time. Business success, however, depends on the characteristics of the whole portfolio of projects that are under realization. Project portfolio management implies: 1) the analysis of all projects within a portfolio as a whole; and that makes it possible to perform; and 2) the analysis of risks that result from simultaneous realization of projects (that implies the analysis of project's interdependencies). Consideration of all these factors leads to building a balanced project portfolio and provides strategies for risk hedging. The concept of project portfolio management that is presented is based on the approaches of MPT, which was introduced by Harry Markowitz in 1952.

Models, methods and approaches of MPT proved to be successful when applied to a stock market. The nature of investment in a project portfolio remains the same: the investor wants to maximize return and minimize the risk. The only difference is that he or she invests in a wider range of activities.

Models of MPT can't be applied to projects without modification. For example, the characteristics of an asset within a portfolio of securities can be defined by its expected return and standard deviation of return (which is treated as a risk of a security).

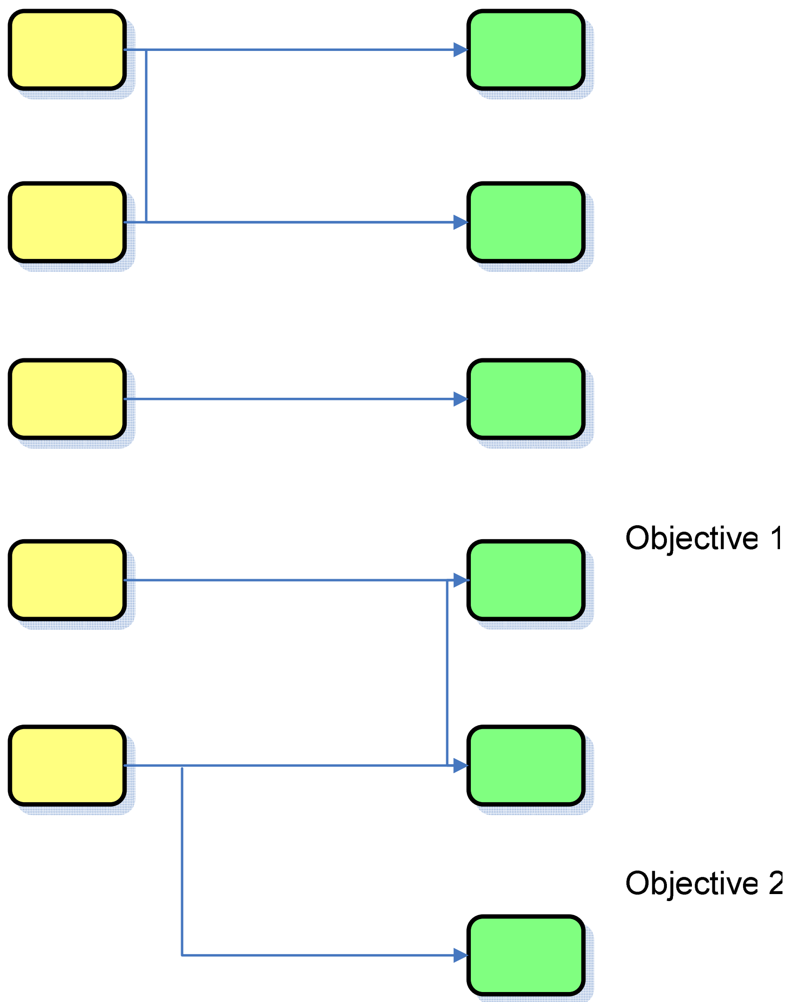
That doesn't work with projects: the fact that the cumulative risk of a project is not formalized makes it impossible to apply the concepts of the MPT to a project portfolio.

Before we introduce the model, some conceptual aspects of project portfolio management need to be underlined: project portfolio management is closely related to the strategic planning process.

Effective strategic planning process and systematic achievement of strategic goals are key factors necessary for an organization's development, competitiveness and growth. Organizations now apply different strategic management techniques (e.g., balanced scorecard). These techniques usually are helpful in the determination of the organization's strategy, but they don't provide any tools for its realization.

