Technological parameters for vehicles in the organization of cargo transportation in the agro-industrial complex

N V Yanykov, A N Smirnov, A I Volkov, D V Lukina and A V Mayorov
Mari State University, Yoshkar-Ola, Russia

E-mail: kafmeh@yandex.ru

Abstract. The result of the research conducted shows that cargo transportation is one of the components of successful activity and efficiency of the enterprise in the agro-industrial complex. The collected data have shown that economic efficiency is influenced by many process parameters. The data collected allowed to make a conclusion that. For the optimization of cargo transportation, the AIC needs careful choice of the number, type and brands of vehicles, taking into account the type of activity of the enterprise, its production volumes and range of cargo transportation. When collecting the data to choose the type and construction of motor vehicles with regard to the operating conditions it was found out that it is necessary to consider many parameters: the type of cargo, the nature and volume of transportation, the mode of operation of motor vehicles, organization of transportation, road and weather conditions. For this purpose, the following information was specified: necessary parameters of the cargo taking into account volume and weight, the choice diagram of the vehicle based on the properties of the cargo. The data received which were used for choosing are provided in tables and graphs. After choosing the type and the number of vehicles and determining the volume of transportation, one of the components of efficient use of vehicles is to optimize the transportation. Optimization of transportation is considered and provided in the form of mathematical formulas. Everything is presented as an example for one of the types of transportation. The issue studied and presented in this article is topical for the farms of the Mari El Republic in conditions of the market economy. That is why the data and calculations received are of practical application in the organization of cargo transportation in the agro-industrial complex enterprises and their optimization for maximum efficiency.

1. Introduction
The peculiar feature of the development of modern transportation is a large number of different types of vehicles used in the agro-industrial complex (AIC). The great increase in the number of cars on the roads leads to a decline in the effective and safe use of trucks. With a significant annual growth in the number of vehicles, the traffic capacity of the existing roads has not changed. This leads to traffic congestion and waste of time in traffic jams [1-4].

There is an economic loss associated with delays. All this is reflected in the increase in the cost of road transportation, the impossibility to implement the technology "just in time" in the conditions of uncertainty of the time of goods delivery, the increase in the ineffective time share in the work due to delays in traffic jams [5-7].

In this study we used the statistics of the Ministry of Transport of the Russian Federation and the Federal State Statistics Service in the Mari El Republic.
2. Experimental research
The experimental procedure includes the following: – collection of experimental data characterizing the mode of traffic movement; – the use of vehicle sensors and modern devices that measure and register the required parameters. Purely experimental research does not exist. In all cases, the definition of the objectives of the pilot study, formulation of hypotheses, construction of quantitative models, or justification of a hypothetical expected results of the experiment are performed theoretically and precede each of the experiments. Experiment planning, interpretation and explanation of its results, preparation of proposals on their practical use also belong to the field of theoretical research. The efficiency of the transport process is influenced by many factors: weight of cargo, volume of cargo; the distance travelled. In addition, it is necessary to establish the relationship of the studied parameters on the factors of transportation. For this purpose, it is necessary to classify clearly the parameters (indicators) which characterize these performance factors most objectively.

3. Results and considerations
The studies conducted served a basis for the solution of a new important scientific and practical task of improving the efficiency of the transportation process management.

The analysis of defining vessel volume depending on the cargo volume to its mass ratio.

Indicators of cargo transportation dependence on vehicle parameters to choose it.

A model of a traffic flow for delivery taking into account the location of the cargo receivers.

The developed method of optimal shortest route for the vehicle.

This reduces the travel time to 28%.

In the AIC one of the components of successful activity and efficiency of the enterprise is cargo transportation. Transportation can often be very expensive. Their economic efficiency is influenced by many process parameters, such as the type of transport used; the type of cargo - dangerous, within loading gauge, requiring special transport or special transportation conditions; the distance and travel time (for perishable products); the choice of the route and conditions for access, loading and unloading. All these process parameters, individually or in combination, significantly affect the cost of cargo transportation and economic efficiency.

The main feature of the AIC is the seasonality of production. The seasonality of cargo transportation is directly connected with the specialization of the economy. The seasonality of transportation is extremely intense in the farms focused on crop plants, less intense in the farms involved in cattle breeding and weak in the enterprises processing agricultural products. Such seasonality causes an uneven load on the cargo transportation. The irregularity of transportation in the AIC of the Mari El Republic is also expressed during years and it directly depends on the number of products produced by the agricultural enterprises.

For the optimization of cargo transportation, the AIC needs careful choice of the number, type and brands of vehicles, taking into account the type of activity of the enterprise, its production volumes and range of cargo transportation.

