Information Technologies for Operational Staff Training for Man-Made Systems under Threats and Risks

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Abstract

The article considers the problem of intelligence assessment in hierarchical systems and the integration of human intelligence in the process of operational and administrative management under threats, risks and information attacks. The concepts of the control system intelligence and the intelligence level of the person being trained are defined, in accordance with the requirements of standards for automatic system control and technological processes for the development of systems with hierarchical structure and automation of control processes at all levels. The definitions of the system intelligence and the intelligence level of the person are introduced, the table necessary for construction of tests is formed, the factors of type of the person's thinking which was formed in the course of training are presented and the expert coefficients of effective thinking are shown. Based on the developed tables and diagrams, test questionnaires are formed depending on the type of activity at different levels of the hierarchy of operational or strategic management.

Keywords

Intelligence, learning, self-organization, goal orientation, object, education, management.

1. Introduction

The growing demands on the professional level of management staff are justified by the situation at the highly automated companies of the oil and gas industry, transport oil and gas systems, railway transport and which use complex, distributed computerized automatic control systems to control processes. Such systems are characterized by the fact that in the process of maintenance and troubleshooting, they are replaced not by elements but by functional units, which requires the procedures for reconfiguration, software correction, and this is another level of staff training.

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This situation is complicated by the complex requirements for professional and knowledge training of both operational and management staff, who implement the objectives of the local and strategic level for systems with a hierarchical organization structure.

To do this, it is necessary to develop new testing methods. Based on the research conducted by the authors, a logical-neural classifier of components of intellectual thinking operations is developed, which are necessary for the formation of the decision-making process under threats, information attacks and system resources blocking.

The authors have created a testing system based on the use of the software system "Virtual Learning Environment" for the course "Design of integrated hierarchical automated control systems." A logical-neural classifier of components of intellectual thinking operations in making managerial decisions and a determinant of the values of these coefficients have been developed.

The aim of the study. To analyse the state of the problem of highly qualified staff training on the basis of systems analysis and to justify the use of information technology and cognitive methods to improve their intellectual level, which is needed to increase effective decision-making under risks and conflicts.

Research objectives. To analyse the problem of the management staff training and the intellectualization of their learning processes, it is necessary to develop methods for solving the problems based on system and information technologies in decision-making under risks:

– to study the state of the problem of staff training for the upper levels of the hierarchy;

– to develop the concept of increasing the staff training level on the basis of systems analysis, IT technologies and logical – cognitive methods;

– to develop a logical-cognitive concept of tests.

2. References analysis

According to the aim of the study, the problem of quality staff training for different levels of the hierarchy has a complex hierarchical structure and requires diverse knowledge in different areas of practice and theory.

In the works [1–4] the basic concepts of public administration in different structures are considered and the use of system and information technologies for decision making is substantiated.

In monographs and collective works [5–12] methods and models of managerial decision-making are considered based on system analysis, methods of information technology for data processing and mathematical models of objects, systems, situations.

In the works [13–18, 20–23] the methods of data processing as the basis of the information base of managerial decision – making are substantiated under threats and crisis situations.

In monograph [19, 28–30] are formed the main provisions of information-resource concept of analysis and synthesis of management systems of complex objects the methods of formation and goal-oriented decisions making under risks and active threats on systems with hierarchical structure are substantiated.

In [24] the problem of decision-making in the risk conditions and conflict situations in the presence of terminal restrictions is considered at the time of resolving the crisis in the complex system management structure.

In [25] construction methods of information technology of formation and decision-making under risk conditions are considered for management of technogenic systems with use of cognitive model of operator activity.

In [26, 27, 31] a novel extensible Multi-hazard Risk Assessment Framework that is a skeleton containing the multihazard risk assessment toolkit dealing with threat/danger, vulnerability, damage, coping capacity, risk, and multi-risk are presented. The risk scenarios within this framework can describe multi-hazards as a multitude of spatially distributed dynamic processes influenced by various drivers. The implementation of the proposed models and framework is also considered. The proposed event-based scenario representation model provides sufficient detailization in space and time and can properly represent multi-hazards, including compound events, cascading effects, and risk-related processes driven by environmental and societal changes.

3. Presentation of the main research material

The great complexity of such systems requires a broad training in the global sense, based on the knowledge of information and computer technology, understanding the structure of the automatic system and the goals of its operation, i.e. on the one hand, the correction of curricula and, on the other hand, the selection of students with a certain level of intelligence and motivation, which could further improve their intellectual and professional level.

