

Mathematical Modeling of Investment Risks

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Abstract: An attempt to explore the role of investment risk management has been made in this article. The main purpose of this article is to identify the key patterns that determine peculiarities of assessing business risks as the main element contributing to the achievement of the economic security of the organization, as well as to make a comparative analysis of methods for investment risk assessment and management. The methods of cognition, retrospective and documentary analysis, as well as synthesis, generalization, and systematization have been used in the article. Various risk management methods are used in the modern economic analysis. The most efficient ways to reduce risks in the context of instability of the economic and political situation in Russia are the method of scenarios and the method of analyzing hierarchies, which have been used to estimate the attractiveness of investment projects.

Index Terms: model, investment, risk, risk management

I. INTRODUCTION

The specifics of investment risks in modern business are explored in this article. The issue of rational risk management and choosing a model of acceptable level of risk assessment is particularly relevant at the current stage of business development, when investment activity intensifies and the growth of risks complicates decisions about possible areas of financing. The critical task today is to predict, reduce, or prevent risks. That is why it is necessary to have an idea of the main types of the risks that require special attention, in order to solve the problem.

Investment risks are inextricably linked with the concept of "investment activity", which can be defined as "investing money, as well as other assets, in the projects that can potentially increase the capital, and, accordingly, bring profit [1-3]. It is important to note that this activity cannot exist without risky assets.

Almost all organizations are engaged in investment activity – it contributes to the increase in production volumes and opens new activities for the company. These factors directly influence the business expansion and growth of influence on the market.

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II. METHODS

A. Concept and types of investment risks

The investment risk is the likelihood of occurrence of unforeseen financial losses in the context of uncertain investment conditions.

Risk classification by sources is as follows:

1. Systematic (market, nondiversifiable) risk. This type of risk is associated with the state of the world economy as such. In most cases, it is determined by external factors that the investor cannot influence when choosing an investment object. Systematic risks include currency risk, political risk, inflation risk, interest rate risk, etc. It must also be noted that the inflation level and interest rate fluctuations should be taken into account when assessing this type of risk.

2. Nonsystematic (specific, diversified) risk. This type of risk is associated with a specific investment object in the specific economic field. Nonsystematic risks include credit risk, business risk, and industry-specific risk. The same as with the systematic risk, it can be noted that this one allows an investor's influence by changing the strategy and choosing the optimal investment portfolio. As a rule, the nonsystematic risk is associated with the problem of developing competition in the particular market segment [4; 5]. Aside from this classification, the main types of investment risks to pay increased attention to should be studied [6-8]:

1. Operational risk – probability of losses, which occur due to certain technical errors during operations in emergency situations, malfunctions in the information system operation, or incorrect personnel actions.

2. Political risk – potential losses associated with a change in the political/economic situation in the country. This type of risk usually results in an unstable situation in the country where there is a likelihood of a drop in effective demand, for example.

3. Business risk – the specifics of a particular type of activity directly influence this type of risk. Each organization is exposed to some factors that determine the market environment. The change in the price of goods/services and subsequently the demand for them can be such factors.

4. Market risk – this type of risk is associated with a rise or, conversely, a fall in the asset value, which is a direct result of changes in exchange rates, stock prices, interest rates, and prices of goods/services that are the most common investment objects.

5. Liquidity risk – this risk is associated with the lack of opportunity to release investment funds, while avoiding the loss in the required amount for a certain period of time. Accordingly, the more difficult the conversion of available securities into cash for an investor is, the higher the magnitude of liquidity risk is.

6. Inflation risk – potential losses that may be incurred due to the depreciation of the real value of assets, investments, and revenues.

Aside from the above types of investment risks, the following can also be mentioned: selective risk, functional risk, risk of profit losses, and country-specific risk.

It is important to note that an investor can choose the most suitable investment object, prevent and avoid significant investment losses only taking all the above risks into account [9, p. 120].

B. Investment risk management.

It must be emphasized that it is impossible to completely avoid risks. However, they can be controlled to prevent undesirable events [10; 11]. Firstly, the external factors that make up the conditions for investment should be analyzed, as well as the investment project taken, which involves identifying potential threats to investing and assessment of potential losses. Besides, various investment scenarios should be reviewed, and risks should be modeled. One of the final stages is to choose an anti-crisis strategy, which could result in risk mitigation or its insurance (reserve creation) [12-14].

Risk minimization is an option of risk management. However, this method cannot be applied to investment risk in general, as it encompasses some other risks. Let us review several options for risks minimization by types:

1. The liquidity risk can be minimized by choosing the most liquid instruments available.
2. The financial risk is managed by monitoring the borrowing volumes and conditions.
3. The investment portfolio is required for the industry risk minimization, which includes shares of organizations from various sectors of the country's economy.
4. The country-specific risk is mitigated by investing in foreign companies.
5. The stocks demonstrating the greatest prospects for growth should be chosen to reduce the business risk.

