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IMPROVING THE EFFICIENCY OF THE ROAD TRANSPORTATION PROCESS IN AGRICULTURAL PRODUCTION

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Abstract. *The article is devoted to the solution of a topical issue – improving the efficiency of the road transportation process on the basis of improving the methods of selecting vehicles for the transportation of certain agricultural cargo under the given operating conditions.*

It has been proved that a significant number of parameters influence the efficiency of road transportation in agricultural production. In addition to the generally accepted factors (costs of maintenance and fuels and lubricants), transportation conditions, cargo type, type of unloading and loading operations have a significant impact in agricultural production conditions.

It is proved that the variety of agricultural cargo within one farm encourages enterprises to form a universal vehicle fleet. As a result of the analysis of purchases of vehicles by agricultural enterprises, it has been determined that there are no stable approaches of enterprises to forming the vehicle fleet, which confirms the thesis of the influence of a large number of factors on the choice of vehicles for transportation in agricultural production conditions.

The approaches to the definition of the reserves for increasing the efficiency of the available vehicle fleet and to the formation of the optimal structure for certain operational conditions have been considered. The objective need for proper grounding of the choice of vehicle for the conditions of agricultural production, due to the need to take into account a large number of parameters that characterize both the vehicle and the cargo and transportation conditions.

In this context, the authors have proposed for practical use an algorithm for selecting a vehicle to perform specific transport work on the transportation of agricultural products, which takes into account the set of vehicles characteristics, cargo type, and transport

conditions. Attention has been drawn to the need for a systematic approach to the selection of transport vehicles estimation criteria in agricultural production. Taking into account the size of the bulk density, the availability of loading and unloading facilities, the peculiarities of transportation conditions, the amount of average expenses per unit of transport allows to comprehensively assess a single vehicle, optimize the choice of vehicle transportation of concrete agricultural cargo, minimize financial losses, thus, to increase the efficiency of the transportation process in agricultural production.

Consideration of the optimal list of vehicle parameters provided by the presented algorithm will increase the efficiency of the transport process in agricultural production, both by reducing operating costs and by saving cargo and time. The clear structure of the proposed algorithm, with a justification of each stage and the purpose of each step, certainty and discreteness make it easy to solve with available software.

Keywords: *algorithm; transportation process; transport work; transportation process optimization; evaluation criteria; road transport; agricultural cargo*

Introduction.

Active development of agricultural production in Ukraine in recent years has actualized the problem of effective use of all available productive resources in agricultural enterprises, including road transport. Ensuring the effectiveness of the transport process in road transport is a matter closely related to the satisfaction of consumer needs in agricultural products of good quality at a reasonable price, in a certain place and time. Therefore, properly organized transportation of agricultural products leads not only to economic but also general social benefits.

It is believed that fuel costs are a determining factor when selecting the vehicle, as their share in the cost of road transportation is significant. However, considering only one parameter when justifying the choice of the vehicle for a particular transport work is not correct, and this thesis is particularly relevant to the transportation of agricultural goods.

The variety of agricultural products that can be produced within one farm determines the heterogeneous vehicle fleet structure, and the seasonality of agricultural production causes the problem of optimum capacity utilization of road transport. In this aspect, managers of agricultural enterprises or their road transport units need to have a simple and clear tool for choosing the vehicle for particular transport work, taking into account all vehicle characteristics, transport conditions, and cargo type, which will improve the overall efficiency of the transport process.

Analysis of recent researches and publications.

The problem of improving the efficiency of the transportation process is always relevant for companies in various industries, so many researchers have devoted their work to this issue. We should separately mark the works in which the problems of transport support for agricultural enterprises are directly studied, because according to Verhun (2006), "timely transportation of goods in the process of production and sale of products significantly affects the whole process of expanded reproduction in agriculture".

Researchers propose various techniques that ultimately aim to increase the efficiency of the transportation process, both by reducing the cost of goods transportation through reducing operating costs and by increasing the productivity of the transportation process.

In particular, Zakharov & Rakytyn (2015) propose a methodology allowing the formation of the rational structure of vehicle fleet, which takes into account: possibility of using gas-powered vehicles or vehicles converted to operate on gas-diesel cycle; possibility of using vehicles, which have never been operated under specified conditions before and for which there are no statistics on operating costs.