That is, to master the systems with a hierarchical structure and automation of control processes at all levels it is necessary to define the concepts – the control system intelligence and the intelligence level of a person being trained, in accordance with the requirements of standards for automatic system control, technological processes. Accordingly, the definitions of the system intelligence and the intelligence level of a person are introduced.

3.1. Analysis of the intelligence problem in man-made systems and organizations

The definition: "System Intelligence" is a system in which the processes [1–4] of goal-oriented activity are implemented:

– perceiving the data from the study object;
– memorizing the data and images based on them;
– establishing the patterns that connect the informative variables needed to solve different types of problems;
– the existence of adaptation, learning, self-learning strategies.

The intelligence level is determined by the class of tasks that can be solved by the staff, respectively, they are characterized by:

– the relationship complexity between the structure and the dynamics;
– the novelty degree relative to analogies;
– the guaranteed success of the problem;
– the criteria for consistency of logical procedures in decision-making;
– the ability to identify the structure and the dynamics of the object;
– the ability to predict situations from current data in the target area of the intelligent system.

The characteristic features of intelligence systems with a hierarchical structure. To assess the situations and make decisions on management under threats to the processes of data selection

and processing as an information basis for the strategies formation for the system goal-oriented operation, the staff must provide:

– the ability to form strategies for achieving goals according to global goal orientation;
– the selection of decision-making algorithms according to the formed strategies to achieve the goal;
– the synthesis of procedures for selecting the optimal algorithms for robust detection, reception and conversion of signals as drivers of data flows to display dynamic situations in the target area and the area of the control system state;
– mastering the knowledge base based on structural and information models of the goal achievement strategy.

Typical tasks that are solved by intelligence systems in the decision-making process:

– the task of optimizing the organizational structure of the management system;
– the task of accurate copying the object reaction to different types of perturbations acting on the system;
– the optimization of logical processor strategies and algorithms of interaction with memory blocks;
– the task of the extreme control optimizing;
– the task of searching for cause-and-effect relationships for events and situations in complex systems;
– the task of assessing the convergence of the staff training process at a finite length of the training sample (Rosenblatt perceptron);
– the task of searching for the extreme, as an intelligent control procedure for optimizing the system dynamics under perturbation.An example of table styling. It is recommended to add cross references to tables, i.e., please, check. The style should be switched to Normal.

3.2. Information sufficiency of the staff knowledge level to make management decisions under emergencies and active information attacks

Information sufficiency for problem-solving procedures is classified according to the degree of a priori data availability on the structure and dynamics of the object and control system, its goal orientation [3]:

– deterministic objects with sufficient information to accurately solve all management tasks;
– stochastic objects with a priori information given in the form of probabilistic characteristics (statistics);
– objects with incomplete a priori information about its structure and dynamics;
– objects about which there is no a priori information both deterministic and stochastic before the implementation of management procedures.

The self-organization concept of O. Ivakhnenko is used to construct a learning system.
The self-organization concept according to O. Ivakhnenko [19–22] is based on the following principles of the automatic control theory, and it can be interpreted in new learning methods:

– the strategies – as the laws of change of the processor regulatory effects on the action of different classes, types of perturbations;

– the feedback theory of the object state assessment when performing compensatory counteractions to perturbations;

– the theory of extreme regulation with the maintenance of the quality functional maximum;

– the strategies of the mode selection for an optimum choice depending on a dynamic situation;

– the strategies of stochastic mode selection;

– the strategies with changing the speed of searching for optimal modes and predicting the probability of guaranteed success;

– the strategies of self-adjustment of control modes in relation to external perturbations;

– the strategies of searching for the functional extreme (minimum standard error);

– learning as a process of selection of the reaction type to environmental conditions, perturbations, influences;

– the strategies and algorithms for predicting events;

– the systems with positive feedback can generate the information and increase its initial organization, which allows one to implement the self-learning procedure in the form of a recognizer and an image classifier;

– the system structuring – an object, a data selection system, situation recognition, logic of decision-making processes, a regulator of influence and action (an executive mechanism);

– the self-determination of the management goal.

