Lecture 13. Basics of decision making and situational modeling

The purpose of the lecture: a meaningful introduction to the basics of decision making and situational modeling of systems.

Lecture plan:
Introduction
1 Decision making
2 Situational modeling
Conclusion

Keywords: decision making, activity, situational analysis, function, decision maker, knowledge, sets, costs, making, decision, cost, profit, utility, reliability, utility of the decision, alternative, value, simulation models, theoretical method, decision making procedure, statistical hypothesis, measure, problem model, efficiency criterion, algorithm, dynamic programming, game theory, network graph, optimality criterion, decision-making system, problem and environment analysis, adaptation, development, analysis and interpretation of results, mathematical programming, preference relation, ranking , situational modeling, banking system, operations, analysis, interest rate, cash flows, authorized capital, profitability, liquidity, withdrawal, amount of risk, dynamic model, convertibility, debtors, accession, probability, vector, conditional probability, assets, receivables, Shannon's formula, amount of information, class, rating, Bayesian risk, model adequacy, flow, effective mechanism, behavior strategy, decision support system, place, multimedia, support, problem monitoring, planned analytical mode, emergency mode, computer.

Contents of the lecture:

Introduction

Decision making and goal-setting resource-oriented human activity in the social, economic, political, ideological, and military spheres are closely related. In them, mistakes are highly undesirable, which can lead to disastrous consequences. But due to the limited information capabilities of a person, mistakes are always possible. Therefore, there is an urgent need for a scientific approach to justification and decision making.

1 Decision making

Decision making, along with forecasting, planning, situational analysis of the situation, execution of decisions, control and accounting, is a management function. All management functions are aimed in one way or another at the formation or implementation of solutions, and any management function can be technologically represented as a sequence of decisions related to a common goal.

When forecasting and planning, decisions are made related to the choice of methods and means, the organization of work, the assessment of the reliability of information, the choice of the most reliable forecast and the best version of the plan.

Thus, the decision-making function is from the methodological and technological points of view more general than other management functions. For a decision maker (DM), decision making is the main task that he is obliged to perform in the management process. Therefore, knowledge of the methods, technologies and means of solving this problem is a necessary element of the qualifications of a leader, the basis for further management.

The end result of any decision-making problem is a decision, a constructive prescription for action. The decision is one of the types of mental activity and has the following features: there is a choice from a variety of possibilities; the choice is focused on the conscious achievement of goals; the choice is based on the formed attitude towards action. The main characteristic of the solution is its efficiency, i.e. degree, rate of achievement of goals and expenditure of resources for making and implementing decisions. The solution is the more effective, the greater the degree of achievement of goals and the lower the cost of costs.

Making a decision is choosing one of the many feasible options under consideration. Usually their number is finite, and each choice determines some result (economic effect, profit, gain, utility, reliability, etc.) that can be quantified. This outcome is commonly referred to as the utility of the solution. Thus, the option with the highest value of the solution utility is sought. An approach with minimization of the opposite estimate, for example, a negative value of utility, is also possible. In practice, we often encounter a situation when a single result corresponds to each variant of the solution (determinism of the choice of the solution), although other cases are also possible, for example, when each variant i and condition j characterizing the utility corresponds to the result of the solution xij. Thus, we can talk about the matrix of solutions $\| x_{ij} \|$, i = 1, 2,…, m; j = 1, 2,…, m. To evaluate a decision, you need to be able to evaluate all its consequences. There are various approaches to this assessment. For example, if the solutions are alternative, then the consequences of each of them can be characterized by the sum of its largest and smallest results, the maximum of the possible such sums, the maximum of the maximums for all options (the optimistic position of the choice), the maximum of the arithmetic mean (the neutral position of the choice), the maximum of minimum (pessimistic position) and others.

Classical decision-making models, as a rule, are optimization ones, aiming to maximize benefits and, on the basis of these models, obtain practical profits. Since theorists are more interested in the first side, and practitioners - in the second, their close cooperation is necessary in the development and use of such models. Practical recommendations (decisions) can be obtained if, when building a decision-making model, greater importance is attached to taking into account the essential structural elements of the modeled system, i.e. development of a simulation model for decision making, using experimental, semi-experimental and theoretical methods. In addition to the classical, optimization decision-making procedures, there are a number of basic non-classical (neoclassical) procedures, decision-making technologies, some of which we will consider.

Decision-making tasks are classified according to various criteria. The most significant are: the degree of certainty of the information; using an experiment to obtain information; number of decision makers; content of decisions; direction of decisions.