As the criterion for justifying the required number of vehicles, a group of researchers (Kotelyanec, 1980; Burlai et al., 1993) chose the cargo turnover, which can be calculated by multiplying the volume of transported cargo in tons by the transported distance in a normative way – through technical-operational and economic indicators.

To improve the planning of agricultural production needs in motor transport, Kulev & Kazantsev (2008) propose a methodology for forming the optimal composition of the cargo vehicle fleet in agricultural enterprises based on the volume of cargo transportation for each type of agricultural product, taking into account the channels of sale and use.

In turn, Mihachev (2012) offers a universal system of relative coefficients of comparison by the criterion of "conditionally technical costs" for a rational choice of the rolling stock of trucks. The proposed methodology allows you to assess the effectiveness of various organizational and technical measures and thereby improve the efficiency of trucks' operations.

Thus, the main emphasis is on the formation of a rational structure of the vehicle fleet, including for agricultural producers.

However, today insufficient attention has been paid to optimizing the process of selecting a vehicle from the existing fleet to perform specific transport work with clearly defined conditions and parameters. The need to improve the efficiency of the transportation processes of agricultural products, and thus reduce the cost of transportation, requires consideration of a significant number of parameters and conditions of transportation when choosing a particular vehicle. The above methods do not fully take into account all parameters that are essential for the transportation of agricultural products, so it is necessary to improve and adapt them to the conditions of agricultural production.

Purpose. The purpose of the study is to improve the method for selecting the vehicle to perform specific transport work on the transportation of agricultural goods, which should increase the efficiency of the transport process by road, based on a set of vehicle characteristics, cargo type, and conditions of transportation.

Materials and methods of research.

General scientific and special methods of cognition were used for the analysis of the basic methods of increasing the efficiency of enterprises' motor transport use, and directly the transportation process. Static methods were used to determine general trends in the formation of the fleet of agricultural vehicles. Assessment of the basic principles of formation of the vehicle fleet, conditions and specifics of the organization of road transportation in agricultural production has been carried out using the methods of analysis, synthesis,

induction and deduction. The method of generalization is used to formulate conclusions about the existing methods of improving the efficiency of the transportation process in motor transport in the aspect of their application in agricultural production. The methods of system approach, algorithmization, and formalization have been applied in the formation of the algorithm of vehicle selection for performing specific transport work, under given operating conditions in agricultural production.

The object of this study is the process of improving the efficiency of the road transportation process in agricultural production. The subject of the research is the algorithm of vehicle selection for transportation of a certain agricultural cargo, which takes into account the set of vehicle characteristics and conditions of transportation.

Results of the research and their discussion.

Transport operations are an integral and price-forming factor in agricultural production. The main modes of transport here are road, tractor, and animal. They account for about 80%, 17%, and 3% of total turnover, respectively (State Statistics Service of Ukraine, 2020).

According to the State Statistics Service of Ukraine for the period 2018–2020, the largest share of total purchases by agricultural enterprises are vehicles with diesel and semi-diesel internal combustion engines with a payload capacity from 5 to 20 tons – from 39% in 2018 and up to 32% in 2020. Vehicles of this category with a payload capacity of 5 tons and less are about 30–35%. Vehicles with spark ignition reciprocating internal combustion engines in total purchases volume are from 5% (2018) to 1% (2020), their payload capacity is 5 tons or less (Table 1).

Analysis of vehicle purchases data showed that there is no stable trend of increasing or decreasing demand for a specific vehicle payload capacity or particular vehicle brands. Thus, in 2019, the purchase of vehicles over 5 tons and over 20 tons increased by almost 20% but already in 2020, the need for vehicles of this payload capacity has decreased.

On the contrary, the demand for vehicles with a payload capacity between 5 and 20 tons has decreased significantly in 2019, especially KAMAZ brand, compared to 2018, according to the statistics. We believe that instability of demand for certain types of road transport is due to the influence of a significant number of factors on agricultural activities.