Project portfolio may serve as a tool for achieving strategic goals. We can determine projects that must be realized in order to achieve each goal. In other words, for a set of strategic objectives we determine a corresponding set of projects or a project portfolio:

Picture 1. Strategic Objectives and a Project Portfolio



Project portfolio is an essential result of the strategic planning process, even if the project portfolio is not recognized as such.

Every project within a portfolio can be treated as an asset which has a number of characteristics. We can see the parallel with portfolio of securities: all projects within a portfolio influence each other; project portfolio is something that can be characterized with risk and return. The task is to build a portfolio that gains maximum return with minimal risk.

The application of this concept thus can provide strategies for strategic risk hedging. Without going into the formal mathematical definition of an efficient project portfolio, we can say that an efficient project portfolio is a portfolio of projects that: 1) complies with strategic objectives of an organization; and 2) has a Pareto optimal “risk-return” ratio.

Project portfolio realization is a tool that leads **to systematic achievement of strategic goals with a minimum level of risk.**

Investment in an asset on a stock market is an endeavor that is unique and limited in time. Hence it can be considered a project. So a generalization of MPT and its application to projects could help significantly mitigate organizations’ risks, which leads to a better business diversification.

2. Model for Building an Efficient Project Portfolio

2.1 Differences between a Portfolio of Projects and a Portfolio of Securities

In order to generalize the classical model of MPT (thus making it applicable to the case when we have projects instead of securities), we need to perform a formalization of the main differences between two types of portfolios. There are significant differences in characteristics of a project portfolio and a portfolio of securities. The main differences are described in Table 1.

Table 1. The Differences between a Project Portfolio and a Security Portfolio.

Aspect	Security Portfolio	Project Portfolio
For what purpose does an investor build a portfolio?	To gain maximum return.	To realize organization’s strategy
What is an efficient portfolio?	A portfolio that yields maximum return with a given level of risk or minimum risk with a given level of return.	Besides classical “risk-return” ratio we can search for portfolios with optimal ratios of different characteristics.
What parameters can be used to formalize the characteristics of an object within a portfolio?	Return, risk, correlation with other assets. The characteristics are mathematically formalized.	A lot of parameters: minimum required investment, duration, required human resources, etc. The characteristics are not formalized.
What resources do we need in order to build a portfolio?	Mostly financial (that can be borrowed).	Financial and human resources. Human resources usually are unique and in case of their insufficiency can’t be borrowed.
Who determines the duration of a portfolio realization?	It can be determined by investor, since usually investors work on a liquid market.	The project’s duration is determined by its lifecycle and scope specifics. Investors can hardly influence

		project's duration.
How can we determine interdependencies between objects within a portfolio?	Interdependencies are determined by correlation of random variables that characterize returns of assets within a portfolio.	Interdependencies are determined by the risks of projects' simultaneous realization (this approach is described below).
Do we have any historical information on characteristics of objects that constitute portfolio?	Yes, statistical information on return of an asset.	Only information on analogical projects that were realized in the past.

The major difference that we can see in the table is that the characteristics of a project are not formalized. Formalization is necessary in order to apply the concepts of MPT to projects.

2.2 Formalization of Project's Characteristics

Based on the results of the analysis of MPT, risk management theory, project management methodology, and financial management, we can pick out the following parameters that characterize a project. Let us consider P_i as a project that is realized in organization and that is a part of a project portfolio. For each project P_i we can use the following characteristics:

Table 2.

Characteristics	Description
1. Minimum Investment Required	W_i - minimum amount of investment required for the realization of the *i* project.
2. Net Present Value (NPV)	NPV_i - Net present value of the *i* project. NPV is a random variable since its value depends on the project risks. We will treat an expected NPV as a basis, which should be calculated under the assumption of favorable realization of a project (when no risks occurred).
3. Human Resources Required	Very often organizations can't realize projects due to the lack of competent staff. That is why we introduce the parameter HR_i - human resources required for *i* project.