The decision-making process is often influenced by various random (stochastic) parameters that complicate the procedure. Lack of information about their distribution (the complexity of their measurement) leads to the need to accept some hypotheses both about the area of their change and about the nature of their distribution (about the probability distribution function). The correctness of the hypotheses used must be checked using methods for evaluating statistical hypotheses. In the absence of sufficient information, such a procedure has to involve a large number of distribution types. Decision-making problems with non-deterministic parameters are called decision-making problems under conditions of insufficient information. The less information we have, the greater the difference may be between the expected and actual results of decisions made in general. The measure of the influence of information (parameters) on the decision result is called relevance. It is especially important in the socio-economic sphere to make decisions when there are risks (non-payments, loan defaults, worsening living conditions, etc.).

Formalized decisions are made on the basis of appropriate mathematical methods (algorithms). The mathematical model of the optimization problem for the formalized solution includes the following elements:

1. *a given optimized objective function (controllability criterion):* $\Phi = F(x_1, x_2, \dots, x_n)$*, where* x_j $(j = 1, 2, \dots, n)$ *are the parameters taken into account when making a decision (reflecting decision-making resources);*
2. *conditions reflecting the limited resources and actions of the decision maker in making decisions:* $g_i(x_j) < a_i$, $k_i(x_j) = b_i$; $c_j < x_j < d_i$, $i = 1, 2, \dots, m$; $j = 1, 2, \dots, n$.

An indispensable requirement for solving the optimization problem is the condition n > m.

Depending on the efficiency criterion, strategies and control factors, one or another optimization method (algorithm) is selected.

The main classes of methods are:

1. *methods of linear and dynamic programming (decision-making on the optimal allocation of resources);*
2. *methods of queuing theory (decision-making in a system with a random nature of receipt and service of requests for resources);*
3. *methods of simulation (decision making by playing various situations, analyzing system responses to various sets of assigned resources);*
4. *methods of game theory (decision-making by defining a strategy in certain competitive problems);*
5. *methods of the scheduling theory (decision-making by developing calendar schedules for work execution and resource use);*
6. *methods of network planning and management (decision-making through the assessment and reallocation of resources in the implementation of projects depicted by network diagrams);*

7. *methods of multicriteria (vector) optimization (decision making under the condition of the existence of many criteria for the optimality of a solution)*

and other methods.

Choosing a decision is the final and most critical stage of the decision-making process. Here the decision maker must comprehend the information obtained at the stages of setting the problem and formulating solutions and use it to justify the choice. In real problems of decision-making, by the beginning of the stage of choosing a solution, there is still a lot of uncertainty, so it is practically very difficult to immediately make a choice of a single solution from a set of feasible solutions. Therefore, the principle of successive reduction of uncertainty is used, which consists in a successive three-stage (usually) narrowing of the set of solutions. At the first stage, the original set of alternative solutions Y is reduced (using resource constraints) to the set of acceptable or feasible solutions $Y_1 \subseteq Y$. At the second stage, the set of feasible solutions Y_1 is reduced (taking into account the optimality criterion) to the set of effective solutions $Y_2 \subseteq Y_1$. At the third stage, a choice is made (based on the selection criterion and additional information, including expert information) of a single solution $Y^* \in Y_2$.

Decision-making system is a set of organizational, methodological, software-technical, information-logical and technological support for decision-making to achieve the set goals.

The general decision making procedure can consist of the following steps:

- ✓ *analysis of the problem and environment (goals of decision making, their priorities, depth and limitations of consideration, elements, connections, resources of the environment, evaluation criteria);*
- ✓ *statement of the problem (determination of specifications of the problem, alternatives and criteria for choosing a solution);*
- ✓ *selection (adaptation, development) of a method for solving the problem;*
- ✓ *selection (adaptation, development) of a method for evaluating a solution;*
- ✓ *solving the problem (mathematical and computer data processing, imitation and expert assessments, clarification and modification, if necessary);*
- ✓ *analysis and interpretation of results.*

Decision-making problems can be posed and solved in the following conditions: deterministic (certainty, formalization and uniqueness of the objective function, its quantitative evaluability), risk (possible decisions, outcomes are distributed probabilistically) and non-deterministic (uncertainty, inaccuracy, poor formalizability of information).

