The use of simulation technologies to optimize the processes of transportation of crop production

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Abstract. Methodological approaches to the substantiation of groups of optimization criteria for mathematical modeling of planning and distribution structures are considered in detail. To justify methodological approaches for optimizing the transportation process, it is necessary to take into account not only transportation conditions, but also indicators of the trouble-free operation of vehicles. It has been established that cost-effective characteristics of transport and technological processes have been studied and determined using mathematical analysis. Based on this model, recommendations have been presented for optimizing transportation processes. The model can be used to study and predict the development of freight transportation systems in the agricultural sector.

1 Introduction

The development of agricultural production inevitably leads to an increase in the volume of transportation. Therefore, the tasks of increasing labor productivity, reducing losses and, as a result, maintaining the quality and reducing the cost of agricultural products during transportation are becoming especially relevant [1, 2]. For the smooth work of an agricultural producer, it is necessary to have a developed transport network, with a rationally formed structure of existing production stocks, to avoid and minimize possible downtime [2,3]. According to FAO (FAO, 2022), the global loss rate of fruits and vegetables at the transportation stage ranges from 3% to 18%. Annual damage from losses amount to about 8 billion rubles, and transportation costs reach 30-40% of the product cost [3].

Vegetable production in Russia in the industrial sector in 2023 amounted to 7.2 million tons, while most of the products were produced in open ground conditions (5.5 million tons). According to Rosstat, in Russia, the largest annual production volumes are onion (113.0 thousand tons), cabbage (101.0 thousand tons), carrot (39.3 thousand tons), table beet (22.5 thousand tons). In open ground conditions, cucumber (870.5 thousand tons) and tomato (724.1 thousand tons) are the leaders in terms of grown products.

The key condition for product safety is compliance with the modes of transportation and storage of vegetables and fruits in accordance with SanPiN No. 2.3.6.3668-20. Perishable products (potatoe, onion, garlic, root vegetables, apples, pears, citrus fruits, greens packed in

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social containers), to minimize transportation costs, are often transported in open trucks without refrigeration systems, which leads to mechanical damage and spoilage of products. The use of transport equipped with a refrigerator ensures a high level of product quality with limited shelf life. Another important aspect is the driver's compliance with the speed limit, these requirements help protect products from mechanical damage. When choosing a package for transporting vegetables, pay attention to two important factors: the environmental friendliness of the material and its ability to protect fruits from friction and impacts. It is not recommended to transport different types of products together, due to the possible negative impact on safety due to different physical and chemical properties, vegetables and fruits that emit ethylene should be transported and stored separately with products subject to harmful effects. For economic expediency, incompatible products are often transported in one refrigerator, placing them in opposite parts of the body, increasing the period of joint storage to two days. The purpose of the study is to optimize the processes of transporting agricultural products by road using simulation technologies.

2 Materials and Methods

A theoretical and methodological analysis of the process of transporting agricultural products has been carried out. The obtained characteristics of cargo transportation, selection of equipment, and delivery methods were processed using mathematical analysis. Based on the developed model, recommendations are proposed for making optimal decisions designed to improve the quality of product transportation and reduce costs. Moreover, the model can be used for the analysis and predictive system of product transportation at enterprises in the agricultural sector, which the neural network will be able to use for training in the future.

3 Discussion

One of the priorities in agriculture is the search and application of effective innovative technologies for the allocation and management of production resources, cost reduction, and optimization of management processes in agro-industrial organizations. This affects all participants in the transport and logistics infrastructure of agricultural products in Russia. The best approach is to develop a strategy to improve transportation and distribution processes between agricultural producers using road simulation technologies. The key feature of this approach is the ability to make an economically sound choice based on the alternatives formed, considering the interests of all parties concerned in the process. During the analysis of indicators affecting the quality and cost of transportation of agricultural products, it was revealed that in addition to the conditions of transportation, namely seasonality, modes of transportation and storage of vegetables and fruits, there are operating costs for transportation (route duration, body type, fuel consumption, etc.).

For real time online monitoring of these indicators, it is proposed to retrofit the vehicle (car) with the following equipment: to record the conditions of transportation, thermal sensors and humidity sensors, cameras for recording the position of the cargo, a telematics unit that will receive and process data from standard (fuel level sensors, vehicle loading, speed and etc.) and additional sensors and send information to the operator's computer, an example of how the system works is shown in Figure 1.

