Formation of an Information Resource Based on Various Sources in Organizational Management System

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Abstract
The peculiarities of obtaining and processing knowledge of different types of specialists as sources of information for organizational management systems are considered in the paper. The mathematical apparatus of fuzzy logic and decision support for use in organizational management systems in the formation of information resources is proposed. A practical example of computations based on the built model (hierarchy of goals) - the knowledge base in the decision support system is presented.

Keywords
organizational management system, information resource, analyst, expert, fuzzy logic, method of targeted dynamic evaluation of alternatives

1. Introduction

According to a study [1], the largest percentage of organizational knowledge (about 42%) is in the minds of specialists. One of the features of organizational management systems (OMS) is the presence of human factor influences within the object and subject of management [2, 3]. Along with objective information (e.g., instrument readings), 5 categories of specialists are also widely used as sources of information in OMS [2]: "source" analysts, analysts for aggregation (generalization) of information to support decision-making at different levels of management, experts, organizers of expertise and knowledge engineers. Thus, an urgent task is to develop a mathematical apparatus for the OMS, which will allow to use qualitatively the knowledge of all these categories of specialists about the formation of an information resource by taking into account their characteristics.

2. Formation of an information resource of the OMS considering the peculiarities of expert knowledge

The activities of the OMS specialists involved at different levels in the processes of generating, processing (aggregating) and analyzing information (data) let's call as analytical activities. To achieve the purpose of this paper, it is necessary to identify and analyze the types of analytical activities characteristic of different hierarchical levels of the OMS.

In [1], a generalized scheme for the formation of an information resource of a certain OMS is presented, which, after shifting the emphasis to determine the place of analytical activities of personnel in it, looks like as one shown in Fig.1. Analysis of Fig. 1 shows that at least five types of analytical activities and, accordingly, groups of specialists can be distinguished within the framework of the OMS.

ITS-2023: Information Technologies and Security, November 30, 2023, Kyiv, Ukraine
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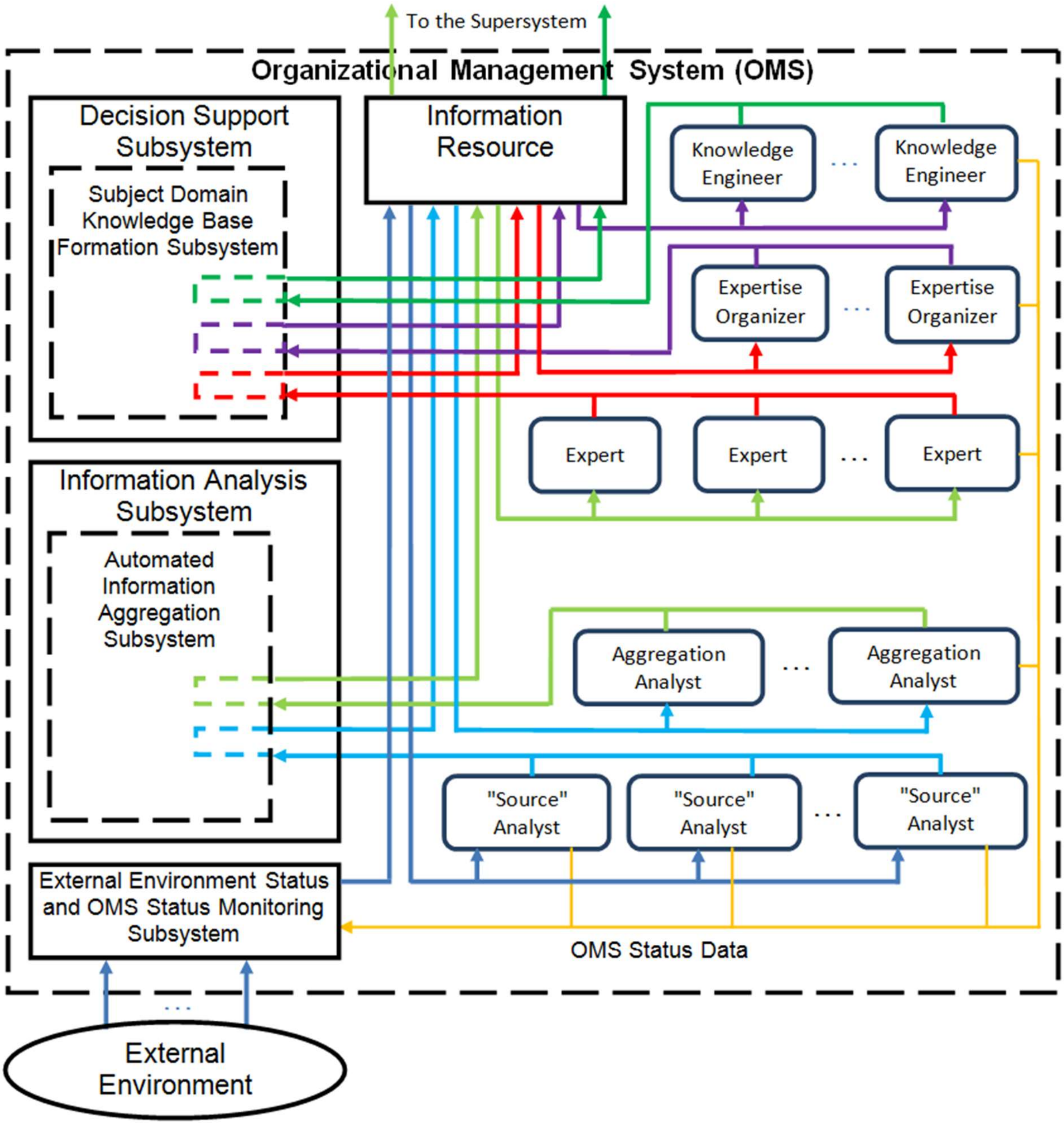