Decision models use different procedures. In particular, the following are the simplest and most effective:

- ✓ *methods of mathematical programming;*
- ✓ *methods of indifference curves;*
- ✓ *multicriteria choice of alternatives based on a clear or fuzzy preference relation;*
- ✓ *consistent evaluation and subsequent elimination of options;*
- ✓ *multidimensional ranking (scaling) of objects and others.*

When choosing a rational solution, it is necessary to take into account the external environment and side effects, the dynamic variability of the decision assessment criteria, the need to rank the aspects and priorities of the decision, their incompleteness and heterogeneity (and sometimes conflict).

2 Situational modeling

Let's demonstrate situational modeling using the example of modeling the bank's activities. The banking system is one of the subsystems of the modern economic system, most susceptible to informatization. The development of the banking system is accompanied by a constant search for adequate optimal methods and management tools, decision-making based on economic and mathematical analysis and modeling of banks' activities. At the same time, it is necessary to take into account the fact that financial transactions also have stochastic components that complicate the already complex processes of calculating interest rates, contributions and payments, regulation and management, investments, etc. These processes are complex not only dynamically, but also computationally, logically ... In addition, the forecast, analysis of inflation rates, the structure of assets and liabilities of the bank, stock returns, exchange rates, interest rates, etc. depend on such forecasts.

A situational analysis of cash flows consists in the based – often on simulation modeling – analysis of the effectiveness of a particular set of financial transactions and procedures (out of many possible and acceptable) by comparing the results of their impact on financial and cash flows with the value of financial and monetary assets without taking into account their impact ... Consequently, situational analysis of cash flows is a dynamic process using optimization methods and optimality criteria. In a situational analysis of some basic values of the value of assets (corresponding to certain financial conditions and obligations, for example, the amount of authorized capital), it is possible, according to some optimality criteria (target optimization functions), to choose the optimal set of possible, admissible financial transactions that provide, for example, the highest profitability. It is possible to build an objective function of maximization taking into account liquidity. It is also possible to obtain a solution to problems indicating the absence of growth (or small growth) of any financial parameters, for example, assets, from which it can be concluded that it is impossible to carry out optimizing operations (procedures).

Let dt be the average level of profitability obtained as a result of some investment measures, and P_t be the interest rate at the time t = 0, 1, 2, ..., T. Then the growth of assets A will be carried out according to the law

$$A = \sum_{t=1}^{T} P_t (1 + d_t)^t$$

and the effectiveness criterion can be used in situational analysis:

$$\sum_{t=1}^{T} P_t(1 + d_t)^t \Rightarrow max.$$

The ratio between the return on assets and the price of liabilities of a commercial bank is the most important indicator that reflects the effectiveness of the bank's monetary policy.

Situational correlation analysis is complicated by a number of factors:

1. *the structure of assets and liabilities can be reflected by loans of various duration, as well as by various schemes for placing and attracting liabilities and securities, for example, the money can be returned according to the scheme of monthly deduction of interest and payment of the loan at the end or according to the scheme of a one-time repayment of the amount of debt and interest at the end lending gap;*
2. *the need to take into account (forecast) inflation expectations and "increase" or "clean up" certain components of assets and liabilities depending on inflation;*
3. *various parameters and factors affecting the degree of risk, difficulty in assessing the magnitude of risk.*

Various structures and schemes of allocation and attraction of financial resources determine different dynamic models.

For example, if the scheme provides for the repayment of debt with interest at the same time, the real rate of the tenge loan d can be determined by the formula

$$d = (z – a)/(1 + a/100) (\%),$$

where z is the nominal rate of the tenge loan (%), and is the inflation for the crediting period (%).

For a foreign currency loan cleared of inflation, taking into account the internal convertibility of the tenge:

$$d = [((1 + z/100) (1 + g/100) – (1 + a/100))/(1 + a/100)] 100 (\%),$$

where z is the nominal rate of a foreign currency loan (%), g is the growth in the exchange rate over the crediting period (%).

If the agreement for the placement of loans provides for taking into account the dynamics of debt repayment (part of the debt) and interest payments, then the real rate can be determined by the following procedure:

1. *the dynamics of urgent payments (part of debt and interest) is determined, which guarantees full fulfillment of obligations for the crediting period, i.e. meeting conditions*

$$\sum_{t=1}^{T} g_t(1+z)^{-t} = S,$$

where g_t is monthly (quarterly, annual) payments, t is the number of the month (quarter, year) at the end of which the payment takes place, S is the amount of the loan issued at the beginning of the lending agreement, T is the number of days (months, quarters, years) of lending ;