Such a popular method as diversification can also be added to the list. This term refers to the capital allocation in favor of objects in order to reduce the negative effects on the entire investment project [15; 16].

C. Investment risk assessment

There are two methods for assessing investment risks:

1. Qualitative method (which determines the degree of risk significance, assesses their consequences, and assists in choosing the method of their prevention). This method includes:

- Expert method (where the assessments of experts with experience in implementing investment projects are dealt with),
- Method of analogies (where a number of similar

investment projects are analyzed and, subsequently, a risk management strategy is developed),

- Method of analyzing the costs appropriateness (detection of possible risk areas with the subsequent task of their minimization), and
 - Hierarchy analysis method (allows to take the human factor into account when making a choice)
2. Quantitative method (this method estimates potential changes in the project efficiency). It includes:
- Monte Carlo method (simulation modeling),
 - Decision tree method,
 - Discount rate adjustment method (using a more significant discount rate in the provision of future income in real time),
 - Method of the performance criteria sensitivity analysis (forecasting the specific performance indicators in the investment project if its conditions change), and
 - Scenario method

Let us analyze the Monte Carlo method in more detail. It is based on the game theory and considers the action of a theoretically taken investment project in order to determine the competitors' reaction. This type of modeling is based on some experiments, the task of which is to determine the degree of influence of certain factors on the dependent indicators [17, 18]. This method allows an investor to estimate the potential risks of the project to the fullest extent, since the investment modeling differs from other approaches by the greatest degree of accuracy.

Simulation algorithm:

1. Creating a financial model, establishing a number of primary risk factors.
2. Allocating probability for each risk factor.
3. Generating all potential scenarios for the project development for each risk factor.
4. Estimating the efficiency of investments in each scenario.

The analysis is carried out after the repetition of the last two points (in order to build a histogram of the probability allocation). It must also be noted that the Monte Carlo method cannot be used without special software [19; 20].

III. RESULTS

However, despite the efficiency of the simulation method, the **scenario method** is the most common. It helps make a forecast of various outcomes of the external environment development and estimations of the investment project efficiency in various conditions. A certain probability is assigned to all possible scenarios (optimistic, most likely, pessimistic) in this method.

Let us consider the scenario method by the example (Table 1):

Table 1. Values of the projects' profitability and their probabilities

Scenarios	Project value, mln. rub.	Probabilities



	A	B	A	B
Pessimistic	-1.5	-2.3	0.3	0.2
Most likely	2.8	2.8	0.6	0.5
Optimistic	6.9	4.9	0.1	0.3

The least risky project should be defined.

1. Find the average value of each project:

$$M(E) = \sum_{i=1}^n x_i \cdot p_i$$

$M(A) = 0.3 \cdot (-1.5) + 0.6 \cdot 2.8 + 0.1 \cdot 6.9 = -0.45 + 1.68 + 0.69 = 1.92$ mln rub.

$M(B) = 0.2 \cdot (-2.3) + 0.5 \cdot 2.8 + 0.3 \cdot 4.9 = -0.46 + 1.4 + 1.47 = 2.41$ mln rub.

2. Find the dispersion:

$$VAR(E) = \sum_{i=1}^n p_i \cdot ([x_i - (M(E))]^2)$$

$VAR(A) = 0.3 \cdot (-1.5 - 1.92)^2 + 0.6 \cdot (2.8 - 1.92)^2 + 0.1 \cdot (6.9 - 1.92)^2 = 3.51 + 0.46 + 2.48 = 6.45$ mln rub.

$VAR(B) = 0.2 \cdot (-2.3 - 2.41)^2 + 0.5 \cdot (2.8 - 2.41)^2 + 0.3 \cdot (4.9 - 1.92)^2 = 4.44 + 0.08 + 2.66 = 7.18$ mln rub.

3. Find the standard deviation:

$$\delta(E) = \sqrt{VAR(E)}$$

$$\delta(A) = \sqrt{6.45} = 2.45 \text{ mln rub.}$$

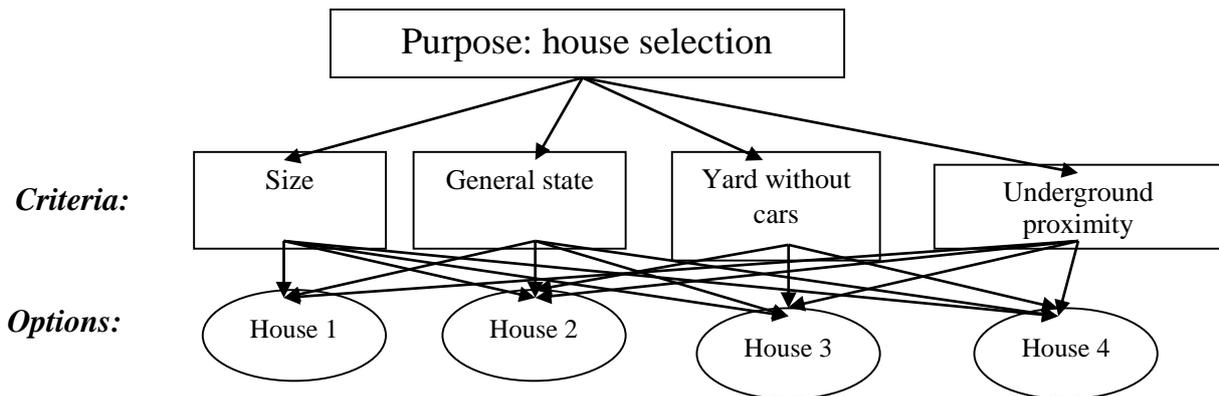
$$\delta(B) = \sqrt{7.18} = 2.68 \text{ mln rub.}$$