Figure 1: Scheme of formation of the OMS information resource

A "*source" analyst* is an analyst who carries out his/her analytical activities within one element of the OMS based on direct observations of indicators characterizing the state of the relevant element of the system and/or data on monitoring of environmental factors. As a result, such an analyst forms judgments about the state of the system element or the state of individual processes and phenomena observed in the external environment of the OMS functioning, based on his or her own ideas and experience. As a rule, such judgments are formed by determining one of the possible states of an element (or a component of the external environment) from a set of predefined states. The judgments of "source" analysts are mainly based on objective observation (monitoring) data, but the source data contain subjective distortions of information as a result of cognitive activity.

The second group includes *aggregation analysts*, who carry out analytical activities by generalizing (integrating) data (information) from "source" analysts. They form judgments about the state of different subsystems or groups of elements of the OMS and, accordingly, are mostly based on subjective data. Since different subsystems can be distinguished within different OMS and hierarchical links between them are possible, it is obvious that the activities of such analysts form a hierarchical procedure of aggregating information with obtaining judgments on the state of subsystems (state of the environment) of varying degrees of generalization. As a result, the subjective distortions contained in the initial judgments (results of analytical activities) may increase due to the imposition of their own cognitive distortions on the cognitive distortions of the "source" analysts. As a result, the information uncertainty about the actual state of the phenomena being analyzed may increase.

Reducing the cognitive distortions of information that are characteristic of the two groups of experts can be ensured by formalizing the process of obtaining and aggregating it to the maximum extent possible, as well as by jointly processing duplicate information from several analysts. For such information processing, tools developed within the framework of fuzzy set theory and fuzzy logic, which were specifically designed to work with expert judgments, can be effectively used. The second way is to reduce the workload on one analyst, taking into account the psychophysiological limitations of a person through the rational distribution of functional tasks among analysts.

Knowledge engineers and organizers of the examination must first familiarize themselves with the relevant subject area before building the knowledge base. For this purpose, they mostly use available open sources (the Internet, articles, lectures, ets), as well as specialized tools, such as content monitoring systems (CMSs). In this case, the cognitive bias "the effect of the illusion of truth" may be triggered [2]. Thus, it is inappropriate to form expert opinions in the OMS based directly on data from popular sources. It is more reasonable to use formalized methods of processing incomplete expert information when conducting an expert assessment. In addition, the expert evaluation organizer selects a group of experts with a sufficient level of competence in the subject area, and further work on building the LR takes into account the level of competence of the expert in each of the expert evaluation issues. In this case, a cognitive bias may be triggered - the Dunning-Kruger effect [2].