4. Project's Duration Time	T_i − expected duration of *i* project.
5. "Obligatory" Feature	Obligatory are projects that shall be included into portfolio due to the regulatory or normative requirements (if $Obl_i = 1,$ a project shall be included into the portfolio, if $Obl_i = 0,$ a project may or may not be included into portfolio).
6. Strategic Objectives Compliance Index	Str_i - strategic objectives compliance index. The compliance to strategic objectives is one of the key success factors of a project (measured in points, from 0 to 10).
7. Cumulative Risk of a Project	Cumulative risk of a project is a random variable $U(\omega)$ (full description will be provided later in the paper).
8. Correlation with Other Projects	Correlation with other projects can be determined by $Infl_j = \{Infl_{ij}\}$ − a vector that shows *i* project's influence on other projects.
9. Human Resources Development Index	This figure captures the extent to which the project is interesting for the organization from the perspective of human resources development (measured in points, from 0 to 10).
10. Business Process Improvement Index	Nowadays a lot of projects are realized with the purpose of improving the quality of business processes of an organization. The return from projects of this type can hardly be measured with financial figures; hence the influence of this kind of projects on organization should be expressed in business performance improvement index (measured in points, from 0 to 10).
11. Organization's Image Improvement Index	This parameter shows the extent to which the realization of a project enhances the image of an organization (is measured in points, from 0 to 10).

Detailed description and formalization of a project's risk along with the approach to measure interdependencies of projects within a portfolio will be introduced later in the paper.

So, project P_i can be described by the following vector of variables (parameters):

$$P_i = \{W_i, NPV_i, HR_i, T_i, U_i(\omega), \{Infl_{ij}\}, Obl_i, Str_i, Hrd_i, im_i, Bpi_i\}$$

NPV and return on investment can be treated as major characteristics of a project since they show its economic effect. At the same time, we should note that there are a lot of projects that are not of "investment projects" type. For these projects, NPV does not work. There are some projects where NPV can hardly be calculated at all.

We suggest that a more comprehensive characteristic should be used—usability of a project. Usability captures the aspects of projects that can't be taken into account when calculating NPV.

We can pick out the key factors that determine the usability of a project:

1. Financial result (which is measured with NPV);
2. Human resources development;
3. Image improvement;
4. Business process improvement.

Utility function looks like the following:

$$Y(P)=F(NPV,HRd,Im,BPI)$$

and is measured in points.

The use of the utility function makes it possible to evaluate projects and to take into account the key factors of usability of the project rather than NPV only.

2.3 Project's Particular and Cumulative Risk

In this section we consider the simplest case when NPV only is considered as a factor of usability of the project. Let's assume that for each project within a portfolio, we can determine a set of risky events $\omega_1, \omega_2, \ldots, \omega_K$.

The risk of a project can be measured by the impact that a certain risky event has on it. The impact that is associated with the risky event ω can be measured as a part $U(\omega)$ of the expected NPV (which is calculated under the assumption that no risky event occurs). We consider the impacts of risky events to be multiplicative: if the risky event ω occurs and other risky events don't, investor gets $(1-U(\omega)).NPV$ instead of an expected NPV.

For example, if the risky event ω results in the rise of interest rate, and that, in turn, causes 30 percent loss for the project, then $U(\omega)=0.3$ and $(1-U(\omega))=0.7$. $(1-U(\omega))$ can also be negative; that means that the risks lead to losses during project implementation.

We treat risk of a project as a random variable, which is defined on the set of elementary risky events Ω characterizing the impact of the risky event on the project. In the simplest case, the random variable is determined by the probability $P(\omega)$ of the risky event and by the magnitude of the impact $U(\omega)$ that the particular risky event has on the project. Below is the probability distribution for the random variable "particular risk of a project":

Probability Distribution of a Particular Project Risk

Name of the risk	*The probability of the*	*The probability that the*

	risk occurrence	*risky event will not occur*
Probability	$P(\omega)$	$1-P(\omega)$
Impact	$U(\omega)$	0

In order to generalize Markowitz theory, we need to formalize the risk of the project in such a way that it allows us to associate each project with a random variable that characterizes its risk. In other words, we need to formalize the cumulative risk of a project.