In agricultural production, road transport operations take place both within the farm and outside. In addition to the final agricultural products, large volumes of seeds and planting material, various types of fertilizers (liquid, bulk, etc.), fuels and lubricants, etc. are moved over considerable distances. It should be noted that such movements can take place on field roads and sometimes off-road. Therefore, the formation of the vehicle fleet in agricultural enterprises takes into account the peculiarities of the industry, namely: seasonality, variety of goods, difficult road conditions, significant distances, a significant share of loading and unloading, recurrence of transportation, and more. These factors determine the special requirements for road transport support of agricultural enterprises, and it is especially important to properly justify the choice of vehicle for specific transport work.

When choosing vehicles or forming the structure of the vehicle fleet are used criteria that assess the various properties of the vehicle: performance, reliability, payload capacity, fuel consumption, tire

1. Purchase of trucks and spare parts by agricultural enterprises, by payload capacity, type, and brand for 2018–2020

No	Name	Quantity, pieces, by years			Deviation from 2020 to 2018 (+/-)
		2018	2019	2020	
1	With diesel and semi-diesel internal combustion engines	513	500	453	-60
1.1	With a payload capacity of 5 tons and less, of them:	153	177	147	-6
	GAZ	38	22	27	
	MAZ	x	x	6	-11
	ZIL, IVEKO	2	x	x	+6
	others	113	150	111	-2
1.2	With a payload capacity from 5 to 20 tons, of them:	200	141	145	-2
	ZIL	4	x		-4
	KAMAZ	71	37	37	-34
	MAZ	43	42	48	+5
	IVEKO	1	x	x	-1
	others	81	62	59	-22
1.3	With a payload capacity of more than 20 tons, of them:	160	182	161	+1
	IVEKO	4	x	x	
	others	156	182	161	+5
2.	With spark ignition reciprocating internal combustion engines, total	26	14	7	-19
2.1	With a payload capacity of 5 tons and less, of them	25	14	5	-20
	GAZ	13	9	x	-13
	others	12	5	5	-7
3.	Engines for trucks	322	218	139	-183
4.	Tires for trucks	95243	89507	85203	-100040

Source: compiled by the authors according to the State Statistics Service of Ukraine.

demand, spare parts consumption, engine life, etc. Therefore, it is necessary to approach the choice of the vehicle for the performance of concrete transport work from different perspectives, taking into account as many vehicle characteristics as possible.

Since a significant share in the cost of road transport belongs to fuel costs, it is considered that these costs are the determining parameter for the selection of the vehicle. However, when choosing the vehicle for a specific transport task it is not correct to consider only one parameter, it is important to consider all parameters together, because the lowest fuel consumption by vehicle does not always provide a minimum cost of transportation, espe-

cially in agricultural production. It is necessary to take into account the conditions of transportation, and the frequency and cost of vehicle maintenance.

It should be noted that modern vehicles with electronic control of basic systems and units, on the one hand, facilitate and accelerate the process of diagnosing faults and conditions of individual systems and mechanisms, and the vehicle as a whole but, on the other hand, their availability significantly increases the cost of maintenance and repair of such vehicles.

As has been repeatedly noted, the main parameters that have a significant impact on the cost of road transport under agricultural production conditions: fuel consumption per 100 km and its cost; maintenance costs; cost of consumables; the need for special equipment for loading and unloading; availability of special conditions for cargo transportation; the need for intermediate operations related to loading and unloading (Holovina & Mieniailova, 2021). Also, the costs should include the introduction of automated cargo movement control.

Because of the above, we propose the following algorithm for selecting a vehicle for a specific transport work, which will allow a comprehensive assessment of the vehicle's efficiency and its ability to transport a particular load under given operating conditions (Fig. 1).