Experts decompose the subject area, divide the goals into sub-goals, determine the criteria and factors that directly affect the outcome of the examination. This process is characterized by the following cognitive distortions: the Ringelman effect, the "focusing" effect, the "survivor's error", and the "bicycle shed" effect [2]. To avoid them, it is advisable to use systems for distributed collection and processing of expert information in the work of an expert group. Expert evaluation aims to reliably determine the degree of preference between alternatives/criteria. Direct scoring and pairwise comparisons are possible. The following cognitive biases should be avoided: the distinction error, the anchoring effect, and the contrast effect [2]. You should also take into account George Miller's research [3] on the limitations of human short-term memory.

3. Aggregation of analysts' knowledge

Here are the heuristic requirements for aggregating data from analysts, which, unlike data from technical sources, are additionally characterized by varying degrees of reliability.

1. If different data is received from the same analyst during the same management cycle, the data is not combined and only the last value of the indicator is considered
2. If several analysts send same data messages with different degrees of reliability (confidence in their truth), the result of their combination should be characterized by greater reliability than each individual message
3. If several analysts provide data that does not match in content, the result of combining them should be characterized by no more reliability than the highest "declared" reliability in the messages
4. If the content of the data provided by the analysts differs significantly, there should be a growing possibility that the indicator actually has a different, "intermediate" value that averages the data in some way, giving more credibility to the value that tends to be more reliable than the "input" message.

In this case, each message about the value of the indicator is formalized as a fuzzy set:

$$S_X = \{\mu_s(x_n)/x_n\}, x_n \in X \tag{1}$$

where $\mu_s(x_n) = [0,1]$ – is the degree of belonging of the value x_n to the fuzzy set S_X $X = \{x_1, x_2, \dots, x_N\}$ is a crisp set that is a carrier of the fuzzy set and contains N possible (valid) values of the indicator.

For the final formalization of the message about the value of the indicator in the form of a fuzzy set, in addition to the indicator carrier set, it is desirable to specify the degrees of membership (x_n) for each of the possible values in the form of a functional dependence. There are many different ways to define a membership function for fuzzy sets, the simplest of which is a triangular function, which is described as follows:

$$\mu_s(x_n) = \begin{cases} 0, & if \quad x_n \le a; \\ \frac{(x_n - a)}{(C - a)}, & if \quad x_{min} < x_n < C; \\ \frac{(b - x_n)}{(b - C)}, & if \quad C \le x_n < b; \\ 0, & if \quad x_n \ge b. \end{cases} \tag{2}$$

where *C* is the value of the indicator determined by the analyst; *a*, *b* are the left and right boundaries of the triangular membership function, which applies to other values of the indicator other than *C* that are between *a* and *b*.

If $|C - a| = |C - b|$, the membership function is symmetric with respect to *C*. The range of values of the indicator $\Delta_s = |b - a|$ determines the list of its values close to *C*, which the indicator may actually take. The membership function can be viewed as an analogy to the distribution of the measurement error of an indicator by any technical means, where the value *C* is the measurement result, $\Delta_s/2$ is the absolute measurement error, and the membership function $\mu_s(x_n)$ is the law of error distribution.

To take into account the reliability of the message, it is necessary to set a numerical correspondence (scale) to the defined linguistic values of reliability (confidence in the value of the indicator). An example of such correspondence is shown in Table 1.

Table 1

Linguistic meanings of the confidence attribute and their corresponding numerical values

The linguistic meaning of the attribute of confidence	The numerical value of the confidence attribute (Ds)
"Reliable"	1
"Probably"	0,7
"Maybe"	0,5
"Doubtful"	0,25

In the next all the values of the membership function are normalized by the corresponding numerical value of the confidence in the expression:

$$\mu_{DA+B}(x_n) = D_S * \mu_S(x_n). \tag{3}$$

Since this transformation of the independence function is linear, it will retain its triangular shape.