2. *the dynamics of inflation is set, for example, a discrete function $a_t = a(t)$, t = 1, 2, ..., T;*
3. *the real rate d is determined – the solution to the equation:*

$$\sum_{t=1}^{T} g_t / \prod_{i=1}^{t} (1 + a_i/100)(1 + d/100) = S;$$

if the loan is in foreign currency, then it is necessary to supplement stages 1 - 3 of this procedure with the following stages:

4. the forecast of the growth of the exchange rate is carried out, i.e. the discrete function $g_t = g(t)$, t = 1, 2, …, T is determined (set);
5. the real rate is determined from an equation of the form (S - loan in foreign currency):

$$\sum_{t=1}^{T} g_t / \prod_{i=1}^{t} (1 + a_i/100)(1 + g_i/100)(1 + d/100) = S;$$

In long-term financial and credit transactions, interest is either paid immediately after it is accrued, or reinvested using compound interest. The initial amount S (base) is increased according to the agreement accepted (by the creditor and the debtor), and for simple interest the base is constant and equal to the initial amount S. The addition of accrued interest to the base amount is called capitalization of interest, t = 0, ..., T.

The most important indicator in situational analysis and modeling of the activity and viability of a bank is reliability, bank or credit risk. The bank's reliability is not just the probability of being a reliable bank at the moment, but the bank's likelihood of maintaining the reliability characteristics and relationships at a certain admissible interval of their variation and for a certain period of time.

Let $x = (x_1, x_2, \dots, x_n) \in \Omega$ be a vector characterizing the bank's reliability, and Ω be some set of its admissible changes. As a measure of reliability, we can take the conditional probability p = p(P⁄Ω), where P is the estimate (degree) of reliability, P/Ω is the estimate provided that x ∈ Ω changes.

Example. Let $\Omega = \Omega(x_1, x_2, x_3)$ be the information resources available to the object (subject) that analyzes the bank's reliability, and $x = (x_1, x_2, x_3)$, where x_1 are the bank's assets, x_2 are the bank's liabilities, x_3 – accounts receivable to the bank.

Suppose, for example, we want to assess the reliability of a bank, but do not have information about the bank (or we have zero information). Then the value of p (P⁄Ω) can be obtained only on the basis of two possible equiprobable states – the bank is either reliable or not reliable, i.e. p (P⁄Ω) = 0.5. The result is not very informative and can be applied to any bank under any conditions Ω. Let it now be known that there are only 30% of reliable banks, i.e. we use this information to assess the bank's reliability. In this case, the bank's reliability can be estimated as $0 \leq p(P/\Omega) \leq 0.3$. At the same time, as in the previous case, such an assessment of reliability will be of little informative, since here, as in the first case, we have two possible states ($p \leq 0.3$ and $p > 0.3$) and, according to Shannon's formula, the quantity information in either case is

$$I = \log_2 N = \log_2 2 = 1 \text{ (бит)}.$$

The more accurate information about the bank the depositor (debtor) has, the easier it is for him to make the right decisions, i.e. the more often and closer the estimates of probability (reliability) p will be to p = 0 and p = 1. The less information, the more difficult it is to make an unambiguous decision, the more often and closer the estimate of probability will be to p = 0.5 ("fifty-fifty") ...

The value p (P⁄Ω) is usually called the posterior probability (a posteriori – after the experiment). Experience here means the process of obtaining information Ω, therefore, p (P⁄Ω) is the probability of being a reliable bank, taking into account the information obtained as a result of experience.

When determining reliability (for example, by experts), errors can be made, including those of a subjective nature. This is the probability of “false classification”. Let p_1 be the probability of assigning (a priori) a safe bank to the class of unreliable banks, and p_2 the probability of assigning (a priori) an unreliable bank to the class of safe banks. If we do not take into account the hypotheses about the degree of their preference (bank rating), then the indicator of the classification quality is the sum of the probabilities of making mistakes, i.e. $p = p_1 + p_2$. You can equip them with weights (preferences) a_1 and a_2, for example, if $a_1 = 1$, $a_2 = 2$, then the probability p_2 is 2 times more important than p_1 (in other words, it is 2 times more dangerous to classify an unreliable bank in the group of reliable ones than a reliable bank in the group unreliable). Then the final indicator is the weighted average sum of probabilities:

$$p = a_1q_1 + a_2q_2,$$

where $a_1, a_2 \geq 0$, $q_1, q_2 \geq 0$, q_1, q_2 are the error probabilities, $q_1 = 1 - p_1$, $q_2 = 1 - p_2$.

