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Expert and analytical technologies in the sphere of agribusiness management

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***Abstract*—An important factor for improving the efficiency of business processes in the agroindustrial complex is the use of progressive technologies of the digital economy at all levels, that include individual agricultural producers and implies an accurate work of agricultural consultancy system. However, the priority spheres of agricultural consulting, as a rule, do not affect the strategic development of the agricultural producers themselves, although the main reserves of efficiency growth are concentrated here. The article considers the possibility of using for planning economic activities of agricultural producers some intelligent technologies for making management decisions based on algorithms of the analytical hierarchy process and analytical network process. Both processes involve polling a group of experts on a predetermined hierarchical process, and all mathematical calculations are carried out automatically using specialized software tools - decision support systems (DSS) and expert analytical systems (EAS), for which DSS Expert Decide and expert and analytical system Expert Solution can be used.**

***Keywords*—agrobusiness, digital economy, agricultural consultancy, analytical hierarchy process, analytical network process, hierarchical process, intelligent computer technology.**

I. Introduction

At the modern stage of the development of the agroindustrial complex in Russia, a mixed economy has been formed, as a result of which competition has intensified both in the external and domestic agri-food market. The world practice shows that one of the conditions for risk reduction, increasing the efficiency and competitiveness of the agroindustrial complex is improving the management system of the agroindustrial complex as a whole and in certain sectors of the agricultural production [1]. It concerns not only federal and regional levels, but also the level of peasant (farm) economies and other small businesses in the field of agriculture; therefore, the functions of regulating and providing agricultural producers with information and innovations should be attributed to the agricultural management system at all three levels.

Recently, these functions are associated with the introduction of the digital economy, which is interpreted not only as a narrow concept, limited to the production and sale of software products for information technologies, but it is also given a "broad" interpretation that takes into account the use of digital technologies in all sectors and fields of the activity [2]. To ensure these functions, it is necessary to adjust the system of receiving and transmitting information between all structural elements, which implies a clear work of the agricultural consultancy system, where both organizations, their business subdivisions and individual entrepreneurs-consultants and experts can be their structural elements [3].

II. Literature review

An important task of the consultancy system is methodological and educational support of agricultural producers, and especially representatives of small businesses in their development. However, practice shows that the priority directions of the development of agricultural consulting, as a rule, do not affect the issues of strategic development of agricultural producers themselves, although the main reserves of efficiency growth are concentrated here.

Thus, it is noted in the work [4] that the most demanded in the structure of the consultants' activity are consultancy services in the field of crop production (17%) and animal husbandry (14%), while economic issues, which take the fourth place, occupy only a tenth of all the services. This indicates a clearly insufficient attention to the strategic issues of planning economic activities of the agricultural producers.

III. Results and discussion

The exceptional importance of strategic planning motivated the Orel State Agrarian University named after N.V. Parakhin (OSAU) to conduct work on surveying agricultural producers in order to identify the needs for information and consulting services, including the level of interest in the potential capabilities of the information and consulting system (ICS) of the Orel region. The questionnaire is aimed at obtaining information on the agricultural producers' assessment of some aspects of the activities of the ICS of the Orel region: 1) consulting categories (technological issues, product sales, business economics, resource provision for production, legal issues, information technology, organization and production management); 2) the actual state of information and consulting services; 3) the level of interest in the capabilities of ICS.

The analysis of the information on these issues will allow clarifying the requirements for the computer system of the information and consulting services of the Orel region, based on the use of modern expert and analytical technologies for making management decisions. Among them the decision support system DSS Expert Decide [5] and the expert analytical system Expert Solution [6], implementing algorithms of effective tools for decision-making under the conditions of risks and initial information uncertainty — the analytical hierarchy process (AHP) [7, 8] and the analytical network method (ANP) [9]. Both processes involve interviewing a group of experts on a predetermined hierarchical process, and experts are encouraged to perform pairwise comparisons of its elements on a linguistic nine-level scale, and all mathematical calculations are carried out automatically using specialized software - decision support systems (DSS) and expert analytical systems (EAS) [10].

