Process Approach for Modeling of Machine and Tractor Fleet Structure

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Abstract. The existing software complexes on modelling of the machine and tractor fleet structure are mostly aimed at solving the task of optimization. However, the creators, choosing only one optimization criterion and incorporating it in their software, provide grounds on why it is the best without giving a decision maker the opportunity to choose it for their enterprise. To analyze “bottlenecks” of machine and tractor fleet modelling, the authors of this article created a process model, in which they included adjustment to the plan of using machinery based on searching through alternative technologies. As a result, the following recommendations for software complex development have been worked out: the introduction of a database of alternative technologies; the possibility for a user to change the timing of the operations even beyond the allowable limits and in that case the calculation of the incurred loss; the possibility to rule out the solution of an optimization task, and if there is a necessity in it - the possibility to choose an optimization criterion; introducing graphical display of an annual complex of works, which could be enough for the development and adjustment of a business strategy.

1. Introduction

The high level of mechanization provides opportunities for cultivation of large crop areas, but at the same time requires a wider range and amount of machinery with different performance indicators for performing individual operations.

The system of technologies and machinery is a system of knowledge about the technical and technological support of the agro-industrial sector. The term technology in the name of the system of knowledge implies that technology becomes the determining factor in influencing the efficiency of agricultural activities. The system includes not only traditional but also newly emerging techniques. The need for the appearance of such a system is caused by the requirement for the adjustment of domestic machines development program.

Agricultural enterprises have significant differences in the characteristics of farms as well as the machinery used on them. Due to the individual nature of requirements, for the optimization of the machine and tractor fleet, it is necessary to have modern information support.

The modeling of agricultural processes is well represented by linear functions. Therefore, it is necessary to consider linear programming as a methodological tool for solving the problem of obtaining
the optimal structure of a machine-tractor park. This approach enables one to consider simultaneously a large number of operations by selecting the optimal coefficients, which optimize the target function (minimization or maximization, depending on the given condition).

For the description of existing and planned business processes and identification of opportunities for their targeted improvement, in particular, reduction of time and material costs, in scientific practice the method of the process approach is widely used. Within it, AS-IS (as it is today) and TO-BE (as it will be in the future) analysis will provide the opportunity to aggregate and detail the existing data and information flows. The analysis of scientific papers on this subject matter showed a lack of interest in it. In the authors’ opinion, modeling and optimization of a machine and tractor fleet structure should be preceded by the development of a process model.

2. Materials and methods

2.1. Process approach

In contrast to a functional approach, which is based on the performance of functions, i.e., activities without the idea of achieving the ultimate goal as a whole, a process approach implies transforming an incoming flow into an outgoing one, i.e. a set of actions that develop in dynamics. The main difference of the process approach lies in the appearance of sequences of actions in time. While carrying out a process, a decision-maker evaluates the input. After that and when a series of transformations is made, they proceed to the next action. There are different approaches to the process approach (Table 1).

### Table 1. The concept of the process approach in scientific research

| Interpretation of the concept | Author’s |
|------------------------------|----------|
| Establishing the organization’s processes to operate as an integrated and complete system. | ISO 9001:2015[1] |
| Technique of management that views a business as a collection of processes, managed to achieve a desired result. | Becker J., Kugeler M., Rosemann M. [2] |
| Management allows measures the full set of activities in one business. For instance, it focuses on internal processes such as customer satisfaction, quality of product and security as well as financial results including revenues, profits, costs, and budget | Badreddine A., Romdhane T.B., and Amor N.B. [3] |

The process approach also allows one to describe all the necessary functions. From how the decision-maker develops the concept, draws up a business plan, assesses the risks, depends on the success of the production process and making a profit [4]. The application of this method will also allow identifying possible "bottlenecks" in certain business processes described earlier. In the authors’ opinion, the main elements of the process approach are a process which transforms incoming elements, and a function, as an activity, the manifestation of some property in the system under consideration.

Advantages of the process approach include clarity, certainty, integration, dynamism, flexibility and, at the same time, high repeatability. The process approach allows us to identify the relationship between the existing forms of the organization of technological process and the capabilities of the organization itself under the conditions of the development of information technology, built-in blockchain mechanisms, mobile applications and others.

2.2. The objectives of the optimization of the machine and tractor fleet

The questions of the optimal use of vehicles were considered in many works of Russian scientists. Examples can serve as a methodology for calculating the needs of collective farms and state farms in the technology of V.A. Bulavsky and L.V. Kantorovich (1962-1963) On the basis of the application of the method of linear programming and computer realization; E.A. Finn, V.V. Shkurba, L.N. Komzanova on the basis of linear programming and the interactive method (1968).
Among scientists, concerned with the optimization of machine and tractor fleet, we might note in particular Danish scientists H.T. Sogaard and C.G. Sorensen. With regard to costs, they singled out the most cost consuming systems - a system of labour and a system of machinery. Therefore, one can talk about the adaptation of these operational factors to real needs. Their model involves such factors as particular farm size, crop plan, etc. The authors developed and described a model which supports the process of choosing the optimal machinery capacity [5].