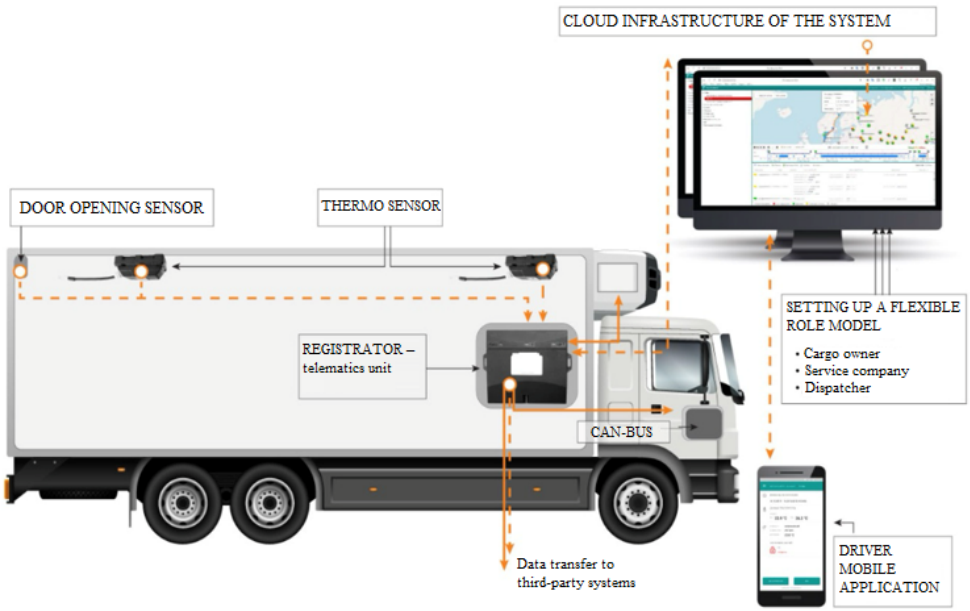

Fig. 1. Architecture of the hardware and software complex.

At the same time, one of the key factors in product delivery is the uptime of vehicles carrying out transportation. In the actual operating conditions of the fleet, the failure of vehicles occurs as a result of accidental failures. One of the key integrated indicators of the fleet is the technical readiness coefficient, which reflects the operation of machines over a certain period. [4, 5, 6, 7]. As a result of the research, 306 trucks of the transport company "Technology of Movement" were monitored, of which 118 KAMAZ units (5490, 4389 F1, M 1840, M 1945, T 2640), 64 SCANIA units (G400, R400, R440), 121 MERSEDES-BENZ ACROSS units (1836, 1841LS, 1844LS, 1845LS, 1846LS, 1848LS, 1853LS, 1840L) and others. The average mileage of cars during the study period was about 700 thousand km per car, since the beginning of operation. To assess the impact of reliability indicators on the efficiency of the vehicle fleet, statistical data on the number of repair and technical impacts relative to vehicle brands have been collected and systematized (Figure 2).

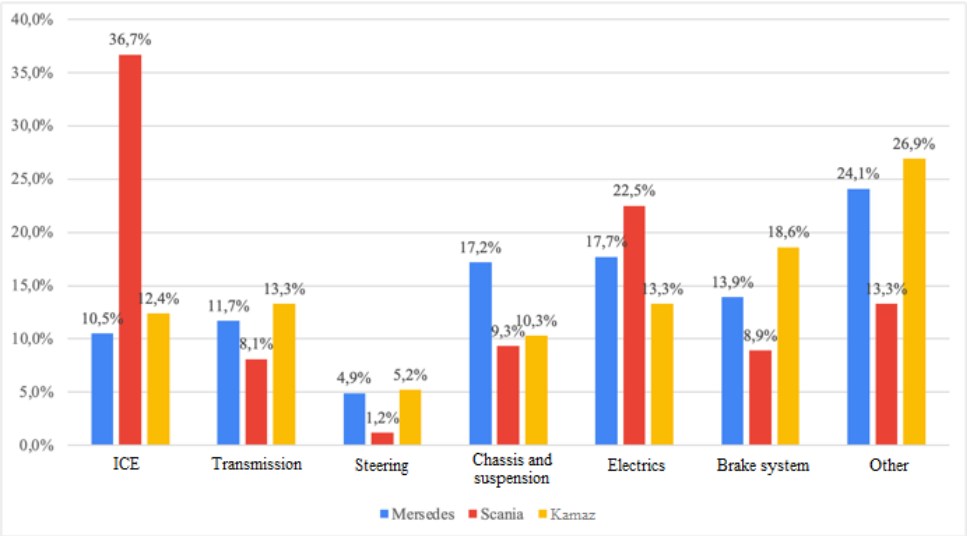

Fig. 2. Comparative histogram of the distribution of vehicle failure rates.

Studies of failures with respect to mileage showed the following dependence: the peak number of failures in all the considered cars falls on the mileage of 320-490 thousand km, while typical failures of vehicles are the following: SCANIA - failures of engine (36.4%), electrical equipment (21.8%), transmission (8.6%); KAMAZ - braking system (18.6%), electrical equipment (13.3%), transmission (13.2%); MERSEDES - chassis (17.2%), electrical equipment (17.7%), and braking system (13.9%). The assessment of failures and their elimination time allows to determine the least reliable components and assemblies of cars that require special attention when preparing the vehicle for trip.