If we have two or more risky events that happen simultaneously, the magnitude of the cumulative risk depends upon the risks' interference type.

Let's denote by ω_{ij} an event symbolizing that both risks ω_i and ω_j occur simultaneously.

1. We consider risks ω_i and ω_j to be additive, if $U(\omega_{ij}) = U(\omega_i) + U(\omega_j)$.

This group of risks usually contains such events as delays in supplies: equipment, materials or services. That results in additional costs (we need to find new suppliers, etc.). If we have two suppliers that delay the shipment simultaneously, that will result in project losses that are equal to the sum of the impacts from the first supplier and from the second one. We suppose that independent risks have such a property.

2. We consider risks ω_i and ω_j to mutually strengthen each other, if $U(\omega_{ij}) = \alpha(U(\omega_i) + U(\omega_j))$ α >1, and mutually mitigate each other, if α <1.

Most of the project's risks belong to this group. Realization of two events of different types usually leads to more substantial losses than the sum of losses associated with two risks that occur separately.

3. If two events ω_i and ω_j occur simultaneously and the impact that the event ω_i has on the project makes meaningless the consideration of the impact of the event ω_j, we say that risk ω_i absorbs risk ω_j. In this case $U(\omega_{ij}) = U(\omega_i) = \max\{U(\omega_i), U(\omega_j)\}$. We also call this type of risks absorbent risks.

In this report we will consider the situation that is determined by the following assumption.

Assumption 1. In a group of dependent risks (the group of dependent risks is comprised by the three groups as described above), the probability that three or more risks will occur simultaneously can be considered negligible and equal to zero.

Under ***Assumption 1***, let's now consider an arbitrary event ω^*. As it was indicated above, each project has a corresponding set of risky events $\omega_1, \omega_2, \dots, \omega_K$.

Among these risks, we choose those that are independent. In other words, the realization of these risks doesn't depend on the realization of other risks. These are usually risks that are external for the project: changes in interest rate, unfavorable weather conditions, etc. Without loss of generality we consider that these risks are numbered respectively 1,…, K_1. At the same time, we group dependent risks in such a way that we could treat risks from different groups as independent.

Again, without loss of generality we consider that there is only one group of dependent risks. All the constructions that are presented below can be broadened to the case with a larger number of groups.

To sum up, we have K_1 independent risky events $\omega_1, \omega_2, \dots, \omega_{K_1}$ and a group of risks $\omega_{K_1+1}, \omega_{K_1+2}, \dots, \omega_K$ that are interdependent. Let's assume that there is only one risk occurring in the group of dependent risks ω_n (n>K1). We denote the probability of this event as P_n. Thus the probability of the event $P(\omega^*)$ is determined by the equality

$$P(\omega^*) = P(\omega_1) \cdot P(\omega_2) \cdot \ldots \cdot P(\omega_{K_1}) \cdot P_n$$

Let the set of all possible events of such type be referred to Ω^*.

When the elementary risky event ω^{**} implies the simultaneous occurrence of two dependent risks (ω_k and ω_m, (k , m > K1)) we have

$$P(\omega^{**}) = P(\omega_1) \cdot P(\omega_2) \cdot \ldots \cdot P(\omega_{K_1}) \cdot P_{k,m}$$

We will use the symbol Ω^{**} in order to denote this set of events.

Thus, denoting by ω_0 the event when no risks occur, we can determine a random variable characterizing the impact of all possible risky events on the project. This random variable is treated as a cumulative risk of a project. The determination of this variable allows us to compare different projects on the basis of the risk criterion. The distribution function for the random variable $U(\omega)$ is presented below:

Distribution Function for the Variable "Cumulative Risk of a Project"

U	$\sum_{l=1}^{K_1} U_l + U_n$	$\sum_{k=K_1}^{K} U_k + U_{k,m}$	0
ω	$\omega \in \Omega^*$	$\omega \in \Omega^{**}$	ω_0

2.4 Cumulative Project Risk Determination Algorithm

Let's consider a bank whose strategic goal is to enter new geographical areas; thus it is launching projects for opening new offices. Opening a new office is a classic example of a project. It is subject to the following risks (as they are presented in the table below):