The p-score is called Bayesian risk. The larger p, the worse the classification is made, and the closer it is to zero, the closer the classification is to the real or a priori classification.

Situational analysis requires adequate payment flow models. As a rule, this stream is discrete. Consider one of the simple submodels of the situational analysis model that complements the above procedure.

Let at time $t_0 = 0$ there is capital x(0) (monetary units), and at time $t = t_1, t_2, ..., t_n$ there are transactions (income, expense) $y(t_i)$, i = 1, 2 , ..., n. Let's consider how it happens in practice, the same time intervals (year, month, day) $[t_0; t_1]$, $(t_2; t_3]$, ..., $(t_{n-1}; t_n]$, that is, $t_i – t_{i-1}$ = const and vectors $t = (0, t_1, t_2, ..., t_n)$, $x = (x(0), x(t_1), x(t_2), ..., x(t_n))$, $y = (0, y(t_1), y(t_2), ..., y(t_n))$, $v = (0, v(t_1), v(t_2), ..., v(t_n))$, where $v(t_i)$ is the discount coefficient over the time interval $(0; t_i]$, that is, the coefficient the relative discount or the ratio of the increment of the loan (capital) for the period from 0 to t_i to the accrued amount.Then the income and expense flows will be, respectively, equal

$$P = x(0) + \sum_{i=1}^{n} x(t_i)v(t_i), \quad R = \sum_{i=1}^{n} y(t_i)v(t_i).$$

We will consider the creditor's (investor's) income as negative values (gives), and the income as positive. Then z(0) = – x(0) is the initial income (initial investment), and $z(t_i) = y(t_i) – x(t_i)$ is the receipt on his account, i = 1, 2, ... , n.

The net cost of the stream Q = R – P is equal to:

$$Q = \sum_{i=1}^{n} y(t_i)v(t_i) - x(0) - \sum_{i=1}^{n} x(t_i)v(t_i) =$$
$$= -x(0) + \sum_{i=1}^{n}[y(t_i) - x(t_i)]v(t_i) = -\,x(0) + \sum_{i=1}^{n} z(t_i)v(t_i)$$

Similarly, the net accumulated flow value at the time $t_i > 0$ is (by entering a (t_j, t_i) – the accumulation factor by $(t_j; t_i]$, j = 1, ..., n – 1)

$$Q_i = \sum_{j=1}^{i} z(t_i)a(t_{j,}t_i).$$

The accumulated value of all payments by the time $t_n = T$ is equal to Q_n.

One of the effective mechanisms for making business decisions (in the problems of investing, developing a strategy of behavior, development, etc.) is the use of IDMS (simply DSS) - information decision support systems, combining modern analytical processing tools and information visualization tools and technologies to support the activities of the expert group.

Example. In the field of organizational management, the most interesting are the so-called situational (emergent) rooms (centers), which allow the decision maker to quickly "immerse" the decision maker in the problem situation under consideration, the situation, help to understand the problem and make a locally optimal (not necessarily globally optimal) decision. For example, the President of the United States has several such rooms. There are situational centers of the

President of the Russian Federation, the Security Council, the Ministry of Emergencies. Situation rooms are a special place to support building, playing a problem situation and making decisions by one person or a group of people. The effect of using the situation room depends on the correctness of the problem posed, the completeness and reliability of the data used, the discussion scenario, technologies of intellectual and computer support (for example, the use of expert systems), the forecast time interval, etc. Simple use of an automated document processing system, search engines, tools visualization and multimedia are insufficient conditions for the functioning of the situation room. The main function of the DMS is to support the mental, heuristic and creative activities of the decision maker. LMS can operate in the following modes:

1. *problem monitoring and updating of information (mass media, authorities, objects of management, etc.) for the purpose of current information and warning about accumulating small negative phenomena;*
2. *planning and analytical mode - scheduled hearing and discussion of analytical reports on a problem situation in order to support and make the heard decision according to a predetermined filing scenario, demonstration of material for analysis "in breadth" and "in depth";*
3. *emergency mode - operational monitoring of information, adoption and control of the execution of decisions on unforeseen, emergency problems in order to reduce negative factors affecting the combination of scenario building, discussion and decision-making, which is usual in such situations.*

In the basic version, the situation room can include a shared screen; a computer (usually a laptop) with the ability to display on a shared screen; means of access to the database (knowledge), including for the purpose of saving the discussion scenario, a system for preparing presentations.

Conclusion

We have considered only the basic concepts of decision theory and situational systems modeling, some examples.

Control questions

See the manual on the organization of students' independent work.