Scientists from Sudan developed a program of assessment of agricultural machinery efficiency to meet the user requirements for machinery management and as educational and research tool. This program calculates field efficiency, helps select optimal equipment, creates a machine maintenance project [6]. The program is written in Visual Basic and is user-friendly and interactive.

The scope of work is closely connected with the notion of intensification level, which can be extensive, of low-intensity, intensive and resource saving. The first three levels are traditional, while the resource saving technology is comparatively new. Different levels imply different climate conditions in which farms are located. The location of a farm predetermines the agro-landscape zone to which a farm belongs to (forest steppe, steppe, taiga, etc.) For each zone flowsheets have been developed containing a set of operations, recommended machinery, the timing of the operations and expected crop yields.

Types of works done and crops define crop rotation, a cycle including a change of crops on fields. Every farm has its own crop rotation plan. It includes field number, field area, the crop for planting this year, the crop planted last year. The task was formulated as follows: Let there be some types of agricultural works, the scope of which is known. They work can be done by various machines and their performance is known. The whole complex of agrotechnical works should be carried out within strict time limits, and each operation – during a specific period of time and in a certain sequence. The machines’ technical parameters also affect the simulation results [7, 8]. The intensity of use of each machine for each type of work was required according to the limiting condition that the full scope of works had to be done within certain time limits. The sum of use intensities of this machines type for all works at any point should be equal to the total amount of this type of machines on a farm, the number of machines is determined by a positive value, and the objective function reaches its minimum.

While the linear programming method did not cause controversy, the choice of the objective function caused a lot of heated debate.

The minimization of the objective function is possible on the following optimality criteria: the search for minimum direct operating costs, energy costs, aggregate costs, resulted expenses, differential costs (table 2).

| № | Names of expenditures | Cost components |
|---|----------------------|-----------------|
| 1  | Direct operating costs | Costs from technological operations, pay, cost of fuel and lubricants, repair and maintenance costs, depreciation charges, costs of basic and auxiliary materials |
| 2  | Energy costs          | Total energy consumption |
| 3  | The resulted expenses | The cost of production and the cost of feedback. The costs of feedbacks take into account the expenditure of all the most important limited economic resources, including labor, the deficit of agricultural products, etc. |
| 4  | Aggregate costs       | Cash, including direct operating costs, and losses from changes in the quantity, quality of products, working conditions of maintenance personnel, the negative impact of technology on the environment |
| 5  | Differential costs    | The operational costs of production, the coefficient of efficiency of capital investments, investments in machinery, equipment and other facilities, the costs of maintaining the staff of the machine operators in the calculation of the intermittent production of the unit |
At the same time the function has the following restrictions: existing staff, existing machinery, time intervals for each operation. As a result we get an optimized machine and tractor fleet tied to types of work and, subsequently, to time interval.

Direct operating costs take into account only the costs directly for the performance of technical operations. Investment in funds for the purchase of new equipment, investments in ensuring wages and social life of village workers, etc. are not taken into account. The same shortcoming is typical for energy costs. The resulted expenses play the important role in an estimation of efficiency of use of new technologies and engineering in various conditions of operation, as they take into account the effectiveness of capital investments. The sum of production costs and feedback costs (the expenditure of labor resources, the deficit of agricultural products, etc.) are the differential costs.

Differential costs in addition to the above take into account the average material costs associated with the maintenance and residence of machine operators and their families in a given rural area (in the same dimension as the resulted costs), i.e. provision of housing, children’s and school institutions, cultural and sports facilities, etc.

Thus, the calculation of different types of costs is determined by the specifics of production. So, to determine the effectiveness of individual aggregates or their groups at actual costs that determine the cost of work, direct operating costs are used. If it is necessary to evaluate the effectiveness of capital investments, the reduced costs are applied. To estimate the same feedback costs, it is necessary to use differential costs.

3. Construction of the process model for the modeling of the machine and tractor fleet
The task of modeling a machine-tractor fleet is a more difficult task than the task of optimizing it. Examples include the use of the method of through-view of the variants of the annual complexes of works, proposed by B.D. Dokin, implemented in the software complex "Agro" [9]; supplement the algorithm for optimizing the machine-tractor fleet with the formation of an optimal schedule for fieldwork, the authors A. V. Lenski, E. M. Ivanov, E. Kazhdan [10, 11].

In the authors’ opinion, the process model for the modeling of machine-tractor fleet contains the following blocks: preparation of the initial information; formation of a basic plan for the use of general purpose tractors; formation of a basic plan for the use of tractors; creation of annual work packages; evaluation of the received plan; output of information and calculation of costs (Figure 1, Table 3).