Having carried out the specified simple formalization of all incoming messages from analysts, you can proceed to solving the problem of their unification. Within the framework of the theory of fuzzy sets, a significant toolkit for working with fuzzy sets has been accumulated. The operation of the algebraic sum of fuzzy sets best corresponds to the unification rules formulated above. To combine two messages A and B, the corresponding expression would look like this:

$$\mu_{DA+B}(x_n) = \mu_{DA}(x_n) + \mu_{DB}(x_n) - \mu_{DA}(x_n) * \mu_{DB}(x_n). \tag{4}$$

The last operation is to obtain the combined value of the indicator and determine its reliability, for which the expression for obtaining the weighted average of the fuzzy set $\mu_{DA+B}(x_n)$ can be used:

$$x_{\overline{AB}} = \frac{\sum_{n=1}^{N} x_n \cdot \mu_{D_{A+B}}(x_n)}{\sum_{n=1}^{N} \mu_{D_{A+B}}(x_n)}. \tag{5}$$

This operation is called defuzzification of a fuzzy set. The reliability of the resulting value will be determined by the degree of membership of the weighted average obtained:

$$D_{\overline{AB}} = \mu_{D_{A+B}}\left(x_{n_{\overline{AB}}}\right). \tag{6}$$

The proposed approach will reduce the influence of the subjective component on the result of data processing from analysts.

4. Aggregation of experts' knowledge

When forming the information resource of the OMS, certain features of expert knowledge should also be taken into account [6]. During the expert evaluation, cognitive distortions of data and knowledge may occur, which significantly affect its result. Human psychophysiological limitations limit the ability to process more than 9 objects at the same time [3]. Expert evaluation is time-consuming and costly, so it should be used only when absolutely necessary. If possible, it is recommended to use previously built knowledge bases (KBs), their fragments and templates (precedents) for solving similar problems in retrospect. Experts may miss assessment sessions, not answer some questions due to limited time, busy schedule, fatigue or unwillingness. Therefore, it is important to be able to process incomplete expert information [7]. At the same time, the need for generalized and systematized knowledge is gradually revealed through decomposition at smaller levels of the OMS hierarchy, and detailed information is aggregated from the bottom up to meet the information needs of users at higher management levels.

To aggregate expert knowledge, the method of goal dynamic evaluation of alternatives (MGDEA) [8, 9] is used for processing of a hierarchy of goals [10]. The hierarchy is the result of decomposition of the main goal into components (subgoals), which, in turn, are also decomposed into subgoals, etc. The decomposition process stops when we get specific activities (projects) as components.

The MGDEA offers a generalized procedure for determining the degree of achievement of any hierarchy goal at a given time *t*. To determine the degree of achievement of a particular goal, it is necessary to analyze the degree of achievement of the goals that directly affect this goal for each subset of compatible goals [8]. Thus, the degree of achievement of the h-th goal at time *t* is described by the formula for $d_i(t)$:

$$d_i(t) = \begin{cases} 0, & if \quad D_i(t) < T_i, \\ T_i, & if \quad D_i(t) = T_i, \\ f\left(D_i(t)\right), & if \quad T_i < D_i(t) < 1 - \sum \left| w_{ij}^{(\bar{k})} \right|, \\ 1, & if \quad 1 - \sum \left| w_{ij}^{(\bar{k})} \right| \leq D_i(t) \leq 1, \end{cases} \tag{7}$$

where $D_i(t) = \sup_k \sum_j w_{ij}^{(k)} d_j(t)$; T_i – is the threshold for achieving the *i*-th goal; $f(D_i(t))$ – is a function of the degree of achievement of the *i*-th goal at time t; $w_{ij}^{(\bar{k})} w_{ihk}$ – is partial coefficients of influence of the *j*-th goal in the k-th group of compatible goals, which has a negative impact on the *i*-th goal.

5. A practical example

As a practical example, the proposed mathematical tools were used to build the knowledge base of the Energy Security Strategy of Ukraine [11]. The results confirmed the applicability of the proposed approach to solving such problems.

In Fig. 2 shows an example of goals' hierarchy built by means of the Solon-3 Decision Support System (DSS) [12].