Risks of the Project for Opening of a New Office

ω_j^i	$P(\omega_j^i)$	$U(\omega)$
1.1 Market Risk (Demand Volatility)	0.05	0.4
1.2 Delays in Equipment Supplies	0.1	0.1
1.3 Uncertainties that Result from the Possible Changes in Regulatory Requirements	0.1	0.2
1.4 Operational Risks	0.2	0.05

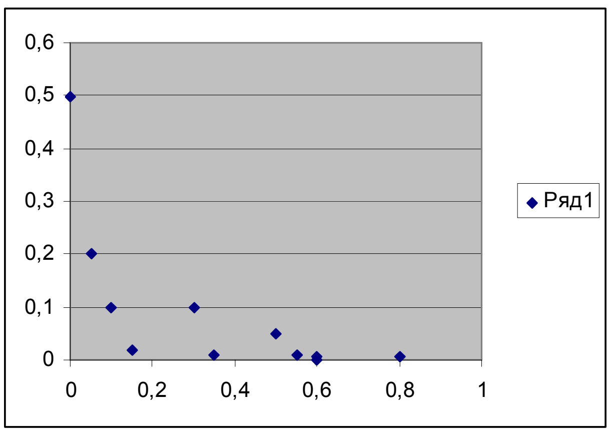
Here we have a list of partial project risks. A project may have any number of particular risks. Our knowledge of particular risks is very important; however, it is not enough if we want to compare projects. In order to do that we need to calculate the cumulative risk of the project on the basis of the model that was described above.

First of all, we need to determine dependent and independent risks. Without going into details, we consider risks ω_1 and ω_4 to be independent. According to the approach described earlier, we determine the elementary events of the Ω set, the probabilities of the elementary events and the impacts associated with these events. While determining the probability of the elementary events we take into account risks interference (we consider risks ω_2 and ω_3 to strengthen each other). As a result, we have the following table that describes the set of the elementary risky events (we note the elementary event of the Ω set as α):

Event	Probability	Description	Impact
α_1	0.499	None of Risky Events Occurred	0
α_2	0.05	Market Risk (Demand Volatility)	0,5
α_3	0.1	Delays in Equipment Supplies	0,1
α_4	0.1	Uncertainties that Result from the Regulatory Requirements	0,3
α_5	0.2	Operational Risks	0,05
α_6	0.005	"Market Risk (Demand Volatility)" and "Delays in Equipment Supplies"	0,6
α_7	0.005	"Market Risk (Demand Volatility)" and	0,8

		“Uncertainties that Result from the Regulatory Requirements”	
α_8	0.01	“Market Risk (Demand Volatility)” and “Operational Risks”	0,55
α_9	0.001	“Delays in Equipment Supplies” and “Uncertainties that Result from the Regulatory Requirements”	0,6
α_{10}	0.02	“Delays in Equipment Supplies” and “Operational Risks”	0,15
α_{11}	0.01	“Uncertainties that Result from the Regulatory Requirements” and “Operational Risks”	0,35

The probability distribution function looks like the following:



The expected value of the cumulative risk of the project is equal to 0,0946.

2.5 Interference Determination of Projects within a Portfolio. Simultaneous Realization of Projects Risk Matrix

The concept that we suggest implies that the interference of projects A and B can be determined through the extent to which the simultaneous realization of projects changes their respective cumulative risks. If two projects are being realized simultaneously and their risks remain the same as if they were realized separately, these two projects are independent. If the risks either decrease or increase, these projects are dependent. In order to formalize the interference (interdependence) of projects within a portfolio, we should determine the risk matrix of a project’s simultaneous realization.

A risk of a simultaneous realization of project *i* and project *j* ρ_{ij} can be determined by experts and is a value in the interval [-1;1]. If ρ_{ij} is equal to zero, the projects are independent; if $\rho_{ij} = 1$, the projects are mutually exclusive; and if $\rho_{ij} = -1$, the projects can be considered complementary.