In the basic version of the AHP, the hierarchical decision-making process contains three levels: the goal (focus) is at the top of the hierarchy, the decision alternatives are at the lower level and the criteria for evaluating alternatives are in the middle. All the elements of lower levels are strictly subordinate to the elements of the upper levels, i.e. feedback between the levels and the interaction of the elements of each of them are not taken into account, and this is a peculiarity of the hierarchy analysis method. In the basic version of the ANP, the restriction on feedback is removed and in addition to the “direct” hierarchy described above, they also consider the “inverse” hierarchy, in which the criteria are at the lower level and the alternatives are at the middle level. So, not only the dependence of the alternatives and criteria priorities, but also the influence of the alternatives on the priorities of the criteria are taken into consideration. However, even in such a simplified version, the work of the experts is significantly complicated.

Both processes, in particular AHP, are successfully used in our country and abroad to solve various problems of multi-objective substantiation of managerial decisions under the conditions of information uncertainty in almost all the industries [11-13]. Although there are still discussions on the mathematical justification of these processes, at present researchers are more interested in the questions of the limits of their applicability, as well as the features of satisfiability for solving various problems. For example, in the work [14] the concept, features, key points and shortcomings of applying the analytical network process to decision making problems are considered, the conclusion is made about the satisfiability of ANP to different networks when solving natural science and some other applied problem; specific features of the AHP in relation to the evaluation of investment projects in the agroindustrial complex, due to the behavior of experts at risk, are given in the monograph [15].

Due to the differing points of view on these issues, we will consider the features of the use of the AHP and the ANP in one of the examples of the choice of a development option for an agricultural organization. As noted above, the essence of both processes lies in the sequential pairwise comparison of elements of different hierarchical levels (factors, alternatives, etc.) with the subsequent calculation of priority vectors, but if in AHP comparison of elements of each level is made with each other by their contribution result or in relation to other elements (factors) of higher levels, the ANP "operates with networks that can take an arbitrary form and contain all kinds of connections, including reverse and cyclic when the factor can influence itself directly or indirectly ”[13, p. 63].

Without losing generality, we compare the results of hierarchical analysis by two fairly simple three-level (basic) processes: 1) a direct hierarchy process and 2) a network process with independent comparison factors and alternatives. As a tool, we will use the expert-analytical system Expert Solution 1.0, which implements the algorithms of ANP and AHP. Despite the relative simplicity of the basic processes - only three-level, they are applicable at all stages of the life cycle of an innovative project.

At the stage of preliminary preparation and evaluation of the target efficiency of an innovative project, which are characterized by strong uncertainty of the initial information, an integrated approach is needed when alternatives are compared according to their benefits, costs, opportunities and risks, thus avoiding errors caused by the wrong choice of investment direction [11]. At the same time, for each goal — assessing benefits, costs, opportunities and risks — within the framework of the AHP, three basic processes are constructed: direct hierarchy process, inverse hierarchy process, and network process. The second basic process has also three-levels, but with the same goal; alternatives are at the second level of the hierarchy and criteria are at the third one. The third process — the network process — contains two components — one with the criteria and the other one is with alternatives. At the next stage of the life cycle of the innovation project, alternatives for the implementation of the chosen project are compared, the degree of uncertainty is much less, and risk analysis processes come to the force [11]. At this stage, three processes are also built - a direct and inverse hierarchy and a network process that allows to take into account the feedback between the levels of hierarchical processes. Finally, at the final stage of the project life cycle, a process of the project’s sensitivity to risk factors is built - a risk management process.

In the work [11], it is shown that, based on the principles of analytical hierarchy, strategic management processes can also be built, at the lower hierarchical level not alternative projects, but alternative scenarios are considered, the number and content of hierarchy levels increase, but in this case the basic three-level processes of either direct or inverse hierarchy. serve as a main construct.

For definiteness, let us analyze a three-level hierarchical process of production efficiency of a multi-industry agricultural organization which is focused on production efficiency; factors of production - economic, social, natural, and environmental - are at the next level; sub-sectors of agriculture: crop production, gardening, poultry farming, cattle breeding and processing of products at the bottom level. The question is formulated the following way: 1) what priorities should these subsectors be developed with and 2) in what proportion should investments in these sub-sectors be distributed?

