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MODELLING IN STRATEGIC INVESTMENT MANAGEMENT

МОДЕЛЮВАННЯ ПРИ СТРАТЕГІЧНОМУ УПРАВЛІННІ ІНВЕСТИЦІЯМИ

Summary. The article explores modern approaches to multicriteria modelling as a tool for strategic investment management. In the context of dynamic changes in market conditions and growing uncertainty, making effective investment decisions requires taking into account numerous criteria that characterize both financial and non-financial aspects of an enterprise. The authors emphasize the importance of a multi-criteria approach for the formation of investment strategies aimed at ensuring long-term growth and competitiveness of companies. The article discusses the key principles of multicriteria modelling and methods of its application in the process of strategic investment management. In particular, the article analyses such methods as hierarchy analysis, linear programming methods, fuzzy logic, and integrated models that combine different approaches. Particular attention is paid to the use of financial indicators such as net present value (NPV) as one of the basic criteria for evaluating investment projects. NPV allows to determine the feasibility of a project, taking into account the time value of money and future cash flows, which makes it an indispensable element of investment analysis. The authors emphasize the importance of a comprehensive approach that combines NPV with other criteria such as ROI, payback period, internal rate of return (IRR), and risk. This approach takes into account the financial sustainability of the project, its impact on the environment, social impacts, and alignment with the strategic goals of the enterprise. The article also discusses the key challenges faced by enterprises when using multicriteria models, including the complexity of building mathematical models, the need for highly qualified personnel, and the limitations associated with access to up-to-date data. The author suggests ways to overcome these problems, including the introduction of modern software tools, automation of data processing and the use of artificial intelligence to improve the accuracy of modelling. The article is of theoretical and practical value for scientists, economists, investors, and managers involved in the development and implementation of investment strategies. It contributes to a better understanding of the possibilities of multicriteria modelling in strategic decision-making and emphasises the role of NPV in the comprehensive assessment of investment projects.

Keywords: modelling, investment processes, strategic management, indicators, single-criteria and multi-criteria models.

Formulation of the problem. The main tool for studying complex economic systems, including industrial enterprises, is modelling. Modelling of any object (system, process) means replacing it with another object, called a model, which is adequate to a certain extent, in order to study the first one. This requires that the basic properties, relationships between elements, and behavior of the model and the modelled object are sufficiently similar to achieve the research objective. In our case, the objects of modelling are the tasks of the subsystem of innovation and investment planning, which is one of the main components of the system of ensuring the sustainability of industrial enterprises.

Analysis of recent achievements and publications. Many modern scholars study the trends and problems of investment development of enterprises. In particular, among the scholars from far and near abroad, it is worth noting the research of I. Ansoff, P. Drucker, V. Zinov, V. Medynsky, M. Porter, V. Santo, J. Schumpeter, and Y. Yakovets. Among the Ukrainian scholars who study the issues of managing the investment activity of enterprises, it is necessary to note the significant contribution of O. Amosha, M. Voynarenko, A. Voronkova, S. Ilyashenko, V. Stadnyk, O. Orlov, and L. Fedulova. Despite the importance of scientific research, certain aspects of investment planning in the process of innovation activity of an enterprise require further study, in particular, in the context of applying a multi-purpose approach.

The **purpose** of the article is to substantiate the use of a multi-purpose approach to solving the problems of investment planning at industrial enterprises.

Presentation of the main material. Let us consider the possibilities of applying in theory and practice both a single-purpose and a multi-purpose approach to justifying the choice of the most efficient variant of an investment project. Depending on the number of optimality criteria present in the economic and mathematical model in the task of forming an investment portfolio of an industrial enterprise consisting of real projects, they can be classified into two large classes: single-criteria models and multi-criteria models. Multi-criteria models contain at least two optimality criteria. At the stage of investment portfolio formation, it is necessary to simultaneously determine the types and number of investment projects to be implemented [2]. A number of mathematical models provide for the formation of an investment portfolio in close connection with the enterprise's production program and taking into account the possibilities of the financing sector. The following classification of investment planning models is characterized by integration of the financial and production spheres of the enterprise into the model. On this basis, we propose to distinguish the following groups of models:

– models that allow forming an optimal investment portfolio in the presence of a production program and a certain capital investment budget set for a given enterprise;

– models that allow simultaneously forming an investment portfolio and determining the sources of financing for a given production program of an enterprise;

– models that allow simultaneously forming an investment portfolio and a production program with a given amount of funds and attracting the necessary financial resources from different (alternative) sources of financing, each of which is focused on the unequal cost of its capital.

Models can also be classified depending on the number of periods during which an investment portfolio can be implemented. In particular, there are models in which:

– the investment planning period consists of only one time period (static model);

– the investment planning period is divided into several identical periods, but specific actions are possible only in the initial period (one-stage model);

– the necessary calculations are performed in different time periods of investment planning (multi-stage model) [3].