To choose the type and construction of motor vehicles with regard to the operating conditions it was found out that it is necessary to consider many parameters: the type of cargo, the nature and volume of transportation, the mode of operation of motor vehicles, organization of transportation, road and weather conditions. Parameters of operating conditions are presented in table 1.

| Table 1. Parameters of operating conditions of the road transport. |
|---------------------------------------------------------------|
| Parameters | Main factors determining the parameter                     |
| Type of cargo | 1. Cargo transportability                                |
|             | 2. Physical properties (condition)                        |
|             | 3. Vehicle dimensions                                    |
|             | 4. Nature of packaging (containers)                       |
|             | 5. Bulk density (weight)                                  |
| Traffic volume | 1. Cargo turnover and traffic volume                      |
|             | 2. Distance of transportation                             |
The factors of operating conditions of road transport in its entirety or separately influence the specific parameters (indicators) of the car ensuring the compliance with the operating conditions when choosing the vehicles.

The type of cargo influences the choice of parameters and the body type of vehicles. The cargo has different classification according to the characteristics presented in Table 2.

Cargo bulk density ($\delta$) is measured in the same units as the rated cargo-carrying capacity of the rolling stock ($t/m^3$) and determines the choice of reasonable correlation between body volume ($V$) and nominal cargo-carrying capacity of the vehicle. It is presented on the graph in Figure 1.

The more the cargo bulk density, the less the body volume and vice versa with the decreasing bulk density the vehicle requires an increased body volume with a relatively small cargo-carrying capacity. The bulk density of cargo carried in the general purpose dropside platforms influence the choice of reasonable size of dropside platforms of the vehicles based on platform length and area ratio at a certain cargo-carrying capacity of the vehicle. The ratio is presented in Table 3.

![Figure 1. Dependence of the body volume and the nominal cargo-carrying capacity on the cargo density.](image-url)
Table 2. Cargo classification

| Classification criterion                                | Cargo characteristics                          |
|---------------------------------------------------------|-----------------------------------------------|
| Physical properties                                     | Solid                                         |
|                                                         | Liquid (semi-liquid)                          |
|                                                         | Gaseous                                       |
| Mode of transportation and loading and unloading        | Bulk                                          |
| (type of packaging)                                     | In-container and single-piece                 |
|                                                         | Liquid                                        |
| Body type                                               | Transportation in the general purpose body     |
|                                                         | (dropside)                                    |
|                                                         | Specialized bodies (tank cars, dump trucks,   |
|                                                         | etc.)                                         |
| Cargo bulk density (determines cargo-carrying capacity)| Heavy                                         |
|                                                         | Average weight                                |
|                                                         | Light                                         |
| Number of simultaneously transported cargo              | Mass (large lots for a long time)             |
|                                                         | Shot lots                                     |
| Urgency of transportation                               | Transportation in a very short time (perishable)|
|                                                         | Transportation can be for a long term.         |

Table 3. The dimensions of the dropside platforms of the vehicles.

| Nominal cargo-carrying capacity, t | Internal area, m² | Internal width, mm | The recommended height of the sides, mm |
|------------------------------------|-------------------|-------------------|----------------------------------------|
| 1                                  | 4.7               | 1.840             | From 400 to 500                         |
| 1.5                                | 5.6               |                   |                                        |
| 3                                  | 7.6               | 2.200             | Up to 700                              |
| 5                                  | 10                | 2.420             | From 500 to 800                         |
| 8                                  | 12.1              |                   |                                        |
| 10                                 | 13.5              |                   | From 500 to 850                         |
| 12                                 | 14.7              |                   |                                        |

The dropside platforms are available in three sizes: normal length to transport the cargo of different density, shortened to transport heavy cargoes with a density of up to 3...3.5 t/m³ and elongated to transport light cargo with a density of 0.2...0.35 t/m³.

The scale of transportation has a significant influence on the choice of the vehicle type taking into account its cargo-carrying capacity and on the structure of the vehicle park. The main indicator is the traffic volume for a certain time and completed work measured in ton-kilometers (cargo turnover). The ratio of cargo turnover to the traffic volume determines the average distance of cargo transportation \( l = \frac{P}{Q} \), where \( P \) is cargo turnover for a period under consideration, thou. km; \( Q \) is a traffic volume for the same period, t.

The number of tons of the cargo transported in the forward \( Q_{\text{for}} \) and backward \( Q_{\text{back}} \) directions define the cargo traffic: \( Q_{\text{for}} + Q_{\text{back}} = Q \).

After choosing the type and the number of vehicles and determining the volume of transportation, one of the components of efficient use of vehicles is to optimize the transportation. This is acute for the farms of the Republic in the conditions of market economy.

When designing the optimal cargo traffic, the conditions having a significant impact are the frequency of cargo acquisition, the availability of interlinked production facilities, their location and
limitations in their traffic capacity. In the AIC there are three types of companies that form the cargo transportation:

- seasonally produced and consumed goods, e.g. grain, involve the following objects: field, barn-floor, and grain reception centre.
- seasonally produced and consumed all year round goods, e.g. feed, involve the following objects: field, warehouse, livestock farm.
- produced all year round and consumed seasonally goods, e.g. mineral fertilizers, involve the following objects: railway warehouse, remote warehouse, field.