3.3. The concept of complex systems managing under threat

Systems of searching for the self-organization goal. The goal of control in the system can be set by a person with a certain intelligence level, or developed in the process of conflict with other systems. In this case, according to the class of behavioural strategies, two types of systems can be distinguished [1]:

– systems of extreme adaptation, with a given goal, to the situation changes, keeping the quality functionality to the maximum;

– systems that learn, strive for a goal, i.e. goal-oriented, but can also adjust the goal depending on the circumstances and previous experience recorded in the knowledge base.

Accordingly, changing the system structure to maintain stability when the situation changes due to perturbations, leads to defining of variable strategies of the system behaviour and, accordingly, the self-organization concept (structural). That is, when the connection is broken, the system seeks for new ways to ensure dynamic stability based on the development of new behaviour rules (strategies).

The self-organization problem [1] is solved on the basis of strategies of deterministic or stochastic search, which provides certain system properties in accordance with structural changes.

Hierarchy of learning procedures [19, 22] regarding the types of management tasks to be solved is:

– learning (adjusting) of the model in ACS structure;

– learning in ACS feedback system (adaptation) for the formation of situation images and their recognition;

– learning in ACS system for the implementation of management heuristics in self-organizing structures.

Then, according to this principle, two classes of system organization can be distinguished:

– systems with learning of the object models;
– systems with feedback learning, which are implemented on the basis of information and measurement subsystems.

Then the task of image recognition is divided [20, 21], respectively, into subtasks:

– the minimization of the description of input images (shapers of situation images) and selection of correct features for their discrimination;
– the task of decision-making in classification procedures based on discriminatory features, in accordance with the given proximity measures of discriminant areas.

The theoretical basis of procedures and strategies for solving problems of learning programs formation includes:

– the theory of statistical solutions;
– the theory of games and dual control;
– the methods of artificial intelligence, cognitive psychology;
– the mathematical logic, terminal logic;
– the theory of algorithms and program construction;
– the systematic analysis of management processes.

The learning concept O. Ivakhnenko [2] is to have:

– a goal-oriented organization and actuation of memory elements of the control system to achieve a specific goal in providing the increased information about the existing perturbations and reactions of decision-making system to them.

Objectives of the staff training under interference:

– copying the teacher's reactions to different types of perturbations on information and resource flows;
– the formation of the feedback structure properties to distinguish the input signals and classify them according to the situation in the area of goals;
– the development of rules of conduct that lead to guaranteed success, i.e. achieving the system goal.

The condition that the system can learn is the need for memory, data processing processor, new knowledge generation and storage system, i.e. it must have a certain intelligence level of the control processor in ACS structure or management structure at the top level of strategic decisions in the hierarchy.

Some definitions are introduced for the learning process construction.

Definition 1. Self-learning [2] is a process in an intelligent system that, based on the processing of available data on the external situation by certain algorithms leads to the new information generation.

Definition 2. A feature of self-learning of the recognition system will be the development of prototypes, patterns, standards of behaviour (decision making).

Definition 3. The deterministic learning mode is based on exact rules (algorithms) of data processing and goal decisions making, proceeding from exact data on the system condition and a situation at the present moment of time on the basis of logical, precisely defined (constructive) rules.

The process of the operational staff training is formed through dialogic interaction, both in theoretical training and professional training and skills of decision-making practice in the standard operation modes of man-made systems and under the influence of perturbations and risks of accidents.

The functional scheme of the model of automated man-made system is considered as a training example for mastering the professional knowledge – Figure 1.

Symbols in the scheme: BM – the executive mechanism of the resource management, DXR – the source of resources, IS – the information-measuring system, $\left\{Si/_{i=1}^{m}\right\}$ – the classifier of situations in the area of the object management system.

The scheme has a hierarchical structure and includes the following resource converters, information and control levels:

R1 – the technological level;

R2 – the information and control level;

R3 – the generation of management strategies;

R4 – the level of scientific base of knowledge and data;