Determination of ρ_{ij} brings us closer to the original Markowitz model since ρ_{ij} is an analogue of the correlation coefficient.

Determination of the risk matrix of projects' simultaneous realization is necessary in order to create an adequate model for building an efficient project portfolio simply because the interference and interdependence of projects within a portfolio have a strong impact on portfolio risk.

The ρ_{ij} matrix is determined with the help of the expert judgments approach. These values give us an opportunity to determine the covariation values and consequently determine the risk of project portfolio.

2.6 Model for Building an Efficient Project Portfolio

Let project portfolio contain L projects that constitute a set $J=\{i_1, \ldots, i_L\}$. If NPV_i is an expected (designed) NPV of the project *i*, and $U_i(\omega)$ is a coefficient of the cumulative risk of project *i,* then the NPV of the portfolio is a random variable that can be defined as a sum:

$$NPV_P = \sum_{i \in I} U_i(\omega) NPV_i$$

By ω here we denote a random risky event of all the projects within a portfolio. Detailed probability description of such a random variable is complicated enough due to the huge number of different combinations of risks.

At the same time, we don't need it in order to calculate the portfolio expected NPV $(E[NPV_P])$ and standard deviation $\sigma[NPV_P]$. All we need to do is to determine the probabilities of a simultaneous occurrence of risky events of different projects α_k^i and α_m^j, where indices *i* and *j* denote the project indices and *k* and *m* represent indices of risky events of respective projects. Symbol ω is substituted with α to stress that here we also consider the composite risks that unite two elementary risky events. We will note these probabilities as $P_{k,m}^{i,j}$.

In accordance with the characteristics of the expected value function we have

$$E[NPV_P] = \sum_{i \in J} U_i(\alpha^i) NPV_i = \sum_{i \in J} \mathrm{E}[U_i(\alpha^i)] NPV_i$$

$E[NPV_P]$ that is determined by this equation is treated as NPV of a project portfolio.

According to the concepts of the MPT, we will treat the standard deviation of the NPV of a project portfolio as a risk of a project portfolio.

In order to determine $\sigma[NPV_P]$ let us denote q_J a vector, which contains values of NPV_i, with $i = i_1, \ldots, i_L$, ($i \in J$).

Covariation coefficients of respective random variables are determined by the following equations, $i, j \in J$:

$$\operatorname{cov}(U_i(\alpha^i), U_j(\alpha^j)) = \sum_{k,m} P_{k,m}^{i,j} \{U_i(\alpha_k^i) - E[U_i]\} \{U_j(\alpha_m^j) - E[U_j]\})$$

In order to calculate the project portfolio risk let us remember that

$$\rho_{ij} = \frac{\operatorname{cov}(U_i(\omega), U_j(\omega))}{\sigma_i \sigma_j}$$

Risk of a project portfolio hence can be presented as

$$\sigma^2 = \sum_{i,j \in J} NPV_i NPV_j \operatorname{cov}(U_i(\alpha^i), U_j(\alpha^j))$$

In other symbols we have

$$\sigma^2[NPV_p] = q_j^T V_j q_j$$

With V_j denoting the covariation matrix for a set of random variables $U_k(\alpha^k)$ with indexes $k \in J$ that corresponds to a given project portfolio, where $\sigma_i = \sigma(U_i(\alpha^i))$.

Evolving the Markowitz approach, we will call a project portfolio P* : J*={i_{1*}, …., i_{L*}} efficient when we can't find any other portfolio P : J={i_1, …., i_M} with:

$$E[NPV_P] \geq E[NPV_{P*}],$$
$$\sigma[NPV_P] \leq \sigma[NPV_{P*}],$$

one inequality being strict.

The definition shows the unimprovability of the efficient project portfolio.

Let us consider a problem of constructing a project portfolio in a simplest case, with NPV as a measure for the project's effectiveness, and when we have a probability space of the risky events. In a more general case, it is appropriate to use the usability function as a tool for estimating the project's effectiveness. The approaches and calculations will remain the same.