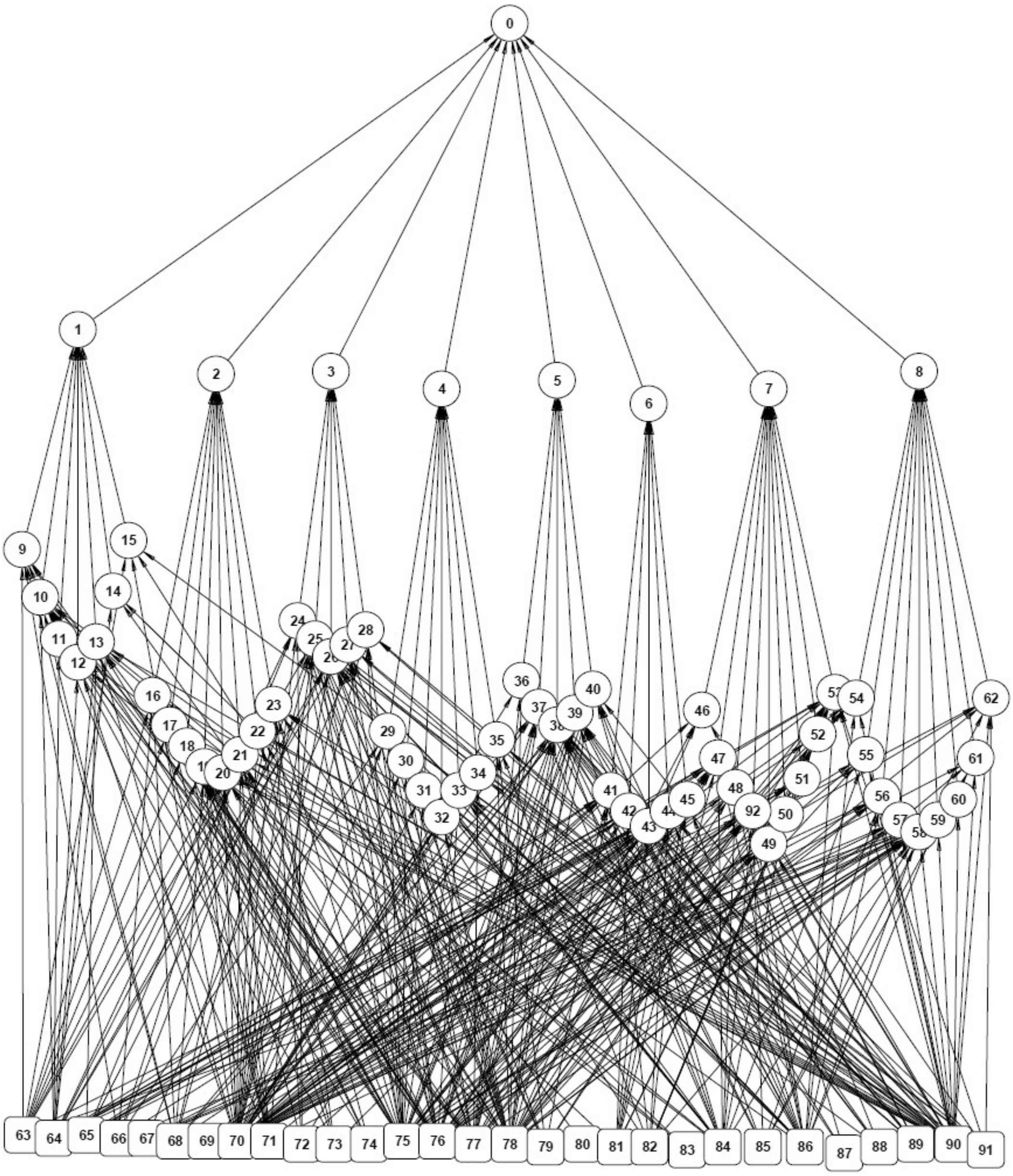

Figure 2: Structure of the goal hierarchy

Below is a list of the hierarchy's goal statements and their corresponding numbers in the goal hierarchy structure (Figure 2):

No. 0 - Energy security of Ukraine

No. 1 - Availability of energy sources and energy resources of all types for consumers