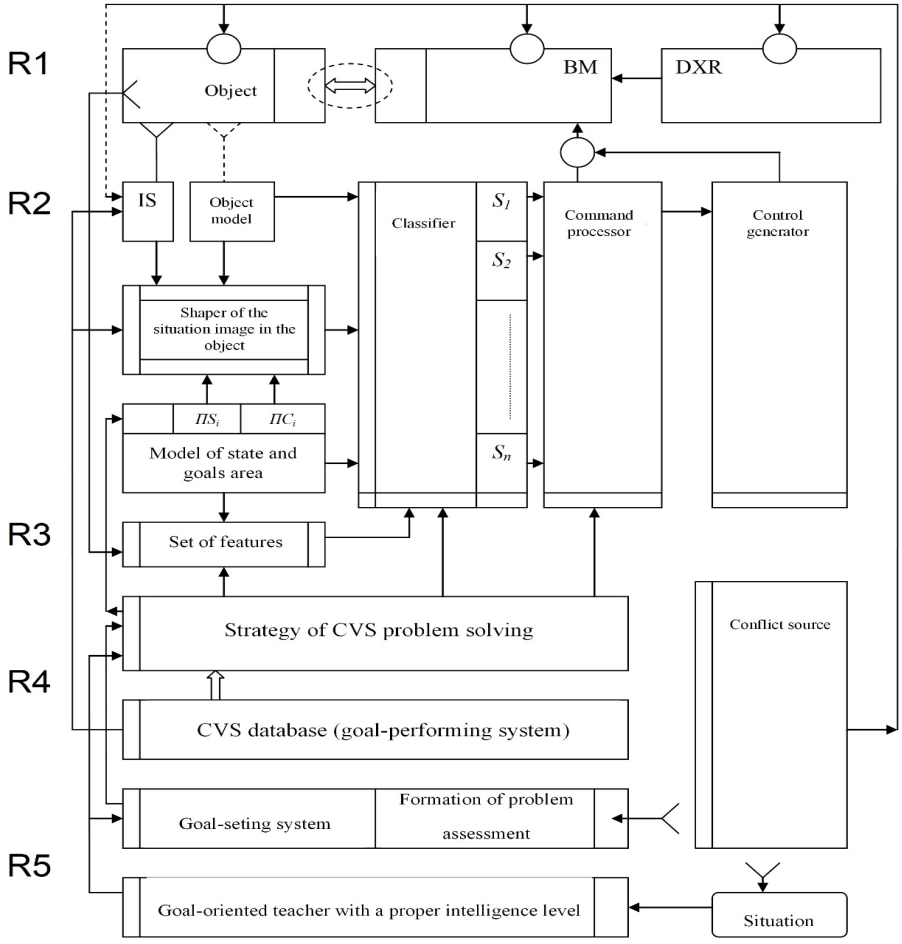

Figure 1: Functional scheme of intellectualization of the operational staff training process of man-made systems with hierarchical structure

R5 – the level of the whole system orientation.

The system structure has the following levels:

– the management object, the executive mechanism, sources of material and energy resources;

– the intelligent structure of data selection and processing – as an information-measuring and control system;

– the goal-setting and shaping system;

– the goal-performing system that generates management strategies;

– the system instructor as a goal-oriented teacher in the managing process in the intellectual dialogue mode.

The initial stage of the staff training is the generation of a strategic goal and its decomposition into local goals according to the program of mastering the management techniques of ACS man-made systems.

Characteristics of the learning process [19–22].

The goal of learning is the exact reproduction of the system-student reactions based on the standard behaviour (strategy) of the system – teacher (rules of conduct).

Learning is a goal-oriented automatic procedure for acquiring knowledge by an organized system necessary to achieve the goal based on the implementation of goal-oriented actions using the acquired knowledge.

The system is capable of self-learning, if it can automatically, based on the experience of previous work, effectively organize its own memory devices (which record the organized knowledge, procedures and decision-making algorithms based on: pattern recognition of situations formed from the obtained data, classification of system status in the goal area based on hypothesis testing according to the division of the system target area).

The system should record and learn the previous work experience or the teacher instructions to determine its future behaviour.

The memory unit must be represented in a broader sense of the word, taking into account the conscious and subconscious components (as a component of the intelligent decision-making processor to achieve the goal).

The stable system position (homeostat) under perturbations is determined by goal-oriented behaviour, i.e. it must have a certain intelligence level.

Self-organization is the process of the structure formation from a set of different elements of a functioning system without the initial minimum organization, while in the self-learning mode – Figure 2. The self-learning concept of an organized system with a certain intelligence level is the basis for designing training programs to increase the professional training level of the operational management staff of organizations, administrative and man-made structures, i.e. it is the "School of Strategies".

