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Conceptual Research Model of Developing the Decision Support System for Agriculture Under Uncertainty

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***Abstract*— In the context of growing human needs for food, an important issue is to increase the efficiency of agricultural enterprises. A modern tool for efficiency is the informatization of all processes, including introducing information systems to support decision-making. The paper presents a Conceptual Research Model for developing the Decision Support System for Agricultural. This model includes four components: goal-setting, principles, functionality, and diagnostic. The considered elements form an integral system providing a process in the development of the information system. The model considers uncertainty in decision-making caused by environmental and economic factors. The objects and subjects of the environment in which the information system operates are determined. Two mathematical models of the description of the decision-making problem in the conditions of uncertainty are offered. Criteria for evaluating the effectiveness of decisions are defined.**

Keywords*— *conceptual research model, decision making, uncertainly, information system

I. INTRODUCTION

The growth of the planet's population leads to an increase in food needs. Initially, these needs could be met using extensive methods to increase the area of land used in agar production. Now, this method cannot be applied in the vast majority of countries. Therefore, the first role is to increase the efficiency of available resources. To increase the efficiency of agricultural enterprises, there are two areas: technology and management.

The technological direction includes breeding new breeds of animals and varieties of cultivated plants, development of new fertilizers, pesticides, disease prevention, etc.

Management involves making more optimal and timely management decisions. Informatization of agricultural production processes gave an extraordinary impetus to the development of management. This process has begun recently and is undergoing a stage of exponential growth. Thus, according to BI Intelligence, the number of high-tech solutions in the agricultural sector, such as IoT, doubles every three years [1]. The amount of data that should be considered in decision-making is overgrowing, so there is a need to use information systems to support the decision making [2]

Many studies are devoted to the study of the process of developing an information system for decision-making. In [3], the information system of decision support is identified as one of the main components of a modern agricultural enterprise. It reveals the prospects of its existence based on a web platform with integrated and centralized databases. It also emphasizes developing and implementing a mobile application as part of an information system designed for geospatial data collection with a complete and customizable interface. The paper [4] discusses the possibility of implementing the technology of the "Internet of Things" on all functional parts of the information system.

New research examines the decision-making management of agricultural enterprises, taking into account the functioning of the enterprise in conditions of uncertainty. Thus, [5,6] proposed an AWEFSM model that can be used for regions where agriculture dominates with a limited supply of resources in uncertain conditions. This model is designed to determine the strategies of functioning in terms of water and energy resources in food production. In [6], the authors considered the literature on the introduction of technology in agriculture, emphasizing the role of uncertainty and learning. Factors influencing the benefits for farmers' adoption and their connection with the innovation process have been identified. The positive consequences of innovation and acceptance of welfare for farmers and consumers are also substantiated. The authors formalized the problem of decision-making in conditions of environmental uncertainty [7] proposed a conceptual information system that can be used to solve this problem [8].

The considered research is directed on studying separate aspects of decision-making in uncertain conditions and needs a specific generalization and systematization. The purpose of this study is to build a

Conceptual Research Model that will include all scientific and technical aspects of developing an information system to support decision-making in the agricultural sector in conditions of uncertainty.

II. CONSTRUCTING THE RESEARCH MODEL OF DMS

We will consider the model of the information system of decision support in the agricultural sphere in the conditions of ecological uncertainty as a particular image of the developed system, which reflects features and critical characteristics of the system and provides achievement for development and use of information system.

The principles of openness of science and transparency of data should be taken into account when developing a model of an information system for decision support in the agricultural sphere in the conditions of ecological uncertainty. These principles are becoming the dominant principles of today [9].

We will divide the construction of the model of the information system of decision support in the agricultural sphere in the conditions of ecological uncertainty into four components (see fig. 1):

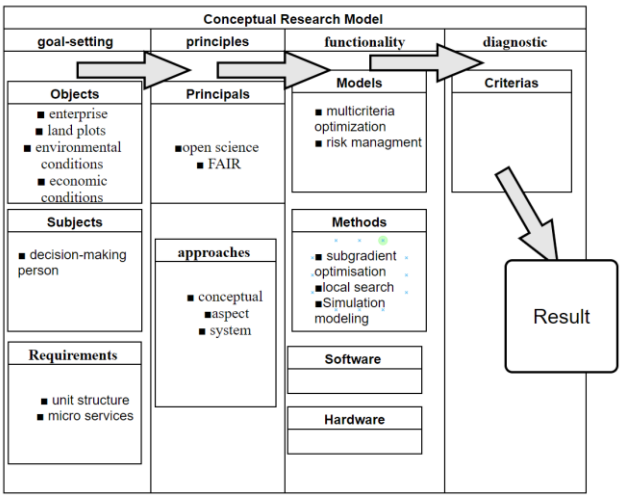

Fig. 1. The conceptual research model of developing the decision support system for agriculture.