2.7 Algorithm for Building an Efficient Project Portfolio

Let's assume that the organization has determined:

1. Strategic goals represented as a vector $S = \{S_1, S_2, ..., S_n\}$, where S_i is a strategic goal *i* of the organization.
2. A budget *B* that organization is eager to invest in projects and
3. *HR*—an overall quantity of human resources that can work with projects (measured in "man-days").[1]
4. Risks that may impact the organization.

Let us assume that the organization has determined a set *P* of projects that might be interesting for organization. For each project, according to Table 2, we determine the following characteristics:

1. Expected NPV;

[1] Let's assume that all human resources are of one type. In a more general case, we should divide the human resources in classes according to their competence level.

2. Cumulative risk of a project $U(\omega)$;
3. Strategic goals compliance index Str_i;
4. Minimum resources required W_i;
5. Human resources required HR_i;
6. " Obligatory" feature of a project, a vector that is comprised of numbers 0 and 1 $Obl = \{1,\ldots,0,\ldots,1\}$, where 1_k means that project k is obligatory and should be included in the project portfolio no matter what, 0_j – project *j* may be or may not be included into the project portfolio.
7. A probability space of risky events of projects.

The problem can be formulated as follows: to build an efficient project portfolio within the given constraints. That means a portfolio that has a maximum level of compliance to strategic goals of organization and can't be improved in terms of "return" and "risk."

First of all, we have to determine a subset of feasible portfolios. As it was stated above, we associate a project portfolio with a vector that contains numbers 0 and 1, where coordinate *i* with a value of "1" corresponds to the case when project *i* is included into the portfolio. When coordinate *i* has a value of "0," it means that the project is not included into the portfolio.

The set of feasible projects portfolios P_p is finite and limited by the organization's budget and human resources constraints.

A set of feasible project portfolios has the following characteristics:

$$\begin{cases} \sum_i W_i \le B \\ \sum_i HR_i \le HR \\ Pp \subset P \end{cases}$$

Obligatory projects are included in the portfolio by default.

Thus an efficient project portfolio is selected from a finite set of feasible portfolios and that can be done by a finite algorithm.

We should select portfolios that have a maximum level of compliance to strategic goals of organization from a set P_p of feasible projects. We will denote this set of portfolios as $P_{s.}$

This set can be characterized with the following equations:

$$\begin{cases} \sum_i W_i \le B \\ \sum_i HR_i \le HR \\ P_s \subset P_p \\ Str(J \mid J \in P_s) > Str(J \mid J \notin P_s) \end{cases}$$

Then for each portfolio from the set P_s we need to determine *NPV* and portfolio risk $U(\omega)$ the way it was described above.

Thus we have a set of efficient project portfolios $P^*=\{J_k\}$ that meet the following constraints:

$$\begin{cases} \sum_i W_i \le B \\ \sum_i HR_i \le HR \\ P* \subset P_s \\ NPV(J_k | J_k \in P^*) \ge NPV(J_n | J_n \notin P^*) \\ \sigma(J_k | J_k \in P^*) \le \sigma(J_n | J_n \notin P^*) \end{cases}$$

The proposed model and algorithm were approbated in several financial and investment organizations.

3. Approbation of the Model for Building an Efficient Project Portfolio

Below is an example of the approbation of the model. The approbation was performed at 'Bank24.ru' (a Russian bank) in September 2006. The set of possible projects looked the following way:

Table 3
Initial Set of Projects

№	Название проекта	*HRd*	*NPV*	*Im*	*Bpi*	*сумма*	*Y(P)*
1	Implementation of ISO 27001:2005 Information Security Management System	10	--	9	10	29	29
2	Implementation of the leasing service	6	200	5	5	16	18
3	Implementation of the factoring service	8	100	7	7	22	23
4	Opening of a new office	3	100	7	6	16	17
5	Implementation of a corporate governance system управления	9	--	10	5	24	24
6	Implementation of a budgeting system	9	--	0	7	16	16

In order to determine the cumulative risk of each project we construct a probability distribution function as it was described above.