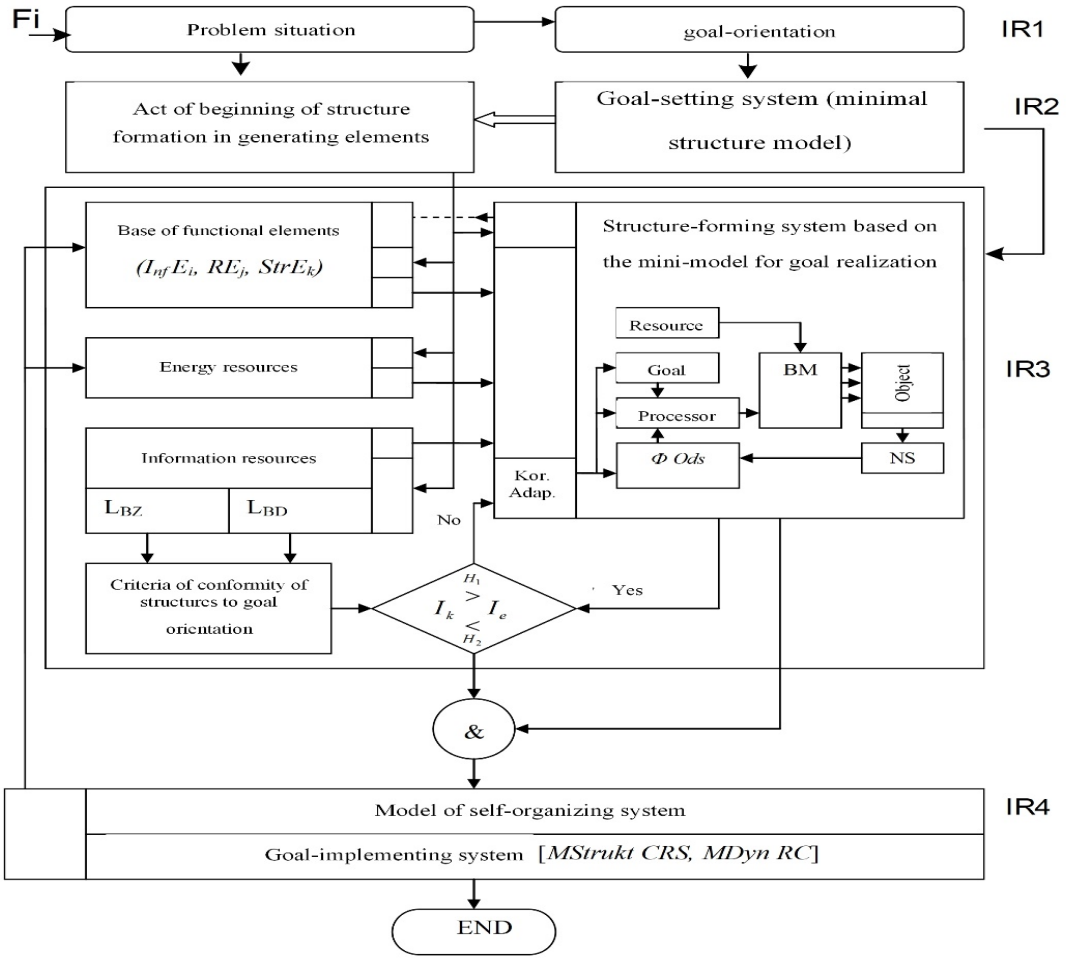

Figure 2: Model of the control system structure formation

Symbols in Figure 2: $(StrEn)$ – a database of structural functional elements, (Lbz, Lbd) – a logical database of data and knowledge, $\{Hi\}$ – hypotheses about the situation, Ods – formation of the situation image, IS – an information system, МДцпRC – a model of the decisive structure, MStrykt CRC – a model of the goal-oriented system structure.

The basic component of this approach is mastering the system structuring process, which is the basis for the management functions implementation to achieve the goal – Figure 2. It includes the following intelligence levels:

IR1 – the system goal orientation;

IR2 – the formation of goal-setting tasks;

IR3 – the system structuring;

IR4 – the self-organization and the goal implementation.

According to the scheme – Figure 2, the curricula are formed that take into account the functioning of all levels of the system and all elements that are part of the control system and the corresponding tests to understand the processes occurring in the elements and functional units of automation and computer software. The criterion for the quality of material mastering is the

assessment of understanding the content of the purpose and operation of the elements, units and ACS systems in the management structure on the basis of the assigned points to the test blocks.

4. Components of intellectual characteristics of a person who has undergone professionally-oriented training under extreme situations

The intelligence level of a person determines the type of tasks that he can solve in the decision-making process, respectively, one can identify components and characteristics that are needed to assess the situation, forecast scenarios, risks, according to selected management strategies, according to the main purpose of the system operation – Table 1.

