Methodology for making management decisions in digital economy systems

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Abstract. For effectiveness assessment of management decisions in modern economic systems, as a rule, single-criterion mathematical models are used, which have several disadvantages. The use of qualitative single economic efficiency criterion for complex production processes comparative evaluation in digital economy leads to high proportion of subjectivity. Modern complex production, based on intelligent communication technologies, operates in specific information situations context that require the use of adequate mathematical tools for making effective management decisions. In such tasks, effective solution choice depends on external and internal environment state of the system being studied and implies the use a number of methods for solving multi-objective tasks. The main methods used in uncertainty situation cases due to information situation complexity are prior ranking or expert evaluation methods. Naturally, methods based on expert evaluation have significant degree of subjectivity. This disadvantage can be avoided if you solve the problem using scientifically based effectiveness evaluating methods of production processes not by one but by several relevant performance indicators.

1. Introduction

As a whole economy digitalization should be viewed as technological evolution natural product, that is, an evolutionary, not a revolutionary process. Next period purpose of digital economy development is to formulate the basic principles for using scientific results in intellectual environment objects, to develop scenarios for transition of individual industries to digital intelligent technologies, to create an infrastructure for transition period support, including scientific support for making new decisions. Achieving this goal implies a change in organizational and technological structure in the basic sectors of national economy under the influence of management systems unification based on digital information technologies, as an inevitable consequence of digitalization. This will lead to creation of a new composition of industries and to fundamental change in the information interaction principles.
between social and technological systems that enter it. Uniting for all problem-oriented systems is infocommunication technology, whose role in the digital era is significantly increasing. Purposeful transition processes regulation to digital technology is one of the most important management tasks in Russian economy. As you know, management is a function of the system, focused on preserving its basic quality and improving efficiency in the face of changes in environment state. In other words, the goal of control systems in the digital economy is to ensure transforming information process into targeted actions that take a managed object from its original state to a given or optimal state corresponding to scientific and technological process development level.

2. Purpose of the study
Management processes in modern complex information digital systems (IDS) are united by information conditions fundamental commonality which determined by:
- changing environmental conditions for the system under study;
- dynamic development of changing parameters process in system itself;
- lack of sufficient degree of certainty for the necessary information state when solving problems aimed at system efficiency improving;
- presence of larger number of goal setting criteria and a multitude possible solutions.

In general consideration of objects interaction conditions in IDS, related to each other by a number of diverse relationships (analytical links), it is necessary to develop algorithms that are able to maintain integrity relations between objects. Modern approaches to creation management information systems (IS) are based on relational principle implementing the subject-oriented approach (SOA) to managing procedures in the system, when the means of interaction are tables or stored procedures. In this case, the control is carried out by a certain set of objects through the determination of regularities, as a rule, of stochastic character from the accumulated statistical data. The main disadvantages of this relational interaction model in complex systems based on a subject-oriented approach are:
1. Projected system, as a tables set is very often difficult to analyze and understand processes.
2. Increasing system complexity, leads to inability fully or reliably track all the necessary places and procedures for changes implementation, and system development process is transformed into poorly managed or unmanaged.

An alternative to this approach is an object-oriented approach (OOP). In the object-oriented approach, the program should represent not only objects description and their properties in criteria form, and relations between them in the form of goal setting, but also the methods of their interaction (methods) in the form of operations on objects. A clear advantage for OOP is conceptual proximity in any subject area to an arbitrary structure and purpose of the system. At the same time, attribute conversion mechanisms or methods should allow building derived objects and structures on the basis of basic ones, thereby creating a model in a more complex subject area with the necessary properties, ensuring continuous analysis possibility and making changes if necessary. In this case, the objects and methods are polymorphic, which makes the software more versatile and flexible.

Despite the clear advantages of OOP, object-oriented control systems have not yet received widespread distribution. At the same time, hybrid object-relational management systems are widely used, which partly use object-oriented working principles with data, but at the same time the data storage representation is performed when implementing the relational model [1–3].