The objective function can be the net present value of NPV, GNI, IR, IRR or other criteria that can be used to assess the effectiveness of an investment project or investment portfolio. Economic and mathematical models of decision-making on the selection of investment projects for financing, which involve the consideration of unknown factors, are divided into deterministic, stochastic and models with elements of uncertainty. We divide the models presented in the literature, implemented under conditions of certainty, as well as depending on the type of objective function and constraints, into four types: linear, nonlinear, dynamic and graphical. A generalized classification of models that can be used to form an investment portfolio is shown in Figure 1.

Depending on the goal and the constraints, single-criteria models can be divided into the following [5]:

1) ranking of investment projects according to the selected performance criterion:

a) in conditions of certainty;

b) in conditions of risk;

2) economic and mathematical models of decision-making on the selection of investment projects for which it is advisable to finance:

a) models of program decisions under conditions of certainty;

b) stochastic models;

c) models with elements of uncertainty.

The above classification of models requires determining their advantages, disadvantages and areas of appropriate application. Ranking of investment projects under conditions of certainty implies that the number of possible situations (options) and their consequences are known. The probability of each event is equal to one. If there is sufficient certainty of the initial data, investment decisions are made in the following sequence [4]:

1) the criterion by which the selection will be made is determined;

2) calculate the values of the criteria for the options being compared;

3) the option with the best criterion value is recommended for selection.

In the case of uncertainty and risk, possible outcomes are predicted and probabilities are assigned. The group of linear models is the most

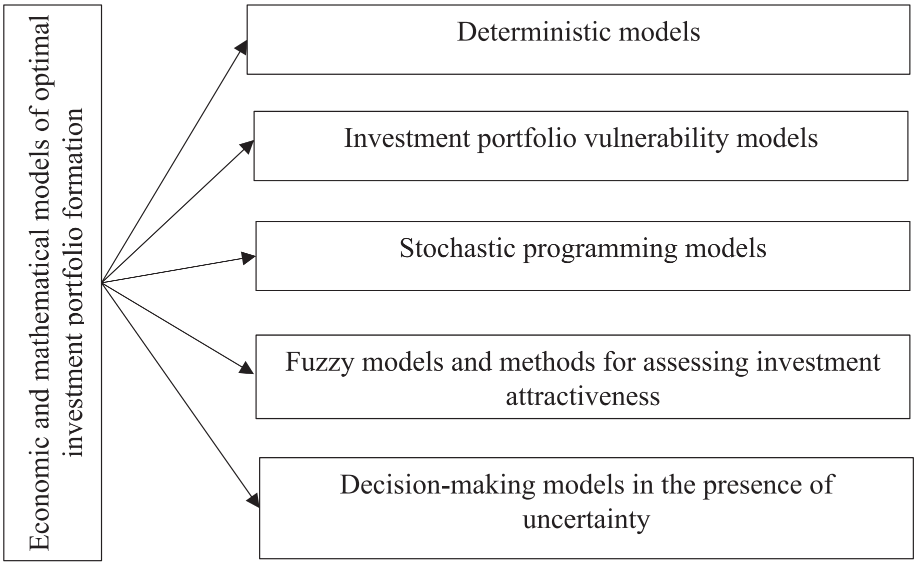

Figure 1. Generalized classification of economic and mathematical models of optimal investment portfolio formation [compiled by the author]

diverse. In linear models, the objective function and constraints are linear in the control variables. By changing the values of the variables, you can get closer to your goal. The linear single-criteria models of considerable theoretical and, most importantly, practical interest include the following

– the 'backpack' model
– the static model of J. Dean;
– Albach's one-stage model;
– multi-stage model of Hux and Weingartner;
– a model with several production stages – the extended Ferstner-Henn model;
– Jacob's model with plant selection and disinvestment options.

Graphical models are represented by various modifications of network models. Stochastic models for choosing solutions in complex situations are usually more adequate to real phenomena and processes than deterministic formulations of management, planning and design tasks. Stochastic programming is a set of methods for solving optimization problems of a probabilistic (stochastic) nature. In stochastic models, the unknown factors are random variables. However, they have known distribution functions and statistical characteristics (mathematical expectation, variance, standard deviation, etc.). In models with elements of uncertainty, it is impossible to collect statistical data for unknown factors, and the values of these factors are not determined.

When making decisions about the composition of an investment portfolio under conditions of complete uncertainty, simulation modelling and criteria (rules) developed in game theory are used. In simulation models, the process of forming an investment portfolio of real projects is carried out on a computer. Numerous simulations and subsequent analysis determine the results of random influences on it. As a result, a variant of the investment portfolio is selected in which the numerical estimate of the objective function (e.g., net present value) reaches the highest value [1].