Table 1

System-information types of management tasks

Intelligence components	Characteristic features of a person
KK1 — the object structuring in the imagination	IX1 — the ability to form strategies to achieve goals
KK2 — the choice of analogies and models	IX2 — the ability to choose the decision algorithms
KK3 — the search logic in the process of solving problems by analogy	IX3 — the ability to assess situations based on the data flows processing in the state area (goal)
KK4 — the assessment of consistency and logic	IX41 — the ability to form a database of structural relationships
KK5 — the ability to identify the object	IX42 — the ability to form a knowledge base of information models
KK6 — the ability to predict the situation based on data	IX43 — the ability to choose strategies

In the process of career-oriented activities in systems of different classes and with different hierarchical structure, a person needs to solve different types of tasks during operational activities, so in the learning process tests are necessary that reflect processes and procedures, informational and intellectual ones, and coordinate management tasks according to Table 2.

Table 2

Information and cognitive characteristics of management taskst

Problem tasks	Career-oriented knowledge
PZ1 — the structure optimization	Z1 — the information about the object structure and dynamics
PZ2 — a reaction to perturbation	Z2 — the knowledge about the object based on data processing
PZ3 — the strategy optimization	Z3 — processing atypical data and gaining the knowledge about the object
PZ4 — the risk optimization	Z4 — decision making with incomplete initial

	knowledge
PZ5 — the detection of causal links of emergencies	Z5 — methods for assessing problem situations
PZ6 — the goal orientation of the learning process during management	Z6 — tasks structuring and goals forming under risk
PZ7 — the control optimization in the perturbation process	Z7 — the knowledge of methods for strategic goals developing

According to the research (the results of which are presented in the previous sections) and intellectual-cognitive components of the system activity (Tables 1–2) during the solution of management problems of learning process and administrative structures, the diagram of the solution procedures of a number of administrative problems is constructed – Figure 3.

The diagram has a multi-level structure and shows a hierarchy of complexity of the tasks that manage the system, so they need to be solved in the decision-making process in accordance with the goals and strategies based on systems analysis and information technology. Accordingly, this is the basis for the decomposition of a complex problem task into a series of successive tasks. On the basis of the developed diagram the method of structural ordering of a problem situation solving process is formed with use of information and logical-cognitive operations which should be mastered by the intelligent agent - operator.

The diagram combines the following components of systems analysis and information technology for its control:

– {Z1|i=1,7} – the sequence of management tasks with increasing complexity;

– {PZ1|i=1,7} – the procedures (algorithms) for solving management and data processing problems;

– {RD1|i=1,4} – the cognitive data processing;

– {IO1|i=1,10} – the types of intellectual operations;

– {KR1|TXi} – the intelligence components and its characteristic features.

Based on the research conducted at Lviv State University of Life Safety 5, the Department of Automated Control Systems of the National University "Lviv Polytechnic", Ukrainian Academy of Printing 1, the tests have been developed to check the knowledge of students and cadets.

The authors have created a testing system based on the use of the software system "Virtual Learning Environment" for the course "Design of integrated hierarchical automated control systems." A logical-neural classifier of components of intellectual thinking operations in making managerial decisions and a determinant of the values of these coefficients have been developed. The interval values of the coefficients have been obtained in the testing process of Master degree students (Nx = 60 students) during the examination session.

The table will summarize the data necessary for the test construction, factors of the person thinking type which was formed in the course of training (Table 3), and it will present the expert coefficients of the effective thinking.

Table 3

Logical and cognitive characteristics of a person

№	Model	Characteristic features of a person	Coefficients
1	ОМСР	Figurative, situational-reflexive thinking	0,2—0,9
2	ФМС1	Physic-mechanical situational	0,2—0,8
3	ФМД	Physics and mathematics oriented	0,5—1,0

4	АМК	Analytical and mathematical cognitive	0,6—1,0
5	ЛКК	Logical-cognitive creative	0,7—1,0
6	ФЛМ	Formal and logical thinking	0,8—1,0
7	ССК	Structural and systemic creative thinking	0,8—1,0
8	ЛКСК	Logical-cognitive, systemic, creative	