3. Research questions
Therefore, as management quality improvement in IDS, transition process from traditional management methods in economic systems to object-oriented analytical management models is natural, allowing management processes automation using modern digital technologies. Analytical solution of this problem is possible on dynamic multicriteria programming methods basis, which allow simultaneous accounting the significant number of indicators values in the solved extremal problem according to a number of criteria depending on IDS environment state conditions at a given time. Quality change process in IDS form a number of additional tasks that are mandatory for implementation. New tasks
formation in any management system inevitably entails changes in its structure. The general theory of systems establishes that complex systems management structure, such as IDS, is hierarchical (multi-level) in nature. In hierarchical structure, the question of optimal elements number which subordinate to the senior element and on the same level is extremely important. The more such elements, the less manageable the system is, but on the other hand, the creation a larger number of hierarchy precedence levels is also undesirable because it will lead to a long process for passing information [4–6].

In the first case, in order to preserve system controllability, it is necessary to develop a mathematical apparatus aimed at finding an effective solution and allowing generation of algorithms for optimizing processes in IDS taking into account several criteria.

In the second case, the transition from level to level, as a rule, reduces the number of tasks to be solved, but their importance and complexity significantly increases. The criteria for junior tasks should be consistent with senior management level interests. Practical implementation of this method is often associated with considerable difficulties, because it is not always, having risen to a higher level, it is possible to formulate and solve a corresponding single-criterion optimization problem.

Based on the fact that the structure of vehicle’s IDS should be built with minimum possible number of stages, and system’s controllability should be provided with an adequate mathematical apparatus, it is advisable to determine system hierarchy and limits of the study. Hierarchy is an abstract representation of any system structure, necessary for studying functional interactions of its elements and their effects on entire system. The hierarchy can take various forms, each of which, as a rule, descends from a common goal down to sub-goals, further to impacts that affect these sub-goals, further away to strategies, and finally to outcomes that are results of these strategies.

4. Research methods
The stages of IDS hierarchy building process are [7]:

1. System objectives are recorded as a higher level assessment based on interaction of various hierarchy levels, and not directly dependent on the elements at these levels.
2. Formed management tasks defined by system environment.
3. Identify criteria that affect the task or tasks of management system. Each individual criterion should reflect the main, rather than a secondary function when governing decision making in system.
4. Criteria hierarchy is determined. The simplest hierarchy is linear, rising from one elements level to a neighboring level. In a non-linear hierarchy, the upper level can be both in a dominant position relative to the lower level, and in a dominated one, for example, in the case of information flow. In the mathematical theory of hierarchies, a method is used to assess level impact on a neighboring upper level by composing a corresponding contribution (priority) of lower-level elements with respect to an upper-level element. This composition may extend up the hierarchy.
5. Technical indicators set is being developed that ensure requirements for system functioning. Technical solution of the problem consists in determining the permissible system parameters values, which determine not only the efficiency of its elements, but also the efficiency of functioning in general, taking into account certain goals.

IDS hierarchy can be considered in various terms:

1. Interactions of its parts.
2. Structures in accordance with physical classification of its parts.
3. Functions in accordance with what the system elements functions are, what goals they should fulfill, parts of which goals of a higher order are these goals (leading to system overall goal).
4. The goals laid down in its structure from the point of view of external environment (the larger surrounding system), for which it is a subsystem [8,9].

5. Research results
IDS hierarchy formation should occur on basic principles of program-target approach [10]:

1) Hierarchy principal difference in IDS functions is several performance criteria imposition on one level. At the same time, the number of hierarchy levels remains unchanged (system flexibility
remains unchanged), but in order to preserve initial system control parameters, a multi-criteria task is being formed that requires an analytical solution.

2) IDS has several levels of different significance goals, therefore it is necessary to streamline them by building goals hierarchy.

3) Systematization and ordering of identified ways to achieve IDS goals is carried out by building subsystems hierarchy.

4) Identification and determination of IDS interaction order, taking into account information situation degree of uncertainty.

The presence in research a number of situations that have a certain degree of uncertainty requires, for its description, involvement certain mathematical apparatus, which would a priori include uncertainty occurrence probability. Nowadays, such an apparatus can be: probability theory; game theory (used to uncertainty describe generated by conflict and "players" antagonistic interests; statistical solutions theory (describes games with a passive environment or "nature", whose behavior is characterized by random variables with known or unknown distribution laws); theory of vague (blurred) sets.

Figure 1 shows methods classification for making management decisions.

