UDC 519.863
DOI: https://doi.org/10.32782/2708-0366/2023.16.15

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CONCEPTUAL MODEL OF THE MANAGEMENT OPTIMIZATION PROBLEM

КОНЦЕПТУАЛЬНА МОДЕЛЬ ЗАДАЧІ ОПТИМІЗАЦІЇ УПРАВЛІННЯ

The decision-making process, algorithmically, is a sequence of steps to achieve the goal of management – choosing the optimal strategy from a set of possible alternatives. From a mathematical point of view, the decision-making process is a stochastic, partially deterministic multi-criteria optimization problem. Application of a single algorithm to models of various control problems is not possible for many reasons. First, the difficulty in choosing modeling tools – it is not possible to apply known optimization schemes, due to the non-determinism of the input parameters, the lack of their numerical estimates, or identifiers of the defining characteristics of the control object. Secondly, the multiplicity of criteria for choosing alternatives. Mathematical theory ensures the adequacy of the solution according to the single criterion of optimality. If there are several selection ratios from a set of alternatives, then the search for an optimal solution cannot be formalized only by mathematical operators. The application of the systematic principle of decomposition simplifies the algorithmization of the model, preserving the condition of optimality at each control step. The versatility of the system approach to building models of management tasks lies precisely in the combination of various methods of scientific knowledge.

Key words: *adequacy, algorithm, decomposition, model, system analysis, parameters, specification.*

Моделювання процесу прийняття рішень в управлінні підприємством досить складна наукоємна задача. Якість моделей, залежить від можливостей формалізованого опису станів системи управління, що є результатом комплексного впливу факторів різної природи та зовнішніх чинників, які змінюють внутрішню структуру об'єкта управління та впливають на ефективність прийняття рішень. Процес прийняття рішення, алгоритмічно, є послідовністю кроків досягнення мети управління – вибору оптимальної стратегії з множини можливих альтернатив.. З математичної точки зору процес прийняття рішення – стохастична, частково детермінована багатокритеріальна задача оптимізації. Застосування єдиного алгоритму до моделей різних задач управління не можлива з багатьох причин. По-перше, складність у виборі засобів моделювання – не можливо застосувати відомі схеми оптимізації, через не детермінованість вхідних параметрів, відсутність їх числових оцінок, або ідентифікаторів визначальних характеристик об'єкта управління. По-друге, не однозначність, або множинність критерію вибору альтернатив. Математична теорія забезпечує адекватність рішення за єдиним критерієм оптимальності. Якщо відношень вибору з множини альтернатив декілька, то пошук оптимального рішення не можна формалізувати тільки математичними операторами. Застосування системного принципу декомпозиції спрощує алгоритмізацію моделі, зберігаючи умову оптимальності на кожному кроці управління. Універсальність системного підходу для побудови моделей задач управління полягає саме в об'єднанні різних методів наукового пізнання. Адекватність моделі, як алгоритму вибору із множини альтернатив, залежить від якості параметричної бази моделі – інформації достатньої для прийняття рішення. У свою чергу, параметри моделі визначається постановкою задачі. Чітке формулювання умови задачі визначає склад параметричної бази та специфікацію моделі прийняття рішення. У статті досліджуються способи поєднання математичних алгоритмів та методів системного аналізу для побудови концептуальної моделі прийняття управлінських рішень.

Ключові слова: *адекватність, алгоритм, декомпозиція, модель, системний аналіз, параметри, специфікація.*

Formulation of the problem. Modeling the decision-making process in enterprise management is a rather complex and scientific task. The quality of the models depends on the possibilities of a formalized description of the states of the management system, and is the result of the complex influence of factors of various nature that change the internal structure of the management object and affect the effectiveness of decision-making. The complexity of the algorithmization of management decision-making models in conditions of uncertainty and conflicts, which is associated with the impossibility of quantitative assessment of parameters and dynamic changes in the structure of the model, stimulates the search for new conceptual decision-making algorithms that will allow the company to adapt to changes in the economic environment. The article examines ways of applying mathematical tools and methods of system analysis to the construction of a conceptual model of management decision-making.

