Simulation modeling of the machine and tractor fleet to improve the technical base of the agro-industrial complex

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Abstract. Modernization of the technical base of the agro-industrial base of the agro-industrial complex should be based on a scientific approach and the use of modern tools. In the article, the authors consider the possibilities of simulation modeling as an addition to the implementation of the task of optimizing the composition of the machine and tractor fleet, for example, to smooth out the peaks of loading of agricultural aggregates. The advantage of simulation models is the possibility of taking into account a large number of factors, the use of nonlinear dependencies between variables, its numerous runs when varying parameters, determining the degree of influence of predicted deviations of production conditions on the value of resource potential at the basic values of the system parameters. This provides estimates of the stability of these parameters and their adequacy to the functioning environment. The authors highlighted the advantages of using simulation modeling tools in the modernization and formation of an optimal agricultural machinery and tractor fleet of an agricultural organization. Modern software products can be divided according to the type of simulation model implementation: system dynamics, discrete-event and agent modeling. When considering the general requirements for the simulation model of the formation of a machine and tractor fleet, special attention is paid to verification. This implies the process of verifying the use of the formed composition of equipment by means of running a simulation model. Adequacy, integrity, informativeness, simplicity, scalability are the main requirements for the simulation model. The authors have identified the input and output parameters of the run of the simulation model of the formation of a machine and tractor fleet. Verification guarantees that the model is checked for compliance with the general requirements for a set of machines. Running the simulation model will allow you to adjust the production plan depending on the technological and technical availability, as well as the selected level of production intensification.

1 Introduction

With the development of information and communication technologies, there are more and more tools that allow you to create automated systems for building crop production technologies, databases of technologies and technical means, solve optimization problems, build simulation models. The task of determining the optimal composition and structure of the machine and tractor fleet for agricultural organizations remains relevant at the present time, both for new enterprises and for existing ones in order to adjust the existing fleet. The optimization task is implemented using the linear programming method [1-5] and the method of end-to-end viewing of annual work packages (when smoothing the peaks of machine loading) [6, 7]. Simulation modeling is also popular and allows you to run a model with a large number of factors, which gives more accurate results. For agriculture, we wanted to give examples of implementation by the following scientists: K. Zhichkin, V. Nosov, L. Zhichkina, N. Fomenko, V. N. Shepel, N. V. Speshilova, M. V. Kitaeva, I. V. Zhupley [8-11].

The relevance of this study is to highlight the advantages of simulation modeling and the formation of general requirements for the simulation model within the framework of the optimization problem and the formation of the machine and tractor fleet of agricultural organizations.

2 Materials and methods

The main emphasis in the study is on the possibility and necessity of using simulation models in the formation of the composition of the machine and tractor fleet of an agricultural organization. The authors highlighted the
advantages of this approach and the necessary main stages of their construction, which is discussed in more detail below.

2.1. Materials

As the literature review presented by us has shown, there are two main directions for solving the problem of forming a machine and tractor fleet of an agricultural organization: graphical, based on the construction and smoothing of peak loading of machines; based on economic and mathematical modeling. The basis of the first approach is the calculation of technological maps, their analysis, determination of the number of machines of a certain brand and type, peak loads for specific agricultural time periods. It is simple, intuitive and accessible to a wide range of users. This approach makes it possible to solve most of the problems associated with the formation and optimization of the composition of the machine and tractor fleet. We recommend it for use in the modernization of the technical base and justification of the promising composition of equipment. It helps in evaluating the effectiveness of the existing composition of the machine and tractor fleet at an agricultural enterprise. One of the minor disadvantages of this approach is that for a large number of types of work and equipment, the construction of these maps is complicated.

The second approach is based on economic and mathematical modeling. During its implementation, models of the formation of the composition of the machine and tractor fleet are built. So a stochastic model can be reduced to a linear programming problem by varying the most appropriate optimality criterion, which is expressed quantitatively, usually tends to a minimum or maximum. The advantage of stochastic optimization models of the machine and tractor fleet is the property of the adequacy of the display of real production conditions. The decision-maker makes the choice of the decision. But it is necessary to note the disadvantages of this approach. Some researchers point out that due to the large number of external and internal factors, it complicates optimization, which leads to the need to reduce the number of variables, and therefore low efficiency in practice of the final solution [11, 12].

Therefore, considering the process of forming a machine and tractor fleet, it is advisable to combine these two approaches. Which leads to the need to use optimization and simulation models in one study. Simulation models are complementary, they allow us to take into account nonlinear dependencies between variables, limit the level of influence of variation in predicted production conditions on the size of the resource potential, and, due to their characteristics, evaluate the verification of the model. As we showed in our study [13], at an acceptable level of risk, if the level of stability of the system is close to critical, it is possible to determine new optimal basic parameters, adjust the input data for the optimization model in accordance with the conditions obtained as a result of running the simulation model.

Our analysis has shown that simulation modeling has the following advantages for research:
- Easy ability to add and analyze discrete variables and their nonlinear properties.
- Construction and research of complex systems containing stochastic parameters.
- Rapid modification of simulation models.
- Getting a set of alternative solutions.
- The ability to choose the most optimal for the given conditions or an effective solution.
- The use of model time for setting up experiments, studying the functioning of the system [14].
- Obtaining probabilistic estimates as a result of running the model.
- Evaluation of system indicators part with varying operating conditions.

2.2. Modeling methods

For any type of the simulation model, there is a set of general rules and stages of construction. These stages are shown in Figure 1 and form a cyclic model.