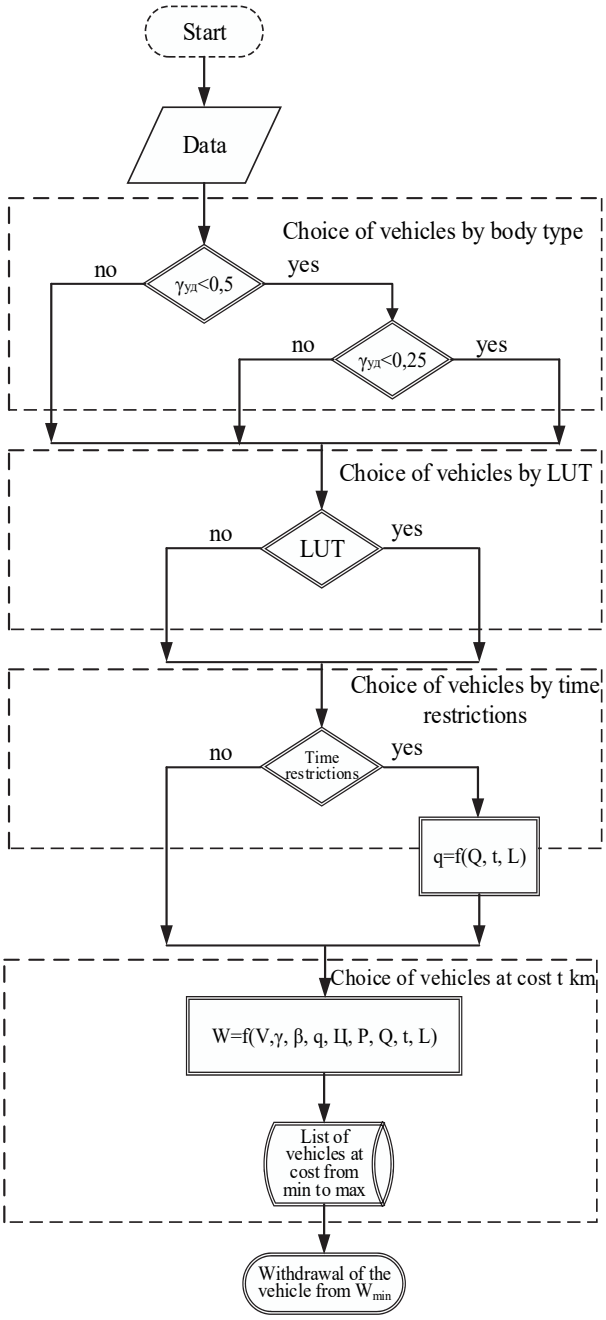
Most often, farmers need to transport bulk, dry bulk, and liquid cargo. Bulk goods include vegetables, coal, firewood, everything that can be transported without pre-packaging in bulk. Dry bulk goods include grains, and liquid cargo includes milk, liquid fertilizers, etc. This variety of cargo involves the use of different types of vehicle bodies for its transportation. Therefore, the first step is to select vehicles whose body type is most suitable for the transportation of particular cargo.

As the agro-industrial enterprises transport cargoes of various densities and compositions, the payload capacity of the vehicle cannot always be used completely in their transportation. One of the parameters that takes into account this difference between the cargo types, their specificity, and size, is its bulk density. To avoid underloading by weight, which leads to the increase in the cost of the transportation process, at the next step of the algorithm it is proposed to choose a vehicle taking into account the specific volume capacity, by comparing the nominal capacity to the full-body volume.

Practice proves that a significant part of the time is spent on loading and unloading in the transport service of agricultural production. Thus, according to scientist's estimates, the above-mentioned work accounts for 25–30% of labor costs and 17–22% of direct operating costs of total costs for production and sale of products, as well as 35–40% of petroleum products of agricultural enterprises (Vlasiuk, 2006).

Therefore, the next step in choosing the vehicle is to determine the need for the use of loading and unloading equipment. If such a need arises, it is necessary to find out how such work will be performed at loading and unloading points. At this stage, the information is needed on equipping the points with special trucks and if there is no such equipment, it is proposed to use vehicles with manipulators.