Then we consider the resource constraints and select the set of feasible projects:

№	Portfolio Structure	Portfolio Budget	Strategic Goals Compliance Index
1	{1,1,1,1,1,0}	1 700	38
2	{1,1,1,1,0,1}	1 400	38
3	{1,1,1,0,1,1}	1 500	42
4	{1,0,0,1,1,1}	1 800	34
5	{0,1,1,1,1,1}	1 600	40
7	{1,1,0,0,1,1}	1 400	35
14	{1,0,1,0,1,1}	1 400	35

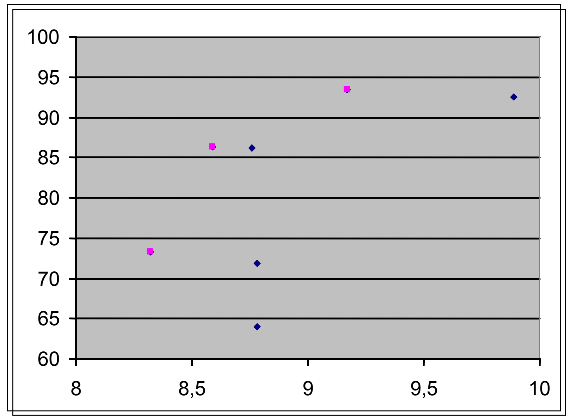
In this sample the risk matrix of simultaneous realization of projects looks like the following:

$$\rho_{ij} = \begin{pmatrix} 0 & 0 & 0 & 0 & 0{,}1 & 0{,}1 \\ 0 & 0 & 0{,}2 & 0 & 0 & 0 \\ 0 & 0{,}2 & 0 & -0{,}1 & 0 & 0 \\ 0 & 0 & -0{,}1 & 0 & 0 & 0 \\ 0{,}1 & 0 & 0 & 0 & 0 & 0{,}1 \\ 0{,}1 & 0 & 0 & 0 & 0{,}1 & 0 \end{pmatrix}$$

Now we calculate the characteristics of each portfolio of the given set:

№	Portfolio Structure	Expected Usability of Portfolio	Portfolio Risk
1	{1,1,1,1,1,0}	93,39	9,17
2	{1,1,1,1,0,1}	86,23	8,76
3	{1,1,1,0,1,1}	92,56	9,89
4	{1,0,0,1,1,1}	73,28	8,32
5	{0,1,1,1,1,1}	86,37	8,59
7	{1,1,0,0,1,1}	71,86	8,78
14	{1,0,1,0,1,1}	63,99	8,78

The set of efficient portfolios can be presented the following way:



Thus, under the given budget and human resources constraints, three efficient project portfolios resulted:

1. №1 - {1,1,1,1,1,0};
2. №4 - {1,0,0,1,1,1};
3. №5 - {0,1,1,1,1,1}.

The fact that portfolio №1 is efficient can be easily explained. It doesn't include the project №1, which has a large amount of risk with the smallest usability. That is why the exclusion of this project from the portfolio makes the latter efficient. Portfolio №4 is efficient since it doesn't contain two projects that increase each other's risks under the assumption of simultaneous realization. The exclusion of project for implementation of the information security management system in portfolio №5 makes it efficient since this project has a very large amount of risk.

4. Conclusion

The methods for project portfolio management that are presented in the paper give organizations an opportunity to consider the "risk-return" ratio when constructing a project portfolio. That is necessary in order to make decisions that lead to a sustainable competitive advantage and growth. These methods broaden the classical model of MPT and make it easily applicable by every organization, not only by investors working in a stock market.

The importance of strategic risk management is recognized worldwide. An organization can use all kinds of approaches in order to develop and implement its strategy. An approach when a strategy of organization is supposed to be implemented through the realization of a project portfolio is introduced in this paper.

The strategic planning process essentially results in a set of projects or a project portfolio. Hence this set of projects absorbs strategic risks of the organization. The use of project portfolio management based on the methods of MPT leads to a better understanding of organization's strategic risks and helps to mitigate these risks. The methods for building an efficient portfolio of projects can be used as a tool for the implementation of a strategy with minimum level of risk, thus leading to competitiveness, diversification and growth.