Figure 1. Decision making methods classification

In accordance with the above scheme, decision-making methods in IDS occur:
1) on decision-making situations - standard;
2) by the nature of information - taken in uncertainty conditions;
3) on decision-making apparatus - settlement and analytical.
To apply a particular mathematical apparatus, it is necessary to classify possible uncertainty gradation degrees or classify information situations $I$. All initial information (quantitative data, etc.) can be represented as a set $Q = \{q_1, q_2, \ldots, q_n\}$ of mutually exclusive SVS - C of their states $Q$. The information situation is defined as certain of uncertainty degradation degree by environment C of their states [11]. Following information situations can be singled out as the main ones:

$I_1$ – the first informational situation is characterized by a priori probabilities given distribution $P_j$ on elements $q_j$ of the set $Q$ (in discrete form):

$$P_j = P\{Q = q_j\}, \quad \sum_{j=1}^{n} P_j = 1$$  \hspace{1cm} (1)

$I_2$ – the second information situation is characterized by a priori probabilities given distribution $P_j$ with unknown parameters on the elements $q_j$ of the set $Q$:

$$P(w) = \{P_1(w), P_2(w), \ldots, P_n(w)\}, \quad 0 \leq P_j(w) \leq 1,$$ \hspace{1cm} (2)

where $w$ – an undefined parameter from parametric set $Q$.

$I_3$ – the third informational situation is characterized by a given system of preferences on the prior probability $P_j$ distribution of the set $Q$. The ordering of environment states $q_j \in Q$ implies the introduction of order relations for the components $P = \{P_1, P_2, \ldots, P_n\}$. For example, a simple order relation $q_1 > q_2 > \cdots > q_n$ is determined by setting the inequality:

$$P_1 \geq P_2 \geq \cdots \geq P_n \geq 0.$$ \hspace{1cm} (3)

$I_4$ – the fourth informational situation is characterized by unknown probability distribution $P_j$ on $q_j$ elements from the set $Q$, on the one hand, and absence of active environment counteraction on the other. Such environment behavior is equivalent to “passive environment” behavior, studied in statistical solutions of “games with nature” theory. It should be noted that in this situation, distribution law ignorance does not exclude possibility of taking into account any information about elements of environment state (various kinds of restrictions, average and variance estimates, etc.)

$I_5$ – the fifth information situation is characterized by antagonistic environment interests.

$I_6$ – the sixth information situation is mixed and is determined by information elements presence that characterize “intermediate” environment behavior.

It is important that information situations $I_2$, $I_3$, can be reduced to the first $I_1$. In the case of information situation $I_4$, if “nature” states probability of the third factors group can be determined, the decision is made under risk. Further, the task of minimizing it should be carried out, that is, information situation also reduces to $I_1$. For $I_4$, when information lack situation or its inadequacy about environment can be considered as under conditions not opposed by “nature”, but its behavior is unknown, the problem is solved under uncertainty conditions.

6. Conclusion

Systemic approach methodology implies the study IDS interaction with external environment, the change of which affects system parameters. System effectiveness as a whole is enhanced by successive series of operations performed, substantiated with help of a number of mathematical and economic methods. In each case, the methods development to ensure overall or local system effectiveness or its elements, we have to work with three factors groups:

1) group of defined factors;

2) group of controlled factors;

3) group of factors classified as undefined (unknown) conditions.
The most complex and close to reality is the third case. The nature of uncertainty for these variables (factors) may be different. Non-stochastic nature indefinite factors can be divided into two subgroups:

1) with known membership functions (the membership function defines a subset of the total allowable factor change range, reflecting the uncertainty degree);
2) with unknown membership functions.

The latter cases have the greatest degree of uncertainty. Usually an expert evaluation procedure is applied to them for ranges of changes in their values. Uncertainty of this type is called "nature" [12]. The presence of this type of uncertainty in IDS is explained by the following provisions:

1. Unrealistically expressed end goal of the research in quantitative characteristics.
2. Insufficient knowledge at the stage of phenomena development which accompanying the system functioning process.
3. Targeted opposition presence from external environment.

In such tasks, the choice of solution depends on the state of “nature”, and mathematical models are called “games with nature”. In these cases, the methods of desired solutions obtained should be based on the rules of games and statistical decisions or can be obtained using vector optimization methods. Information situation I₅ requires involvement of game theory. Information situation I₆ requires involvement of decision theory and game theory.

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