To build this process, which is a direct hierarchy in its structure, we will use Expert Solution 1.0 expert-analytical system, and since this example aims to demonstrate the difference in results obtained by analyzing hierarchies and analytical networks, we will limit ourselves to interviewing only one expert who is an agricultural expert in the sphere of production.

Fig. 1 presents the results of the processing of the judgments of this expert, obtained in the Expert Solution 1.0 system - a hierarchical process of the production efficiency of a multi-industry agricultural organization.

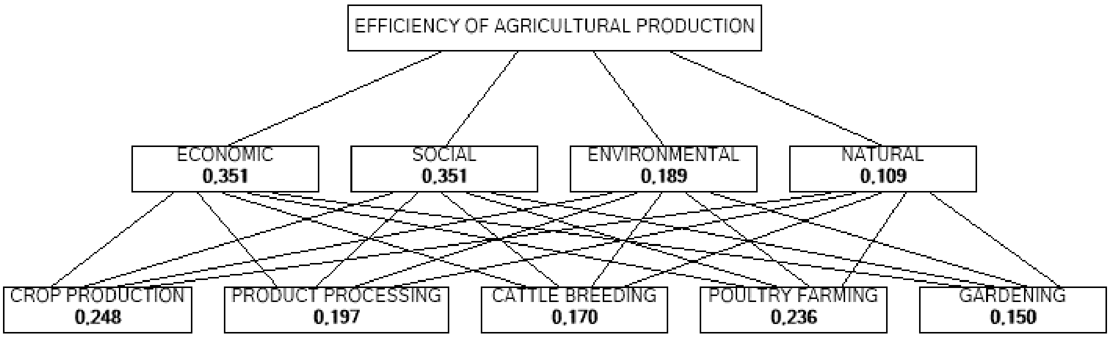

Fig. 1. Direct hierarchy (Efficiency process of the sectors of agricultural production)

Based on the information process presented in the figure, it can be concluded that, according to the subjective judgments of the interviewed expert, crop farming and poultry farming (priorities 0.248 and 0.236, respectively) are the most effective sub-sectors for the agricultural organization, processing is less effective (priority 0.197), which is followed by cattle breeding and gardening with priorities 0.170 and 0.150. According to the theory of T. Saaty, these sub-sectors should be developed with this priorities and in such proportion to distribute the investments in these sub-sectors.

The information process presented in Fig. 1 was obtained with the assumption that the elements of the lower levels are subordinate to the elements of the upper levels, which corresponds to the postulates of the analytical hierarchy process. We note here that since the purpose of processing is to rank in the efficiency of the sub-sector of agricultural production, experts' polling is more reliable in a direct hierarchy, in which the global vector of priorities is estimated by the local priorities convolution with weights of groups of factors.

We'll show these vectors - Table 1.

TABLE I. MATRIX OF LOCAL PRIORITIES OF SUB-SECTORS OF THE AGRICULTURAL PRODUCTION

Sub-sector	**Group of econo-mical factors (вес 0,351)**	**Group of social factors (вес 0,351)**	**Group of ecologi-cal factors (вес 0,189)**	**Group of environmental factors (вес 0,109)**	**Global priopity**
Crop production	0,096	0,428	0,127	0,367	0,248
Processing	0,135	0,285	0,127	0,232	0,197
Cattle breeding	0,154	0,161	0,272	0,074	0,170
Poultry	0,342	0,080	0,421	0,077	0,236
Gardening	0,274	0,046	0,053	0,250	0,150

The user interface of EAS Expert Solution 1.0 is designed in such a way that the expert is first asked to compare pairwise groups of factors in terms of their impact on the efficiency of agricultural production, and then also to compare sub-sectors of agricultural production in pairs according to their importance economic, social, natural and environmental groups. . These are questions of a direct hierarchy, and the result of expert judgment is prioritizing of the sub-sectors. However the criteria , not only determine the significance of the sub-sectors, but the criteria also differ in relative importance for different sub-sectors, so it is now necessary to clarify the weights of groups of factors by inviting experts to answer questions on the inverse hierarchy, i.e. first, compare the sub-sectors in their effectiveness, and then groups of factors in their relative importance for the sub-sectors entered into the process.