Analysis of recent research and publications. The quality of a management model depends on the completeness and degree of formalization of the data that describe the characteristic and situational parameters of the object being managed, that is, on the initial conditions of the decision-making task. Regarding initial conditions, the decision-making process can be divided into two classes of problems [1]:

– decision-making under conditions of complete determinism, where the input data are known with precision according to the parameters of the model;

– decision-making under conditions of uncertainty, where it is not possible to describe the model parameters even with relative characteristics such as weighting coefficients of their significance in the decision-making process.

Decision-making under conditions of risk can be considered as a partial case of the second class of problems, where uncertainty can be assessed as a numerical value – the level of risk. In such cases, although the model parameters may be uncertain, a quantitative assessment of the risk level can be made [2].

Algorithms for second-class problems are weakly formalized, and methods of systems analysis are typically used for their description [5–7]. The main advantages of systems analysis methods, compared to other partially formalized modeling approaches, lie in representing the managed object as a complex emergent system, which allows for the application of decomposition methods to study its integral characteristics [8; 9]. The adequacy of the system model is substantiated at each step of decision-making algorithm construction, starting from the formation of the model's parametric base, description of quality evaluation criteria for decisions, and further selection of modeling methods to obtain decision alternatives, among which the optimal one is chosen [10]. Systems analysis can be conducted even at the level of logic or rational thinking. Systems analysis is considered a scientific method only when a scientific approach based on quantitative assessments is used at all stages.

Presentation of the main research material. In the theory of management, the fundamental principle is that a decision is justified if there is a possibility to choose alternative options [11]. As a consequence of this axiom, there is a sequence of stages in the decision-making process. The first stage is the process of forming a set of alternatives. Successful completion of this stage ensures that all possible alternatives will be considered in the choice. The second stage involves defining criteria for evaluating the quality of the decision, which are aligned with the management objectives. The choice presupposes the existence of a criterion for assessing the quality of the alternative – the management operator. Therefore, the concept of management can be formulated as an optimization process of decision-making to achieve defined goals, under certain conditions – the states of the managed object and the operators that transition the object from one state to another.

The successful formulation and solution of an optimization problem depend equally on two conditions:

– how well the set of alternatives is described;

– the determinacy of the criterion for evaluating the alternatives.

The measure of description of alternatives implies not only the formalization of parameters for each individual alternative but also a complete enumeration of all possible options. In the mathematical formulation of the optimization problem, the set of alternatives $X = \{X_i\}, (i = 1 \div n)$ is considered complete if it is a subset of a broader (not necessarily formalized) set – the space Ω. Additionally, a "membership function" must be described, which is an algorithm that determines the relationship of each element in the space Ω to the set of alternatives $X = \{X_i\}, i = 1 \div n$. The practical implementation of these requirements is achieved by constraining the space Ω to a time interval for decision-making and using statistical assessments of the elements X_i.

Different formal schemes are used to describe the criterion $F(X)$ for selecting the "best" alternative among the possible alternatives [12]. The specification of the selection criterion on the set of alternatives is acceptable for modeling if it can be evaluated using quantitative characteristics, at least in the form of ranks. Typically, the most suitable representation for algorithmization is the functional representation of the optimization criterion as a numerical objective function defined on the set of alternatives X: $F(X) = \underbrace{exstr}_{X \in \Omega}\left[F(X_i)\right]$.

The mathematical theory provides a good approximation of optimization models only when the objective function is unambiguously defined. Several mathematical methods [1; 3; 11] have been developed to enable multi-criteria optimization, although mathematicians do not provide definitive recommendations. In such cases, the search for the optimal solution is based on the personal judgments of experts, specialists from different fields of knowledge, and decision-makers, using methods of system analysis. The essence of the systems approach lies in representing the management object as a complex system, combining formal modeling methods with non-formalized expert knowledge. Therefore, it is widely applied to management problems that cannot be solved using available mathematical methods.