![Simulation cycle](image)

It reflects the real, conceptual and formal representation of the elements. At the first stage, the definition and formulation of the problem for which the simulation experiment is conducted takes place. Then it is necessary to collect, structure and classify the available and used data and information flows. After the data analysis is completed, the stage of forming a conceptual model begins, and then a simulation model. Next, the model is
run, a series of experiments is set up, and a set of output data is collected. At the end, the analysis of the data obtained is carried out, conclusions are formulated and recommendations are made about the modeling object.

Thus, the simulation process is a cyclical process. Its results should be compared with the conceptual and real model. The presence of iterations during the simulation model run allows it to become approximating to the real system. At the same time, the main difficulty, in our opinion, is in collecting a large amount of input data.

3 Results and discussion

3.1. Software for the implementation of simulation models

Currently, there is a wide range of software products available; they allow you to implement simulation models using not only programming languages, but also visual programming. Let us consider modern tools that allow you to create any simulation models (Table 1).

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<tr>
<th>System</th>
<th>Discrete-event models</th>
<th>Agent-based modeling</th>
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<tbody>
<tr>
<td>AnyLogic</td>
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<tr>
<td>Pilgrim</td>
<td>Arena</td>
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<td>Simulink</td>
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The existing tools are focused on a specific approach, i.e. for discrete dynamics, discrete-event models and agent-based modeling. For some of them, the choice is more diverse, this is explained by the peculiarities of each of the approaches, the presence of limitations in the construction of the model and the scope of the result. For agent-based modeling, the software appeared later than others and was presented in the early stages through libraries in Java or C++.

The analysis of the table demonstrates that the AnyLogic tool allows them to create simulation models for any type needed by the researcher. As you know, this software product is based on languages and methods used to create large information systems. The user receives a variety of tools (compared to other software presented in Table 1), which is not limited to the types of simulation research methods. The following advantages of AnyLogic should be noted: it is a convenient interface and libraries for building models, an intuitive way of setting and introducing probabilistic parameters. Thanks to the use of Java, the simulation model can be created as an independent application that runs independently of the software of a particular user.

3.2. General requirements for the simulation model for the task of forming a machine and tractor fleet

In the task of forming a machine-transport fleet, it is necessary to carry out actions that allow checking for errors in the generated plan for the use of equipment. As practice shows, verification is used for this, the procedure of which checks whether the output data and results meet the previously set implementation requirements. The verification process is based on the criteria applied to the software, the actions of the standard, the elimination of errors and shortcomings. There are approaches to solving the verification problem. The first approach suggests using methods of simulation modeling and other modeling, hardware emulation. But you can use the second approach. It is based on the methodology of the verification process, i.e. on the transfer of these procedures to more initial stages of design. As practice shows, researchers with a combination of these two approaches [15] obtain the optimal solution.

For the considered task of forming a machine and tractor fleet of an agricultural organization, we consider verification as a process of verifying the use of the formed equipment composition based on iterations of the simulation model.

Therefore, for our task, the verification procedure consists of the following stages: checking the formed duration of the periods of the agricultural year, ranking the distribution of technical means between technological operations for specific acreage; loading of the machine and tractor fleet, including modeling the load shares for the periods of the agricultural year for the formed complex of technical means and the block formation of an alternative plan and adjustments, taking into account verification carried out. Conceptually, the simulation model should correspond to the first three stages and allow the user to analyze the graphical representation of the data.

For our task, the verification procedure consists of the following stages: checking the duration of the agricultural year, the ranked distribution of the machine and tractor fleet between technological operations for agricultural operations; checking the workload of the machine and tractor fleet, including modeling the load shares for the periods of the agricultural year, the formation of adjustments and alternatives. There is a plan for the use of equipment at the entrance. And at the output we will get an alternative production plan or an adjustment of the plan taking into account the verification carried out. Conceptually, the simulation model should correspond to the first three stages and allow the user to analyze the graphical representation of the data.

Let us highlight the general requirements for simulation and analytical models. This is adequacy, integrity, informativeness, simplicity, scalability. Let us
consider them more specifically for the task of forming a machine and tractor fleet.

To identify and formalize the requirements for the simulation model, which should correspond to the process under consideration, we will use the UML diagram of use cases (Fig. 2). The figure explicitly reflects the purpose of the simulation model being created, the necessary functional links between the projected model and external operating sources, both users making decisions and external data stores or other information systems.

After correcting the data, you can perform the rest of the calculations. As we have already noted, the periods of agricultural operations are set, depending on the natural and climatic zones, the weather and climatic conditions of the region, the availability of labor reserves. Researchers can vary the values of indicators of hourly loading of machines, the duration of technological operations, coefficients determining heat and water availability, the cost of agricultural machinery, the timing of ripening of crops. The function of the total costs of agricultural production in the model should tend to a minimum. At the next step, for a given set of equipment, productivity, reliability, and work readiness coefficients for each technical means, the workload for agricultural operations is calculated under conditions of limitation by the values of the size of annual work volumes and time periods. After running the simulation model, it is possible to estimate the level of workload of technical means, the probability of performing the specified volumes of technological operations, taking into account differences in cultivation technology, capacity and duration of work.

The information obtained after running the model allows the user to understand and analyze the efficiency of using equipment, the level of workload when changing the duration of technological operations, as well as to detect a shortage of technical, labor resources and adjust the initial data [6, 16].

Thus, the implementation of verification for the task of forming a machine and tractor fleet is the same as checking for compliance with the general requirements for a set of machines. When implementing verification, the adequacy, integrity, informativeness, simplicity and scalability of the model are checked. The user who applies simulation modeling can adjust the agricultural production plan. Existing software products allow implementing methods of system dynamics, discrete-event models, agent modeling. We consider AnyLogic to be the most universal.

Simulation modeling, on the one hand, is an excellent addition to solving optimization problems. And on the other hand, it can be used separately, because in particular cases it will be enough to make decisions.


References