As a result the program Expert Solution 1.0 generates one more information process, on the bottom level of which are not sub-sectors but groups of factors – figure 2.

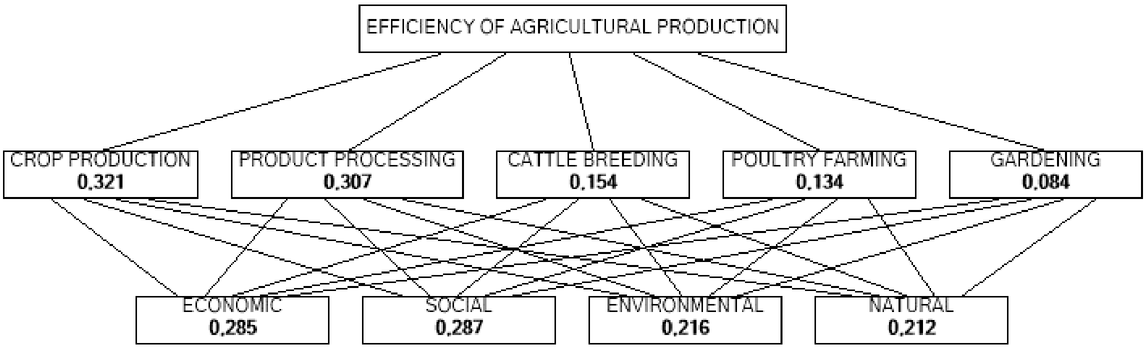

Fig. 2. Reverse hierarchy (Efficiency process of the sectors of agricultural production)

Comparing the information processes of direct and inverse hierarchies, we can note a significant adjustment of expert judgments. So, if the priority of crop production in the direct hierarchy was 0.248, then according to the expert judgment on the inverse hierarchy, the priority of this sub-sector has risen to 0.321. The priority of processing products also increased from 0.197 to 0.307, and, on the contrary, the priority of gardening decreased from 0.150 to 0.084. Accordingly, local priorities (weights) of groups of factors have also changed - Table 2.

TABLE II. MATRIX OF LOCAL PRIORITIES OF AGRICULTURAL PRODUCTION FACTORS

Group of factors	**Crop produc-tion (priority 0,321)**	**Proces-sing (priority 0,307)**	**Cattle breed-ing (priority 0,154)**	**Poultry (priori-ty 0,134)**	**Gardening (priority 0,084**
Economical	0,199	0,240	0,362	0,558	0,200
Social	0,398	0,376	0,148	0,096	0,097
Ecological	0,167	0,177	0,327	0,249	0,291
Environmental	0,236	0,207	0,163	0,096	0,412

In EAS Expert Solution 1.0, based on the information on local priorities of factors and sub-sectors of agricultural production, the main mathematical construct of the network process with independent comparison factors and alternatives - the supermatrix is formed (Fig. 3).

$$
\begin{matrix}
0,000 & 0,000 & 0,000 & 0,000 & 0,000 & 0,096 & 0,428 & 0,127 & 0,367 \\
0,000 & 0,000 & 0,000 & 0,000 & 0,000 & 0,135 & 0,285 & 0,127 & 0,232 \\
0,000 & 0,000 & 0,000 & 0,000 & 0,000 & 0,154 & 0,161 & 0,272 & 0,074 \\
0,000 & 0,000 & 0,000 & 0,000 & 0,000 & 0,342 & 0,080 & 0,421 & 0,077 \\
0,000 & 0,000 & 0,000 & 0,000 & 0,000 & 0,274 & 0,046 & 0,053 & 0,250 \\
0,199 & 0,240 & 0,362 & 0,558 & 0,200 & 0,000 & 0,000 & 0,000 & 0,000 \\
0,398 & 0,376 & 0,148 & 0,096 & 0,097 & 0,000 & 0,000 & 0,000 & 0,000 \\
0,167 & 0,177 & 0,327 & 0,249 & 0,291 & 0,000 & 0,000 & 0,000 & 0,000 \\
0,236 & 0,207 & 0,163 & 0,096 & 0,412 & 0,000 & 0,000 & 0,000 & 0,000
\end{matrix}
$$