1. The goal-setting component. This component defines the main objects and subjects of the environment and the requirements for the properties of the final product, and the implementation of the model.

2. The principles component. This component defines scientific approaches and principles that correspond to science and FAIR's openness, taking into account the specifics of decision support, environmental uncertainty, and agriculture.

3. Functionality component. This component includes appropriate mathematical models and methods, software, hardware.

4. Diagnostic component. This component includes criteria and indicators for assessing the functioning of the system.

The considered components form a holistic outline for building a model of an information system for decision support in the agricultural sector in environmental uncertainty conditions. Consider in more detail each of the components of the information system.

The goal-setting component is developed following international and national requirements for information systems. The peculiarities of the subject area of research are also taken into account: the agricultural sphere, which functions in ecological uncertainty conditions. The component declares the purpose, which involves developing an information system—using this system as a tool to simplify the decision-making process in the agricultural sector. The information system should help to achieve better results in the process of enterprise operation.

During the development of the goal-setting component, the following main objects of the environment in which the information system will operate were identified:

1. An enterprise that carries out certain activities in the agricultural sector. It can be an enterprise that grows certain crops such as wheat, rice, cabbage, potatoes, etc. It can also be a company that breeds certain animals, such as cows, pigs, chickens, etc. Can the company combine these activities? Let's summarize the concept of "agricultural enterprise" and will continue to consider it as an object that uses land, funds, and other resources to generate a resource of another kind. The agricultural enterprise is the basic unit of functioning. It is also an object that is controlled using the appropriate information system.

2. Land plots are considered as the primary resource of the agricultural enterprise. This object has specific characteristics on which the result of the functioning of the agricultural enterprise depends. These characteristics are not homogeneous and stable. They depend on the geographical location of the site and the impact of other objects. In particular, from the history of the agricultural enterprise. For example, if you grow sunflowers in one field for several years without using appropriate fertilizers, the soil yield can be significantly reduced. Environmental conditions also have a significant impact on the characteristics of the land plot. Soil characteristics are known parameters. They do not change very quickly, and therefore for a certain fixed period, such as one season, they can be considered constants. The characteristics of the land are usually known. Consequently, they can be regarded as clear input parameters of the information system for decision support in the agricultural sector in environmental uncertainty conditions. The desired characteristics of the land can also be used as a component in formulating the agricultural enterprise's purpose.

3. Environmental conditions are also relevant. Environmental conditions include meteorological indicators such as precipitation, temperature, humidity, solar radiation intensity, etc. Environmental conditions also include environmental pollution factors such as air, water, and water pollution by harmful substances. Environmental factors can also include biological factors such as pests, bacteriological and viral diseases. All these factors are united by the fact that chaotic processes describe them. Therefore, long-term forecasting is not possible [10]. However, the short-term prediction of such values is possible. Particularly useful methods of forecasting environmental conditions used in agriculture are methods using fuzzy logic [11]. Therefore, we will consider ecological conditions as a specific object of the environment described by fuzzy quantities. The values that represent environmental items change very quickly. These values should be considered as fuzzy input parameters of the information system for decision support in the agricultural sector in ecological uncertainty conditions.

A formalized approach to environmental monitoring can be used to obtain indicators of environmental conditions [12 – 14]. According to this approach, information systems provide data on the current state of indicators and use methods to predict their state in subsequent periods [15].

4. Economic conditions are also essential to keep in mind. The economic conditions, first, include the prices for products manufactured by the agricultural enterprise. Prices are determined by methods independent of the agricultural enterprise. These can be both market trading methods on the commodity exchange and administrative processes, which are to regulate prices by the authorities.

5. The main subject is the decision-making person is the director of the agricultural enterprise or a collective body as a supervisory board. Approves the purpose of the agricultural enterprise Also makes the final decision on the choice of operating strategy. Has motives for finding a solution to the problem of managing an agricultural enterprise, including financial incentives. The decision-maker also determines what means are eligible to achieve this goal. The decision-maker is the primary user of the information system to support decision-making in the agricultural sector in environmental uncertainty conditions.