No. 2 - Sustainability of the energy sector

No. 3 - Economic efficiency of the energy sector, energy supply systems and import substitution of mineral raw materials

No. 4 - Energy efficiency of energy resources use and energy efficiency of the national economy

No. 5 - Environmentally acceptable impact of energy on the environment

No. 6 - Integration of the energy sector into the EU's political, technological, technical, economic and legal space

No. 7 - Independence of the state in the formation and implementation of domestic and foreign policy in the energy sector, ensuring the realization of national interests

No. 8 - Development of scientific, technical, innovative and educational potential of Ukraine for the needs of the energy sector

No. 9 - Improvement of the technical condition of end-user energy supply systems

No. 10 - Preventing the deepening of energy poverty and increasing the share of household expenditures on energy supply

No. 11 - Improving mechanisms for supporting certain categories of consumers and eliminating cross-subsidization in energy markets

No. 12 - Introduction of simplified procedures and guarantee of non-discriminatory connection of consumers and other users to the energy supply networks

No. 13 - Stimulating the development of energy exchange trading

No. 14 - Implementation of an effective mechanism for informing household consumers about comparative prices and opportunities to change suppliers

No. 15 - Implementation of a data management system based on big data, digitalization of processes, creation of convenient services for citizens

No. 16 - Ensuring cybersecurity and physical security of critical infrastructure in the energy sector

No. 17 - Implementation of a system for conducting risk assessments and exchanging information on risks and threats to critical infrastructure of the energy sector

No. 18 - Formation of a system for preventing the realization of threats of any type and responding to crisis situations, implementation of the energy sustainability plan of Ukraine

No. 19 - Ensuring a balanced development of energy supply systems, taking into account the uneven consumption and operation of individual energy producers

No. 20 - Development of territorial communities' capacities for self-sufficiency in the conditions of disruption of the national energy supply systems

No. 21 - Formation of a system of minimum stocks of energy resources and critical energy equipment

No. 22 - Introduction of a mechanism for cooperation and interaction between the state and operators of critical infrastructure in the energy sector in case of crisis, in particular, to involve state representatives in participation and control over the implementation of crisis response plans

No. 23 - Adaptation of the energy sector to the negative impact of climate change

No. 24 - Introduction of efficient energy markets, ensuring transparency of their functioning and regulation, increasing the capitalization of energy companies, and developing the exchange trading system

No. 25 - Renewal of fixed assets of the energy sector, in particular by creating favorable conditions for the introduction of mechanisms to support the implementation of large-scale investment projects for the development of critical infrastructure in the energy sector

No. 26 - Stimulating competition in energy markets, in particular by strengthening antitrust legislation and developing mechanisms of state influence on market participants that violate antitrust laws and/or license conditions

No. 27 - Stimulating import substitution, in particular through the development of bioenergy, wind energy, and a reasonable increase in energy production

No. 28 - Improving corporate governance, stimulating the attraction of highly qualified personnel

No. 29 - Implementation of a set of measures and programs to improve energy efficiency by sectors of the national economy, in particular in the fuel and energy complex, as well as in the housing and communal sector, households and the public sector

No. 30 - Introduction of the principle of "energy efficiency first" for government and business decision-making

No. 31 - Simplification of procedures and development of services for the implementation of energy efficiency projects

No. 32 - Ensuring the accounting of energy consumption

No. 33 - Implementation of a set of measures to expand the use of local alternative fuels

No. 34 - Development of a set of measures for the integration of consumers using renewable energy sources for their own consumption into the operation of the Integrated Energy System of Ukraine

No. 35 - Formation of an institutional framework to ensure access to high-quality energy audits and promote the implementation of energy management programs

No. 36 - Optimization and determination of the mechanism for financing measures for the greening of coal-fired generating facilities

No. 37 - Significant reduction of greenhouse gas emissions from the activities of fuel and energy enterprises, promotion of the replacement of traditional fuels in transport with electricity and biofuels

No. 38 - Implementation of a reasonable increase in the share of renewable energy sources, taking into account the requirements for ensuring the operational security of energy supply systems and the impact on the price parameters of the energy market