Fig. 3. Supermatrix (network process of agricultural production factors)

All further calculations and constructions are carried out in the EAS Expert Solution 1.0 software in automatic mode, and as a result, diagrams representing the global weight vector of groups of factors (criteria) – Fig. 4 and the global priority vector of the sub-sectors of agricultural production (alternatives) – Fig. 5 are shown on the display.

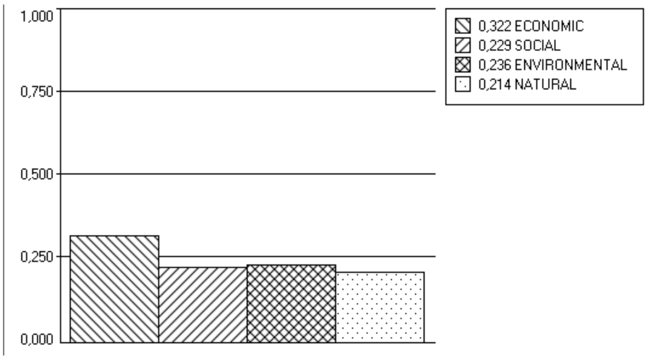

Fig. 4. The weight vector of groups of factors (network process).

Fig. 5. Priority vector of sub-sectors of agricultural production (network process)

For the convenience of comparing the results for different processes, the results of the calculations are summarized in Tables 3 and 4.

TABLE III. COMPARISON OF PRIORITIES OF SUB-SECTORS OF AGRICULTURAL PRODUCTION, CALCULATED ACCORDING TO DIFFERENT PROCESSES

Process	**Crop production**	**Processing**	**Cattle breeding**	**Poultry**	**Gardening**
Direct hierarchy	0,248	0,197	0,170	0,236	0,150
Inverse hierarchy	0,321	0,307	0,154	0,134	0,084
Network	0,237	0,188	0,166	0,244	0,164

TABLE IV. COMPARISON OF WEIGHTS OF FACTORS OF AGRICULTURAL PRODUCTION, CALCULATED ACCORDING TO DIFFERENT PROCESSES

Process	**Group of economical factors**	**Group of social factors**	**Group of ecological factors**	**Group pf environmental factors**
Direct hierarchy	0,285	0,287	0,216	0,212
Inverse hierarchy	0,351	0,351	0,189	0,109
Network	0,322	0,299	0,236	0,214

Comparing the results of the calculations of the demonstration example shows that the assessments of the priorities of the sub-sectors of agricultural production according to the network process are closer to the corresponding assessments of the direct hierarchy process (table III), and the estimates of the weights of the factors of agricultural production by the network process, on the contrary, are closer to the assessments by the inverse hierarchy process (table IV), however both of them made on the network process are significantly different from the assessments obtained in the two-level hierarchies.

IV. CONCLUSIONS

The obtained results convincingly show the advantages of preparation of management decisions in the sphere of agriculture using analytical network process, in comparison with application of the analytical hierarchy process, which is also used for this purpose. Despite huge labour intensity calculations based on the network process provide significantly higher reliability of derivation, and when using the corresponding software, for example, of the expert and analytical system Expert Solution 1.0 there is no considerable inconvenience both for organizers of the examination and experts. On the other hand, the results of the conducted research disclosed serious shortcomings of the simplified approach to preparation of management decisions on two-level hierarchical processes when ranging of alternatives' priorities is carried out not as a result of their multicriteria assessment, but "directly", actually without deep analysis of factors of production.

The OSAU has accumulated a positive experience in the application of these expert and analytical technologies for making management decisions in the sphere of the agroindustrial sector, the approaches to build a computer system for information and consulting services have been developed. Updating the information about the state of information system and needs of agricultural producers in information and consulting services will allow identifying certain segments of potential consumers. It is a prerequisite for the effectiveness of the ICS.

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