The presented algorithm takes into account the transportation of goods that require special conditions of transportation. Such cargoes include agricultural products that are raw materials for the food industry: milk, eggs, meat, vegetables, fruits, etc. For their transporta-



γ_{spec} – coefficient of specific payload capacity;
VE – vehicle
LUT – loading and unloading transport
q – capacity of the vehicle
Q – freight turn over
t – time on the route
L – length of the route
W – cost
V – average speed on the road
γ – load factor
β – loaded mileage proportion
P – price of fuel per 1 liter
P – fuel consumption per 100 km

Fig. 1. Algorithm for choosing the vehicle to perform transport work in agricultural production

Source: developed by authors.

tion it is necessary to use specialized transport, taking into account certain delivery times, transportability terms, temperature regime. A vehicle with an isothermal van or refrigerator is chosen depending on what kind of cargo needs to be delivered chilled or frozen. Therefore, the proposed algorithm takes into account the possibility of transporting goods that require special conditions of transportation (including fruits, berries, milk, etc.) for the transportation of which it is necessary to use specialized transport, taking into account delivery times, and temperature (Holovina & Mieniailova, 2021).

The last step is to allocate the selected vehicles in order of the costs increasing per unit of transport output, i.e. in order of the costs increasing of transport work. The cost is considered as a function of fuel costs, route length, vehicle speed, loading and unloading time, availability of empty mileage, maintenance and repair costs. The final choice is left to the vehicle that has the lowest cost. It should be noted that the use of the simplest MS Excel spreadsheet or software such as Mathcad will automate the performance of frequently repeated operations of the proposed algorithm, significantly reduce time, and minimize vehicle selection errors.

Conclusions and future perspectives of the study.

As a result of research, we can state that the vehicle in agricultural production should perform its function of transportation, ensuring, on the one hand, the minimum cost of transportation and, on the other hand, the safety of goods and their on-time delivery. To achieve this goal in the practical conditions of management, the algorithm for selecting the vehicle to perform transport work in terms of agricultural production is proposed.

The advantages of this algorithm are the ability to comprehensively evaluate a separate vehicle, which allows you to optimize the choice of the vehicle for the transportation of specific agricultural products under the given conditions. The proposed algorithm is easily suitable for automation based on the use of simple and accessible software tools, which will significantly increase the efficiency of the decision to choose the vehicle and avoid expensive mistakes and additional financial losses.

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Анотація. *Дослідження, що представлені в статті, довели, що на ефективність перевезень автомобільним транспортом в аграрному виробництві окрім загальноприйнятих чинників (витрати на технічне обслуговування та паливо-мастильні матеріали) суттєвий вплив мають умови перевезень, тип вантажу, вид розвантажувально-навантажувальних робіт.*

Аналіз закупівель сільськогосподарськими підприємствами автомобілів встановив відсутність стійких підходів щодо формування автопарку, що підтверджує тезу про вплив значної кількості чинників на вибір автомобілів для виконання транспортної роботи в умовах сільськогосподарського виробництва.

Розглянуті підходи до визначення резервів підвищення ефективності використання наявного автомобільного парку й до формування його оптимальної структури визначили об'єктивну необхідність належного обґрунтування вибору автотранспортного засобу саме для умов сільськогосподарського виробництва.

У цьому контексті авторами запропоновано до практичного використання алгоритм вибору автотранспортного засобу для виконання конкретної транспортної роботи з перевезення сільськогосподарських вантажів. Врахування в представленому алгоритмі величини об'ємної маси, наявності вантажно-розвантажувальних засобів, особливостей умов транспортування, розміру витрат, що припадають у середньому на одиницю продукції тран-

спорту дає можливість комплексно оцінювати окремо взятий автотранспортний засіб, оптимізувати вибір автомобіля для виконання перевезення конкретного сільськогосподарського вантажу, мінімізувати фінансові втрати й у такий спосіб забезпечити підвищення ефективності перевізного процесу в сільськогосподарському виробництві.

Беручи до уваги оптимальний перелік параметрів автотранспортного засобу, що передбачено представленим алгоритмом, можливо підвищити ефективність перевізного процесу в сільськогосподарському виробництві, як внаслідок зменшення експлуатаційних витрат, так і завдяки збереженню вантажів та витрат часу. Чітка структура розробленого авторами алгоритму, з обґрунтуванням кожного його етапу і, мети кожного кроку, визначеність і дискретність робить його придатним для рішення за допомогою доступного програмного забезпечення.

Ключові слова: *алгоритм; перевізний процес; транспортна робота; оптимізація перевізного процесу; критерії оцінки; автомобільний транспорт; сільськогосподарський вантаж*