No. 39 - Implementation of measures to clean up coal-fired generating facilities in order to preserve the medium-term prospects for competitive development of electricity generation based on the use of domestic energy resources

No. 40 - Development and implementation of a long-term program for the replacement of coal-fired generating facilities

No. 41 - Bringing Ukrainian legislation in line with EU law (EU acquis) to create common energy markets

No. 42 - Termination of electricity imports from the Russian Federation and the Republic of Belarus and testing of the integrated power system of Ukraine in the mode of separate operation during 2022

No. 43 - Physical separation from the power grids of the Russian Federation and the Republic of Belarus

No. 44 - Synchronization of the operating modes of the Integrated Power System of Ukraine and the European Network of Transmission System Operators for Electricity

No. 45 - Implementation of economically feasible projects for the expansion of cross-border interconnectors between Ukraine and the EU countries

No. 46 - Formation of a system for harmonizing the goals of development of the national economy and the fuel and energy complex with the priorities of ensuring national security and realization of national interests

No. 47 - Preventing Ukraine's increasing dependence on external suppliers, ensuring an appropriate level of diversification of energy resources and technologies, in particular through economically justified growth of the share of renewable energy sources and local sources

No. 48 - Economically justified growth of natural gas, oil and other energy resources production

No. 49 - Increasing the share of localization of equipment production for the fuel and energy sector, in particular for nuclear power, hydropower, renewable energy, and heat power

No. 50 - Implementation of effective mechanisms of public-private partnership to ensure energy security

No. 51 - Establishment of a permanent Ukraine-EU and Ukraine-NATO format to discuss regional energy security issues

No. 52 - Creation of a regulatory framework and development of an action plan for the return of assets and resources of the fuel and energy sector that were seized as a result of the temporary occupation of part of the territory of Ukraine by the Russian Federation

No. 53 - Setting priorities and coordinating foreign economic cooperation to support the competitiveness of the Ukrainian energy sector in global markets, diversification of energy sources and supply routes

No. 54 - Meeting the needs of current and future generations to ensure the use of the latest energy technologies, including hydrogen energy

No. 55 - Introduction of a mechanism for the use of budget funds and other sources of financing for technological innovation changes in the energy sector

No. 56 - Development and transfer of technologies that help to solve current global environmental challenges, mainly caused by climate change and the impact of energy on the environment

No. 57 - Consumer-oriented educational activities and promotion of the latest technological know-how and energy-efficient technologies among the general public

No. 58 - Creating conditions for the involvement of new types of energy resources and energy sources in the updated energy balance based on the principle of self-sufficiency, increasing the choice of energy types that will contribute to the formation of an updated energy balance and self-sufficiency in energy resources

No. 59 - Application of the latest technological solutions to improve the technical characteristics of nuclear power plants subject to unconditional compliance with all requirements for safe operation of nuclear facilities

No. 60 - Scaling up the successful experience of scientific and innovative pilot projects, in particular for the transformation of coal regions and reform of the coal sector

No. 61 - Determination of priorities of the state technical policy in the energy sector

No. 62 - Modernization of the personnel training system for the energy sector by introducing new specialties and retraining programs in accordance with the needs of the fuel and energy complex

No. 63 - Cyber threats / cyber incidents against critical infrastructure in the energy sector

No. 64 - Influence of pressure groups on the energy sector

No. 65 - Resistance to the introduction of European rules for the transparent functioning of energy markets

No. 66 - Blocking the supply of necessary resources and equipment for the energy sector of Ukraine

No. 67 - Personnel shortage (loss of qualified personnel and the system of training/retraining)

No. 68 - Increased depreciation of fixed assets of energy infrastructure facilities

No. 69 - Failure to comply with the requirements and measures to interconnect Ukraine's systems (networks) with the EU electricity and gas supply systems, including the expansion of the capacity of interstate crossings (interconnectors)

No. 70 - Absence of a system of strategic planning and coordination of economic and energy development