Requirements for the properties of the final product and the result of implementing an information system to support decision-making in the agricultural sector in conditions of environmental uncertainty are described in [8].

Particular attention should be paid to the requirements for the modularity of the system. The advantage of using the system's modular structure is the ability to expand and modify each of the modules independently of the others. This structure significantly increases the stability and flexibility of the system. A modern approach to software development, such as the use of microservices, should also be considered. Each module must be implemented as an independent microservice [16].

The component of the principles includes the following principles that should be followed in the process of development and operation of the information system to support decision-making in the agricultural sector in conditions of environmental uncertainty:

1. The principle of open science is to use in the design, development, and implementation of information systems of the latest research results.

2. FAIR's principle is to use such inputs and formulate the system's results so that they are easy to find access, data are compatible with other information systems, and can be used repeatedly.

Developing an information system, it is essential to follow a sequence of scientific approaches. First, using a conceptual approach to develop the necessary provisions that determine the general direction, course, and architecture of decision support systems. Then, based on the aspect approach, identify the most significant components. And complete the determination of the nature of the relationships between aspects and their properties using a systems approach.

The functionality component primarily includes those mathematical models and methods that ensure the functioning of the information system to support decision-making in the agricultural sector in conditions of environmental uncertainty.

As shown in [17], we can consider two main approaches to determining the optimal solution.

The first approach is to formulate the problem of decision making as a problem of multicriteria optimization:

$$c_i(s(x)) \to \max, i = \overline{1,m},$$
$$G_j(x) = 0, \ \ j = \overline{1,r},$$

where x is a fuzzy vector value that represents the factors of the environmental conditions and economic conditions, $s(x)$ is some strategy of the agricultural enterprise functionality, c_i are criteria based on which the strategy can be evaluated, m is the number of criteria for evaluating the strategy of the agricultural enterprise functionality, G_j are functional restrictions that determine the feasibility of implementing a suitable strategy of the agricultural enterprise in terms of available resources and r is the number of restrictions/

Appropriate methods should be used to solve this problem of multicriteria optimization. The traditional approach is to use one of a family of local search methods. This method makes it possible to find local optimal solutions to the optimization problem. [18]. It is

also traditional to use subgradient methods [19–20]. A more modern approach to solving optimization problems is simulation [21].

The second approach to decision-making is to minimize risks [22]. First, there is the identification of risks, which consists of compiling a complete list of risks that may positively or negatively affect the activities of the agricultural enterprise. For this model, all fuzzy input parameters, namely environmental and economic conditions, are risk factors. Next is the analysis of risk distribution functions. The functions of losses or gains in the event of a relevant risk situation are assessed.

Let f is a function of estimating losses or gains at a certain fixed value of some risk factor x. Then the overall expected effect from the activities of the agricultural enterprise can be calculated as a mathematical expectation:

$$M(x) = \int_{x_{\min}}^{x_{\max}} f(x)\mu(x)dx ,$$

where $x_{\min}$ and $x_{\min}$ are the minimal and maximal possible values of the factor x and $\mu(x)$ is a membership function.

The standard deviation determines the risk of the activity:

$$\sigma(x) = \sqrt{\int_{x_{\min}}^{x_{\max}} \left(f(x) - M \right)^2 \mu(x)dx} .$$

Since there are many risk factors, integration should be carried out for each of the risk factors.

To find the optimal solution in terms of risk management is the solution of such a problem of minimizing the coefficient of variation

$$\frac{\sigma(x)}{M(x)} \to \min .$$

Finally, consider the diagnostic component. This component includes criteria and indicators of the functioning of the agricultural enterprise. It makes it possible to quantify the result of activities for a given season. It is a diagnostic tool that allows you to assess the decision-maker and increase the agar company's efficiency in the coming seasons.

III. CONCLUSION

As a result of research, a Conceptual Research Model of developing the Decision Support System for Agricultural was built, including four components. The goal-setting component defines the objects and subjects of the environment in which the information system operates. It also contains requirements for the final product's properties and the expected results from the implementation of the Decision Support System. The Principles component defines the principles to be used when developing a Decision Support System. It is especially important to follow the principles of open science and data. Component functionality determines mathematical models of multicriteria optimization and risk minimization model. The diagnostic component defined the criteria for evaluating the effectiveness of decisions. The considered components form a holistic system that provides the process of developing a decision support system.

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