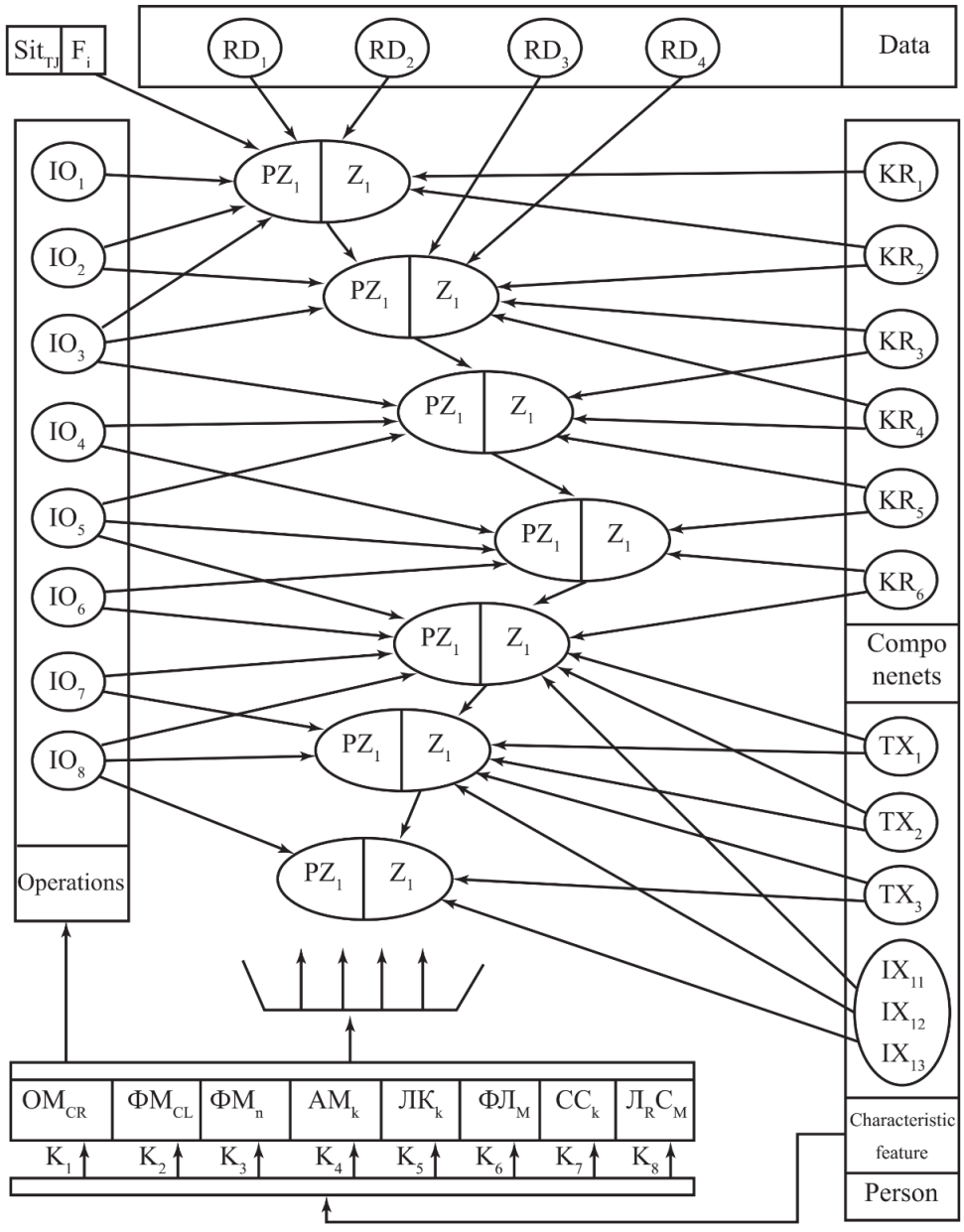

Figure 3: Factor diagram of the process of sequential solution of management problems

Based on the developed tables (Tables 1–3) and diagrams, test questionnaires are formed depending on the activity type at different hierarchy levels of the operational or strategic management.

5. Conclusion

The approaches to the staff training of man-machine systems are considered on the basis of the self-organization concept of O.Ivakhnenko as well as the processes of human-ACS interaction in the learning mode and the operating mode, which ensures the goal achievement of the organization and man-made structure functioning based on the use of systems analysis, information technology and logical-cognitive methods of activating a person's thinking. A logical-neural classifier of components of intellectual thinking operations in making managerial decisions and a determinant of the values of these coefficients have been developed.

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