Based on the calculation results, it can be concluded that it is better to choose project A, since it is the least risky one.

Hierarchy analysis method

A house should be selected based on the optimal multicriteria analysis (Figure 1).

Figure 1. Problem of a multicriteria analysis of the house choice



Let us conduct a comparative analysis based on some criteria (Tables 2 – 6):

Table 2. Pairwise comparison matrix:

	K1	K2	K3	K4	β	K
K1	1	1/5	1/2	3	0.08	0.05
K2	5	1	2	1/7	0.36	0.23
K3	2	1/2	1	4	1.00	0.63
K4	1/3	7	1/4	1	0.15	0.09
Σ	8.33	8.70	3.75	8.14	1.58	1.00

Table 3. Matrix of paired comparisons of alternatives by the first criterion:

K1	A1	A2	A3	A4	β	α
A1	1	2	1/4	1/5	0.03	0.01
A2	1/2	1	5	1/7	0.09	0.03
A3	4	1/5	1	6	1.20	0.43
A4	5	7	1/6	1	1.46	0.53
Σ	10.50	10.20	6.42	7.34	2.77	1.00

Table 4. Matrix of paired comparisons of alternatives by

the second criterion:

K2	A1	A2	A3	A4	β	α
A1	1	6	1/7	1/2	0.11	0.04
A2	1/6	1	1/5	3	0.03	0.01
A3	7	5	1	1/7	1.25	0.49
A4	2	1/3	7	1	1.17	0.46
Σ	10.17	12.33	8.34	4.64	2.55	1.00

Table 5. Matrix of paired comparisons of alternatives by the third criterion:

K3	A1	A2	A3	A4	β	α
A1	1	7	1/3	1/7	0.08	0.06
A2	1/7	1	4	5	0.71	0.48
A3	3	1/4	1	3	0.56	0.38
A4	7	1/5	1/3	1	0.12	0.08
Σ	11.14	8.45	5.67	9.14	1.48	1.00

Table 6. Matrix of paired comparisons of alternatives by the fourth criterion:

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K4	A1	A2	A3	A4	β	α
A1	1	1/6	3	4	0.50	0.33
A2	6	1	1/5	1/3	0.10	0.07
A3	1/3	5	1	2	0.83	0.55
A4	1/4	3	1/2	1	0.09	0.05
Σ	7.58	9.17	4.70	7.33	1.53	1.00

$$\alpha^1_1 = 0.01 \quad \alpha^2_1 = 0.04 \quad \alpha^3_1 = 0.06 \quad \alpha^4_1 = 0.33$$

$$\alpha^1_2 = 0.03 \quad \alpha^2_2 = 0.01 \quad \alpha^3_2 = 0.48 \quad \alpha^4_2 = 0.07$$

$$\alpha^1_3 = 0.43 \quad \alpha^2_3 = 0.49 \quad \alpha^3_3 = 0.38 \quad \alpha^4_3 = 0.55$$

$$\alpha^1_4 = 0.53 \quad \alpha^2_4 = 0.46 \quad \alpha^3_4 = 0.08 \quad \alpha^4_4 = 0.05$$

Choose the optimal alternative:

$$A_1: W_1 = \kappa_1 * \alpha^1_1 + \kappa_2 * \alpha^2_1 + \kappa_3 * \alpha^3_1 = 0.08$$

$$\text{Similar for } A_2: W_2 = 0.32$$

$$\text{Similar for } A_3: W_3 = 0.42$$

$$\text{Similar for } A_4: W_4 = 0.18$$

As such, the algorithm of the optimal multicriteria choice results in choosing House 3, as it corresponds to the highest value of the components of the general priority vector. $W_3 = 0.42$.

IV. CONCLUSION

Summarizing the above, it can be stated that the problem of risk management is more relevant today than ever. Taking the wide range of factors influencing investment projects into account (both internal – for instance, those arising directly within a particular company or a sector of investment activity, and external – those relating to changes in the global economy as such), minimizing or circumventing risks is necessary. For this reason, it is necessary to analyze the current state of the market and forecast its future before making investments [21, 22].

Aside from the above analysis, risk management skills applied to each type of the appropriate method are also required. Of course, the investment risk assessment with the identification of the likelihood of a given situation is one of the most important stages. Efficient investment activity is impossible without these actions.

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