Considering the available information about the vehicle fleet, as well as data obtained from additional equipment installed by us on vehicles, it allowed to accumulate information to describe the process and develop an algorithm for optimizing indicators that affect the cost and quality of transportation of agricultural products.

To determine the value of indicators of operational planning for the transportation of agricultural products, a model was built and studied in the AnyLogic simulation environment [7, 8]. The use of the simulation method allows to obtain a solution when changing input parameters, and also provides a detailed analysis of the system dynamics, considering changes in subsystems and environmental parameters, monitors all logical conditions and the nonlinearity of processes.

The structure of the model is shown in Figure 3, it consists of several interconnected blocks that describe the behavior of vehicles during the transportation of agricultural products.

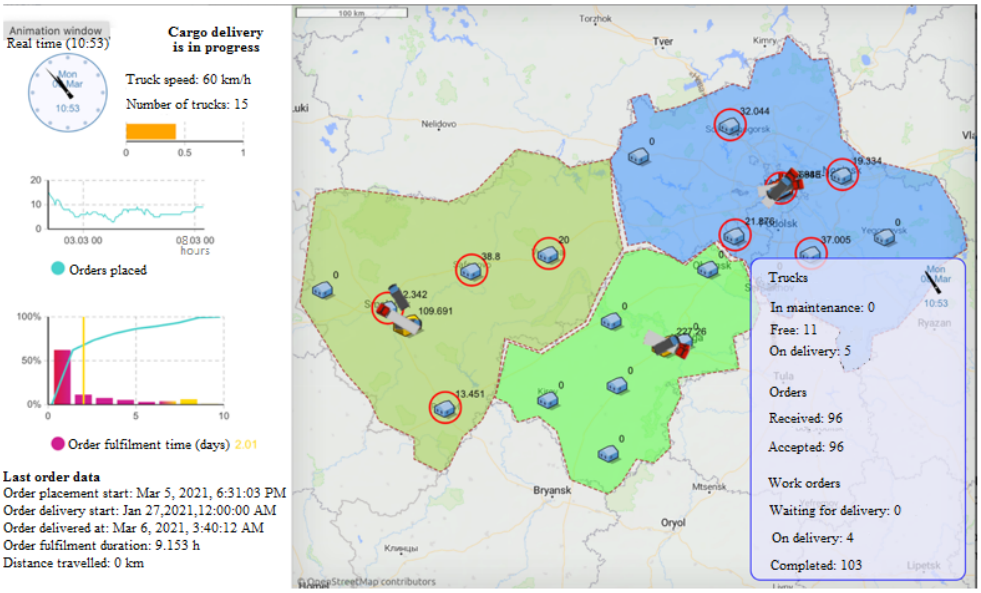

Fig. 3. The structure of the simulation model.

In general, the programming of the model blocks is reduced to a mathematical description of the operating cycles of vehicles with reference to the system time of the simulated process, considering the parameters. With the help of the developed model, the route is adjusted, the vehicle is selected considering the specifics of the cargo being transported, considering the vehicle reliability indicators. A comparison of the simulation results with the data obtained during operation shows the following trend, namely, a decrease in the duration of the route: from 1175 to 1139 km, from 653 to 630 km, from 169 to 134 km, depending on the transportation route, this effect averaged 20-60 km. The volume of cargo transported increased from 16 to 17.55 tons, from 16.7 to 17.8 tons, from 16.9 to 18.1 tons. Fuel costs decreased from 21337.00 rubles to 19828.00 rubles, from 11610.00 to 10595.00 rubles and 2180.00 to 2621.00 rubles, respectively.

The approbation of the developed methodology during the operation of vehicle fleet in the transport company "Technology of Movement" showed a decrease in the time to eliminate failures by 7%, a decrease in the costs associated with their elimination by 5%, resulting in a total cost savings of 10,299 thousand rubles. This economic effect allows TC "Technology of Movement" to receive additional resources for further development.

4 Conclusion

As a result of studying the issue of transportation of agricultural products, it was determined that the level of losses of vegetables and fruits during transportation ranges from 3% to 18% in the world, in Russia about 15-20% of fruit and vegetable products do not reach the consumer due to the poor quality of transportation. Downtime at loading and unloading points takes up to 50% of the time, which worsens the safety of products. It has been established that to control the conditions of transportation and the trouble-free operation of the vehicle during the transportation of agricultural products, it will be enough to integrate a control and information system and auxiliary monitoring sensors into the vehicle design, as well as configure the logic of constructing an algorithm for transmitting and receiving information about the vehicle condition. Based on the obtained research results, a simulation model (software and computing complex "Sapphire") has been developed for the automated

distribution of vehicles between agricultural producers and consumers, as well as the calculation of economic indicators for the transportation of agricultural products. The use of the developed methodology on the example of the functioning of the transport company "Technology of Movement" showed a reduction in the time to eliminate failures by 7% and a reduction in costs associated with their elimination by 5%, resulting in overall cost savings of 10,299 thousand rubles without reducing the quality of transported agricultural products.

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