![Figure 1. A process model for modeling the structure of the machine and tractor fleet](image-url)
Table 3. Input and output information flows

| Type and number of flow | Explanation of flow                                      |
|------------------------|---------------------------------------------------------|
| Input 1                | Crop rotation                                           |
| Input 2                | Production plan                                         |
| Output 1               | The structure of the machine and tractor fleet           |
| Output 2               | The technological maps of cultivation and harvesting of crops |
| Output 3               | Alternative technologies of crop production             |
| Output 4               | Maintenance (operational) costs                         |
| Output 5               | The required number of machine operators and workers     |
| Output 6               | The cost of the machine and tractor fleet                |

The process begins with the preparation of information about the farm. Initial data include crop rotation and a production plan. Crop rotation includes information about the type of crops they planted (including steam), allocated space and culture to it, which was inoculated on this area in the past year. If the same culture is sown in different fields – the areas of these fields are combined in the calculation. Under the production, a plan is understood as: the existing composition of the machine and tractor fleet, the number of machine operators, technology, material resources, optimization criteria. The available initial data must be brought to the form that corresponds to the input variables of the optimization model.

Further, in accordance with the technological maps, a baseline version of the plan for using the machine and tractor fleet is made in the form of a list of used equipment and its total load for the year. The received version of the plan is checked for liquidity and is characterized by compliance with the optimization criteria. In case of non-compliance with the required conditions or the need to consider alternative options, the production plan is changed. Alternative technologies for production of agricultural crops are selected based on three indicators: yields; unit cost of production; labor costs, i.e. the staff requirements. This can be both existing and new technologies. It is the process approach that allows the inclusion of alternative technologies in the model, solving the bottleneck problem.

After carrying out a positive check of the basic plan for compliance with the established requirements, a complete set of technical means is formed, including information on the use of technical means during the year, the required number of machine operators and workers, the timing of the operations. On the basis of the formed ready-made technical complex, the calculation of costs and profits is performed. The optimization task is laid in the blocks "the formation of the basic plan for the use of general purpose tractors", "the formation of a basic plan for the use of tilled tractors and the evaluation of the results obtained." In the authors’ opinion, the implementation of such model is possible with the use of a statistical method (for the implementation of blocks for preparing initial information, outputting information and calculating costs), an imitation method (for creating an annual work package), linear programming (for blocks for the formation of a basic plan for the use of general tractors, the basic plan for the use of tilled tractors and the evaluation of the received plan).

The formation of annual work packages should be visual, depicted graphically. An example of such imitation is shown in Fig. 2.
Often, with a small amount of data, to make a decision based on alternative technologies, it is sufficient to conduct a graphic analysis of the loading of the equipment.

When modeling the structure of the machine and tractor fleet, the decision maker must be able not only to enter data of his agricultural enterprise, but also to select the target function in the optimization task. It is he who determines what types of costs are most important for him. Moreover, in the software complex the possibility of modeling the structure of the machine and tractor fleet should be realized without its optimization, for example, under the machinery available in the farm. This will provide a choice not the best option from the point of view of the optimization task, but the necessary managers for some purpose. In addition, we consider that the condition of strict compliance with the timing of operations (which results from setting an optimization task) is controversial, it is quite possible that a small shift in terms, although it will lead to the loss of part of the crop, will ensure a reduction in costs for the production of agricultural products. The second option is that due to the weather conditions of each specific year, a shift in the timing, increase or decrease, is possible. These facts should also be taken into account when creating a software package for modeling the machine and tractor fleet.

In addition, the analysis of the existing software complexes for the simulation of the machine and tractor fleet made it possible to identify the following shortcomings, which must be eliminated:

1. The focus is mainly on optimizing the machine and tractor fleet.
2. Fixed optimization criterion.
3. An obsolete programming language that significantly hinders the work with the software.
4. The program works only in legacy operating systems. To work in modern operating systems, additional software is required.
5. The requirement of direct participation of the operator in the process of optimization and in the process of forming technological maps.
6. Significant duration of the optimization process.
7. The need for specialized software to provide the ability to view databases.
8. Modular layout of the program, which requires the launch of individual blocks of the program to solve certain tasks.

Based on the implementation of the process model and with the help of the projected software solution, the formation of technological maps (Figure 1) should be made, which will allow further automating the preparatory stage of business process reengineering based on rules and precedents.

4. Conclusion
The development of a software complex for the simulation of a machine and tractor fleet should be based on a process model that can identify bottlenecks in business processes. The analysis made it possible to identify the shortcomings of existing software systems. It is not possible to model the structure of the machine and tractor fleet without the block for solving the linear programming problem. The decision-maker cannot use the set of objective functions, change the timing of operations beyond the permissible limits. The obsolete programming language owing to the work in older operating systems, the need for additional software, the modular layout of the program, which requires the launch of individual units and the direct involvement of the operator, a significant length of the modeling process bring another set of inconveniences and problems to the user. It is actual to have a database of alternative technologies for the production of agricultural crops and a unit for the formation of annual work packages, including their imitation on the charts. This will increase the output options.

Elimination of shortcomings and the authors’ proposals will allow us to improve the software complex for modeling the machine and tractor fleet, which will provide more flexible decision-making.

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