Let us consider that the set of alternatives X is limited, and the elements of the set X_i are effectively described (unambiguously defined, enumerated, or predicted) within the time interval of management $\boldsymbol{T} \in [\boldsymbol{t}_0; \boldsymbol{t}]$: $\boldsymbol{X}(\boldsymbol{t}) \in [\boldsymbol{X}(\boldsymbol{t}_0); \boldsymbol{X}(\boldsymbol{t})]$. Let's examine the characteristics of decision-making models based on the quality of input data – the set of alternatives and selection criteria.

1. Deterministic model: The set of alternatives is unambiguously described in terms of parameters, and the optimization criterion is specified as an objective function. The optimization model follows a classical, linear mathematical programming scheme. In practical implementation, such a model is generally not adequate to reality. However, in system analysis, the mathematical apparatus is used not as a means but as an auxiliary tool in the decision-making process. The analysis of the linear optimization result is used to refine the problem, adjust the problem conditions, determine the direction of additional alternative search, and clarify the selection criteria.

2. Partially deterministic model: There are two possible ways to describe the input data.

Decision-making under uncertain selection criteria: The set of alternatives is deterministic, meaning the numerical characteristics are determined with precision for each individual alternative. However, the optimality criterion is not uniquely defined, or the number of partial optimization criteria, their interrelationships, and their degree of influence on the result are not specified. The model structure may have a "weak" specification. The selection is made based on the analysis of trends in previous periods or as a result of predictive calculations, exhaustive enumeration of the alternative set, where each alternative, with some probability, can be an optimal solution. The final choice is made by the decision-maker.

2.2. In decision-making under risk conditions, the criterion assessments are determined and formalized, but the set of alternatives is non-deterministic, with some model parameters being random variables. We have a stochastic model with parameter dependencies described by probability distributions. Such situations arise in real economic systems. The set $X = \{X_i\}, (i = 1 \div n)$ of alternatives represents n-states of the management system under new economic conditions – states affected by risks and parametric uncertainty. Parametric uncertainty can be addressed by limiting the range of possible parameter values. The bounds of the interval are specified by approximate values or qualitative characteristics. The distribution of parameter values within the interval is determined using statistical analysis methods, such as probability distribution functions. Decisions are made based on the criterion of expected value, which effectively corresponds to the extremum value of a utility function (maximum expected profit or minimum expected costs).

3. Anon-deterministic stochastic model. Decision-making under uncertainty requires implementing alternative solutions for a set of random natural states. The optimality criterion can be specified by a payment matrix $K_{n\times m} = K\left(X_i; S_j\right)$. The elements of the matrix are considered as assessments of individual alternative X_i for a specific natural state S_j. The natural states $S_j, \left(j = 0 \div m\right)$, are random variables with unknown distributions. Limited information about the system states within a time interval complicates the modeling process and is one of the sources of uncertainty in decision-making models. Statistical analysis tools yield good results for parameter estimation and structure selection in stochastic models [12]. Using the system decomposition principle simplifies the modeling process. The initial problem is divided into p stages corresponding to the natural states S_j. At each stage, the optimal decision is determined based on the evaluation of alternatives using a partial optimality criterion. The decision-making process algorithm under uncertainty, based on system analysis methods, includes tools that gradually form the model, justifying its adequacy at each step: initially, in the selection of the parametric base, then in formulating the optimality criteria, and subsequently in selecting the model specification and analyzing alternative solutions to choose the best one.

Conclusions. The main reasons for seeking new decision-making model concepts can be highlighted. Firstly, the complexity of selecting modeling tools – it is impossible to apply familiar optimization schemes due to the non-deterministic nature of input parameters, the absence of their numerical assessments, or identifiers of defining characteristics of the control object. Secondly, the ambiguity or multiplicity of alternative selection criteria. Mathematical theory ensures the adequacy of a decision based on a single optimality criterion. However, if there are multiple choice relationships among alternative options, the search for an optimal decision cannot be formalized solely through mathematical operators. The universality of a systemic approach to building control problem models lies precisely in the integration of various methods of scientific knowledge. The adequacy of a model as an algorithm for selecting from a set of alternatives depends on the quality of its parametric basis, which is information sufficient for decision-making. In turn, the parameters of the model are determined by the problem formulation. A clear formulation of the problem condition determines the composition of the parametric basis and the specification of the decision-making model.

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