No. 71 - Threats to the physical security of energy infrastructure facilities

No. 72 - Uncontrolled change in the structure of generating capacities

No. 73 - Lack of energy reserves

No. 74 - Lack of capacity for "crisis" response

No. 75 - Increased deficit of capital investments in energy development

No. 76 - The ongoing armed aggression of the Russian Federation against Ukraine

No. 77 - Low energy efficiency of the national economy

No. 78 - Continued shadowing of relations in the energy sector, in particular through improper accounting of resources

No. 79 - Imperfection of legislation on energy market regulation (preservation of the subsidy system, the mechanism of public special obligations or restrictions on the rights of certain energy market participants)

No. 80 - The impact of climate change on the structure and modes of energy consumption

No. 81 - Obstruction by the Russian Federation of the interconnection of Ukraine's systems (networks) with the EU electricity and gas supply systems

No. 82 - Failure to adopt legislation necessary for the implementation of energy rules in accordance with the provisions of EU law (EU acquis)

No. 83 - Deepening of energy poverty, increase in household energy costs

No. 84 - Insufficient level of competition and regulation of monopolies in energy markets

No. 85 - Delays in the adoption and implementation of decisions on the refusal to use coal for energy needs

No. 86 - Inefficiency of technologies and technological processes of energy market participants

No. 87 - High level of industrial emissions and wastewater from the fuel and energy sector

No. 88 - High level of greenhouse gas emissions from the fuel and energy sector

No. 89 - High carbon intensity of final energy consumption

No. 90 - Loss of scientific and technical potential of the energy sector

No. 91 - Lack of development of corporate management, inefficient operation of fuel and energy enterprises in market conditions

No. 92 - Bringing coal production volumes in line with the needs of Ukraine's energy sector on the basis of market principles of management and competition with the determination of the term of coal use for energy needs.

Table 1 shows the threat numerical rating computed using the Solon-3 DSS.

Table 2

Rating of threats to Ukraine's energy security for pessimistic, probable and optimistic scenarios

No. of goals in the hierarchy	Pessimistic scenario		Probable scenario		Optimistic scenario	
	Rank	The value of potential efficiency	Rank	The value of potential efficiency	Rank	The value of potential efficiency
70	1	0,13758	1	0,13828	2	0,14156
76	2	0,10562	2	0,11900	1	0,14459
75	3	0,09779	4	0,10063	4	0,08592
78	4	0,09656	3	0,10572	3	0,11246
64	5	0,06934	5	0,08115	5	0,07582
77	6	0,05879	6	0,06578	6	0,07245
90	7	0,05348	7	0,05534	8	0,04557
84	8	0,04891	10	0,03376	11	0,02886
71	9	0,04805	8	0,05433	7	0,06628
86	10	0,02949	9	0,03404	9	0,03768
63	11	0,02948	12	0,02655	16	0,01276
68	12	0,02764	11	0,02967	10	0,03062
81	13	0,02302	23	0,00611	24	0,00427
74	14	0,01794	14	0,01664	15	0,01356
83	15	0,01734	15	0,01655	13	0,01492
91	16	0,01719	13	0,01806	12	0,01874
82	17	0,01620	21	0,01000	22	0,00861
73	18	0,01553	16	0,01400	17	0,01272
65	19	0,01330	25	0,00351	26	0,00245
72	20	0,01094	18	0,01217	18	0,01218
67	21	0,01077	19	0,01130	20	0,01006
79	22	0,01058	17	0,01384	14	0,01479
66	23	0,01035	27	0,00239	27	0,00144
89	24	0,00983	20	0,01068	19	0,01146
85	25	0,00878	22	0,00926	21	0,00922
69	26	0,00654	28	0,00185	28	0,00125
88	27	0,00512	24	0,00552	23	0,00590
87	28	0,00261	26	0,00282	25	0,00295
80	29	0,00127	29	0,00106	29	0,00092

Conclusions

The article shows the peculiarities of knowledge of analysts and experts, which are typical for OMS, which further form the information basis of databases and KBs in the formation of the OMS information resource. Five types of specialists (sources of information in the OMS) are assigned.

Using the fuzzy logic apparatus to process information from "source" analysts and aggregation analysts in the information-analytical subsystem of the OMS is proposed.

Using information received from analysts after its preliminary processing along with objective and expert information when building the KB of the decision support subsystem of the OMS is suggested.

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