The classification of economic and mathematical models that can be used in the formation of an optimal investment portfolio is completed by a group of models with elements of uncertainty. In the case of uncertainty and risk, it is expected to predict possible outcomes and assign probabilities to them. Various methods and criteria can be used to make scientifically sound management decisions related to choices in the above conditions. A situation that will illustrate different methods of making the best investment decisions will be presented in the form of a decision matrix. It reflects a state of affairs where:

– there is a finite set of alternative investment projects (IPs) and environmental states;
– the net present value is the final characteristic of the economic effect corresponding to each alternative IP option;

NPV is the only important objective function of IP, which reflects the single-objective nature of this task.

The NPV reflects different environmental states, which may be due, for example, to different bank rates at which different investment institutions offer capital. The following symbols may be used in the decision matrix:

IPj – j-th variant of an alternative investment project (j=1,...,m);

NPVi – net present value corresponding to the i-th variant of the investment project (i = 1, ..., n), UAH.

A generalized version of the decision matrix is shown in Table 1. Based on the numerical material contained in the decision matrix, the investor can use various methods to select the best investment project. Let us consider the essence of the methods that are of the greatest practical interest and illustrate the corresponding calculation system using conditional examples.

Wald's or maximin's rule. According to this rule, the one that has the highest net present value under the most unfavorable environmental conditions is selected from the alternative investment projects (IP_j). To do this, find the minimum value in each row of the decision matrix, i.e. for each alternative NPV^i. Then the maximum value is determined among the identified minimums. The investment project of an IP that corresponds to the maximum value is considered to be the most economically feasible – IP_{opt}.

$$IP_{opt} = arg\ max_i\ min_j\ NPV^{ij}. \quad (1)$$

An investor who makes a decision and is guided by this rule shows a low risk appetite. He assumes an extremely negative development of the environment and accepts the least favorable development for each investment alternative. The environment is assessed as an opponent in a «two-person zero-sum game». This way of investor behavior reflects an attitude to the inevitability of unfavorable external circumstances.

The maximax rule. For an optimistic investor, the possibility of choosing the best investment project is associated with the use of the maximax rule. He chooses the investment project with the highest numerical value of NPV. In this case, the investor does not take into account the risk associated with unfavorable environmental development when making an investment decision. The optimal variant of an investment project is determined by the formula:

$$IP_{opt} = arg\ max_i\ max_j\ NPV^{ij}. \quad (2)$$

Hurwitz's rule. Hurwitz's rule combines both the maximum and the minimum rule. This is achieved by linking the maximum of the minimum values and the maximum of the maximum values using a convex linear combination. It is a rule called optimism-pessimism. The investment project is selected according to the formula:

$$IP_{opt} = arg\ max_i\ \{(1-\alpha) min_j NPV^{ij} + \alpha\ max_j\ NPV^{ij}\}, \quad (3)$$

where α is the optimism coefficient, which can take values from zero to one.

If α is equal to 1, then the choice of an alternative project should be made according to the maximax rule, and if α = 0, then the maximin rule. If the investor has a negative attitude to risk, then he takes α = 0.4.

Bayes' criterion (rule). If the probabilities of occurrence of possible states of the environment P^j in relation to the value of the NPV_{ij} are known, it is advisable to apply the Bayesian rule. The value of the mathematical expectation MO^J of the alternative investment project j plays the role of the criterion, according to which the choice is made. The value of the mathematical expectation is calculated by multiplying the net present value of the j-th alternative by the corresponding value of the probability of occurrence of this state and then summing. The investment project option is determined by the formula:

$$IP_{opt} = arg\ max_i \sum_{j=1}^{n} NPV^{ij} P^{j}, \quad (4)$$

Let's assume that the probabilities of the environmental states are known:

$$P = \{0,1;\ 0,2;\ 0,3;\ 0,2;\ 0,2\},\ \sum_{j=1}^{n} P^{j} = 1, \quad (5)$$

According to the Bayesian rule, the second investment project (IP_{opt} = 2) should be considered optimal, since its mathematical expectation value is higher than that of the other projects. The above rule implies that the elements of the NPV_{ij} matrix also express the utility of investment effects. Thus, the change in utility in relation to the change in NPV is assumed to be proportional, and the attitude to risk is assumed to be neutral.