Take the example of seasonal goods – the grain. When calculating optimization of cargo transportation, we use the following indexing of the production facilities where: "k" is a consuming object (grain reception centre); "j" is an intermediary object (barn-floor); "i" is an initial cargo-handling point (field). Let's take this example to consider the variant to solve and design the optimal cargo traffic in the related objects of agriculture. On the territory of the Republic there are fields, barn-floors, and grain reception centres. We know the capacity of each object; the need of the grain reception centers in grain; methods of grain harvesting and transportation; the distances, the cost of harvesting and transporting of 1 ton of grain. You need to determine the optimal cargo traffic between the related objects using the optimality criteria which is the minimum reduced cost for grain harvesting and transportation in the required amount.

Let's introduce the legend: i (i = 1;2;......I) is a field number; j (j = 1;2;......J) is a barn-floor number; k (k = 1;2;.... K) is a grain reception centre number l (l = 1;2; ...L) is the number of the method of harvesting and transportation of grain. We have ai is the capacity of the i –th field (the capacity of working combines); bj is the capacity of the j –th barn-floor (the capacity of grain cleaning and handling units), ak is the need of the k –th consumer in grain.

The transportation of grain is possible from the i-th field to the j-th barn-floor; from the i-th field to the k-th user. Transportation from the j-th barn-floor to the i-th fields is prohibited.

Let $X_{i.j}$ is the volume of grain transportation from the i-th field to the j-th barn-floor by l-th method; $X_{k.j}$ is the volume of grain transportation from the j-th barn-floor to the k-th consumer by the l-th method; $X_{i,k}$ is the volume of grain transportation from the i-th field to the k-th consumer by the l-th method $C_{i,j}$ is the reduced costs of harvesting and transporting of 1 ton of grain from the i-th field to the j-th barn-floor by the l-th method $C_{j,k}$ is the reduced costs of transporting grain from the i-th field to the k-th consumer by the l-th method $C_{i,k}$ is the reduced costs of transporting grain from the j-th barn-floor to the k-th consumer by the l-th method.

The target function $R(π)$ is the sum of the reduced costs in the amount of the annual demand of the Republic, i.e.

$$R(π) = \sum_{i,j,l} C_{i,j,l} \cdot X_{i,j,l} + \sum_{i,k,l} C_{i,k,l} \cdot X_{i,k,l} + \sum_{j,k,l} C_{j,k,l} \cdot X_{j,k,l}.$$  (1)

Limitation on the capacity $a_i$ of the combines:

$$\sum_{j=1}^{J} \sum_{i=1}^{I} X_{i,j,l} + \sum_{k=1}^{K} \sum_{l=1}^{L} X_{i,k,l} \leq a_i .$$  (2)

The conditions of satisfying the k-th user in grain that is delivered there both from the i-th field and the j-th barn-floor:

$$\sum_{j=1}^{J} \sum_{i=1}^{I} X_{i,k,j} + \sum_{j=1}^{J} \sum_{i=1}^{I} X_{i,j,k} \geq a_k .$$  (3)
The conditions of inbound and outbound grain balance for the \( j \)-th barn-floor (all grain delivered with the \( i \)-th field to the \( j \)-th barn-floor must be transported to the consumer):

\[
\sum_{i,l} X_{i,j,l} = \sum_{k,l} X_{j,k,l}.
\]  

(4)

Limitation on the capacity of barn-floor:

\[
\sum X_{i,j,l} = b_{j}.
\]  

(5)

Nonnegativity constraints of the variables:

\[
X_{i,j,l} \geq 0, \quad X_{i,k,l} \geq 0, \quad \sum_{k,l} X_{i,k,l} \geq 0.
\]  

(6)

The resulting model is a general linear programming problem in which it is necessary to minimize the functional (1) under conditions (2-6). The number of variables equal to the sum:

\[IJI + JKL + JKL.\]

As you can see, this task by its nature is close to the practical activities on the arrangement of cargo transportation for suppliers and consumers.

4. Summary

The results of the studies of cargo traffic allowed to assess and identify the most problematic areas in cargo transportation in the field of the AIC.

1. The results of experimental studies confirmed the nature of dependencies of choosing the vehicle on the kind of transported cargo.

2. The regularities of the experimental studies allowed to develop a model of the routes taking into account transportation efficiency.

References

[1] Zhang H 2015 Field Crops Research 215 1-11
[2] Manzeke M G et al 2017 Field Crops Research 213 231-44
[3] Zuber S M 2017 Soil and Tillage Research 174 147-55
[4] Manatt R K 2013 Environ. Res. Lett. 8 035037
[5] Maheshwari M et al 2017 The Indian Nitrogen Assessment 175-86
[6] Cao X 2015 Ecological Indicators 55 107-17
[7] Martín-Romero A et al 2017 Agricultural Water Management 192 58-70