Bernoulli criterion. According to the Bernoulli criterion, it is possible to replace the values of

Table 1

Decision matrix for selecting the best investment project

Alternative options for investment projects (IP^j)	State of the environment: numerical estimates of NPV for investment project alternatives (NPV^i)			
IP^1	NPV^{11}	NPV^{12}	…	NPV^{1n}
IP^2	NPV^{21}	NPV^{22}	…	NPV^{2n}
…	…	…	…	…
IP^m	NPV^{m1}	NPV^{m2}	…	NPV^{mn}

mathematical expectation and risk levels of objective functions (e.g., NPV) with expected utility (benefit). Instead of monetary objective functions, the utility that a decision maker associates with the goals set and the expected degree of their achievement, taking into account the personal attitude to risk, is used.

The assumption is that the decision maker is able to assess the benefits of various investment projects. The RBM is responsible for finding the maximum moral hazard (MH). This maximum is calculated for each alternative using the following formula:

$$\text{MH}_{opt} = arg\ max_i \sum_{j=1}^{n} \beta(NPV^{ij}) P^{j}, \qquad (6)$$

де $\sum_{i=1}^{n} \beta(NPV^{ij})$ – a digressive increasing utility function;

NPV^{ij} – is the net present value of the investment project i, corresponding to the state of the j-th external environment;

P^{j} – is the probability of occurrence of the state of the j-th environment.

Conclusions. As shown, the single-objective approach to solving investment planning problems has become quite widespread in practical activities to ensure the sustainability of enterprise development. However, the single-objective approach has a number of significant drawbacks that can be avoided by using the methodology of multi-criteria optimization, which is more efficient (effective). Any task related to the development of an investment plan (or the formation of an investment portfolio consisting of real assets) and solved in the system of ensuring the sustainability of the enterprise's development is mainly an economic task, since mathematical models of planning tasks always contain at least one optimality criterion, the nature of which is economic. Therefore, it is quite legitimate to use the term «investment planning and economic task». In order to achieve the best possible final aggregate result of production and sales of finished products, an enterprise pursues not one, but several goals that are different in nature. This means that the main approach to solving optimization planning and economic investment tasks, which used to dominate in theory and practice, should be recognized as a multi-purpose approach rather than a single-purpose one. The expression «to achieve the maximum effect at the lowest cost» is quite common in the economic literature, meaning that it is necessary to develop a draft management decision or find the best solution to an investment problem while taking into account the numerical values of two optimality criteria. This corresponds to the concept of a multi-objective approach to solving problems. A multi-purpose economic formulation and its adequate mathematical formalization (i.e. an economic and mathematical model) usually more fully corresponds to the essence of optimization tasks solved in modern systems of internal corporate planning and management. The multi-purpose approach to solving planning, economic, investment and commercial tasks differs not only quantitatively due to the use of a larger number of criteria, but also qualitatively. This may be a direction for further research.

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Анотація. У статті досліджуються сучасні підходи до багатокритеріального моделювання як інструмента стратегічного управління інвестиціями. В умовах динамічних змін ринкової кон'юнктури та зростаючої невизначеності ухвалення ефективних інвестиційних рішень вимагає врахування численних критеріїв, що характеризують як фінансові, так і нефінансові аспекти діяльності підприємства. Автори акцентують увагу на значенні багатокритеріального підходу для формування інвестиційних стратегій, які спрямовані на забезпечення довгострокового зростання та конкурентоспроможності компаній. У статті розглянуто ключові принципи багатокритеріального моделювання та методи його застосування в процесі стратегічного управління інвестиціями. Зокрема, аналізуються такі методи, як аналіз ієрархій, методи лінійного програмування, нечітка логіка, а також інтегровані моделі, що поєднують різні підходи. Окрему увагу приділено використанню таких фінансових показників, як чиста приведена вартість (ЧПВ, або NPV – Net Present Value), як одного з базових критеріїв оцінки інвестиційних проєктів. ЧПВ дозволяє визначити доцільність реалізації проєкту, враховуючи вартість грошей у часі та майбутні грошові потоки, що робить його незамінним елементом інвестиційного аналізу. Автори підкреслюють важливість комплексного підходу, що поєднує ЧПВ з іншими критеріями, такими як рентабельність інвестицій, строк окупності, внутрішня норма дохідності (IRR) та рівень ризику. Такий підхід дозволяє врахувати фінансову стійкість проєкту, його вплив на екологічну ситуацію, соціальні наслідки, а також відповідність стратегічним цілям підприємства. У статті також обговорюються ключові виклики, що стоять перед підприємствами під час використання багатокритеріальних моделей, зокрема складність побудови математичних моделей, необхідність високої кваліфікації персоналу, а також обмеження, пов'язані з доступом до актуальних даних. Запропоновано шляхи подолання цих проблем, зокрема впровадження сучасних програмних засобів, автоматизація процесів обробки даних та використання штучного інтелекту для підвищення точності моделювання.

Ключові слова: моделювання, інвестиційні процеси, стратегічне управління, показники, однокритеріальні та багатокритеріальні моделі.