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ПОВЫШЕНИЕ ЭФФЕКТИВНОСТИ ГРУЗОПЕРЕВОЗОК АВТОМОБИЛЬНЫМ ТРАНСПОРТОМ

Аннотация: *Настоящая статья посвящена математическому моделированию воздействия факторов, организующих систему, на повышение эффективности перевозки тяжеловесных и (или) крупногабаритных грузов автотранспортом.*

Ключевые слова: *тяжёлые грузы, крупногабаритные грузы, автотранспорт, эффективность перевозки, математическое моделирование, факторы системы, транспортная логистика.*

INCREASING THE EFFICIENCY OF CARGO TRANSPORTATION BY ROAD TRANSPORT

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Abstract: *This article is dedicated to the mathematical modeling of the impact of system-organizing factors on improving the efficiency of transporting heavy and/or oversized cargo by road transport.*

Keywords: *heavy cargo, oversized cargo, road transport, transportation efficiency, mathematical modeling, system factors, transportation logistics.*

The article discusses the mathematical modeling of various systems, methods, and factors for the efficient transportation of heavy and large-sized cargo by road transport. The main goal is to analyze the interaction of these factors and find ways to optimize them in order to increase transportation efficiency. To enhance the effectiveness of transporting large and heavy cargo (oversized cargo), it is necessary to consider all factors comprehensively and identify the interdependencies between factors and parameters. Additionally, it is important to assess the contribution of each factor that constitutes the system to the overall transportation cost. In accordance with the objectives of this work, the relevant criteria that make up the system are discussed below.

Dimensions and Weight of Cargo: Heavy and large-sized cargo requires special transport vehicles and road infrastructure. To efficiently transport such cargo, the performance characteristics of the transport vehicles and the restrictions they impose must be taken into account.

Road Infrastructure: The quality and specific characteristics of the road (e.g., road width, load-bearing capacity, and gradients) affect transportation efficiency. In mathematical models, the suitability of the road for transporting the cargo is also considered.

Transport Vehicles and Technical Specifications: The capacity of vehicles to carry large and heavy loads, the load distribution on the transport axles, and the necessary safety measures need to be considered.

Logistics and Transportation Organization: Optimizations in the transportation process, cargo storage, transport routes, and management systems for time savings are examined.

To track the interdependencies between the factors and determine their relationships, a mathematical model of the factors constituting the exploitation-technological system was developed. This model describes the impact of these factors on the efficiency of transporting large and heavy cargo. In the discussed model, the efficiency criterion (Q) for transporting large and heavy cargo (oversized cargo) is presented, which can be expressed as a mathematical model showing the effect of the factors that constitute the system on the efficiency of transportation. This model is represented as a function depending on a limited number of factors (n) and demonstrates the impact of these factors on the final transportation cost.

$$Q=f(x_1,x_2,x_3,x_4\ldots\ldots x_n) \quad (1)$$

x_1 – The actual mass of the vehicle (road train) with cargo, in tonna

x_2 – Actual axle load, t/axle. This is determined taking into account the number and type of axles, the distance between them, and the placement of the cargo on the semi-trailer(trailer)

x_3 – Dimensions of the vehicle (road train) with cargo: length, width, height;

x_4 – Route length, km.

x_5 – The permitted axle loads on the route, which depend on the road category, the calculated axle load for these roads, and the presence of temporary restrictions;

x_6 – Artificial structures on the route (bridges, underpasses, railway crossings, and others);

$x_7 \ldots x_n$ – Other factors affecting transportation efficiency

Based on the analysis of the selected model, it can be concluded that the key factors influencing the efficiency of such transport operations are: the characteristics of the vehicle (or road train) with respect to the cargo, such as the number of axles, their mutual arrangement, the actual axle loads, the mass of the vehicle with the cargo (or vehicles), as well as the dimensions of this vehicle and its direction of movement. The direction is chosen based on available options, considering factors such as the category of the roads, the type of road surface, the existence of temporary (seasonal) restrictions, and the presence of artificial structures and toll sections on the roads.

Without taking into account the main variable costs (C), depreciation deductions, and expenses for lubricants and cleaning materials, the total costs for transporting large and/or heavy cargo via roads can be expressed as the sum of the following costs (formula 2.6): compensation for damage caused by the road transport, fuel costs (usually diesel fuel is used for transporting heavy cargo), the costs of using standard sealing machines, compensation for damage on federal roads of national importance, and toll costs through the "Platon" system [19, 59]. Additional variable costs are determined separately for each case, and their calculation is carried out by specialized organizations. Therefore, this study does not aim to optimize these costs further, which allows us to treat these additional costs as a constant value.

$$C = \sum_{i=1}^{5} C_i \qquad (2)$$

Here, C1 refers to the costs associated with compensating for damage when increasing the maximum permissible mass of a vehicle (or road train) on the roads of the Republic of Uzbekistan, measured in millions of Uzbek soums.

The costs C1 and C2 are determined for each road section based on the appropriate method for calculating the amount of damage caused by the transport vehicles (specifically, those engaged in heavy cargo transportation). There are specific methods for regional and local roads, and based on these methods, the damage compensation cost for every 100 km of road is determined. Typically, these calculations are simplified using special collection tables, especially when the total mass and axle loads increase by 60%. For large and/or heavy cargo transportation, federal roads are mainly used because they are designed to accommodate higher axle loads compared to regional and local roads.

Most regional roads are designed for a maximum axle load of 10 tons, while roads with paved surfaces for passing must not exceed 6 tons per axle. Federal roads, on the other hand, are usually designed for axle loads of 10 tons, and in some cases, they can handle up to 11.5 tons per axle. It is also important to note that regional and local roads should be closed for drying in April, which reduces the permissible maximum axle loads (usually by half), leading to a significant increase in the cost of transporting goods with increased axle loads.

In the territory of the Republic of Uzbekistan, the maximum permissible mass for vehicles (road trains) with six axles or more, including tractors and trailers, may be up to 44 tons. For large and/or heavy cargo, the mass of the vehicle with or without cargo is specified in the special permit and is calculated based on the following formulas:

In this case

- m_b – the mass of the road train without cargo,
- m_c – the loaded mass of the road train,
- m_{ct} – the mass of the fully equipped tractor,
- m_{cp} – the maximum mass of the fully equipped semi-trailer,
- m_y – the mass of the indivisible cargo.

The amount of damage caused on federal roads when exceeding the permitted maximum mass and axle loads can be calculated using the following formulas (1 – 5).

The fee paid to compensate for the damage caused by transport vehicles when transporting heavy cargo via roadways is calculated separately for each road section, and this section corresponds to the direction of the vehicle.

$$k = m_c - m_{retvm} \quad (3)$$

In this case: m_r – the permitted vehicle mass.

When the total mass increases, the fee for damage compensation (P_{pm}) for the road section is calculated as follows:

$$P_{pm} = S \cdot T_{tg} \cdot R_{pm} \cdot K \quad (4)$$

Here:

P_{pm} – The amount of damage caused when increasing the permitted vehicle mass, set for the given road section;

S – The length of the road section (in hundreds of kilometers);

Base compensation index – The current year's base compensation index, equal to 1.8136;

K – This value is equal to 0.6.

When the permitted axle loads are increased, the fee for damage compensation (P_{pm}) for the road section is calculated as follows:

$$P_{o'q} = S \cdot T_{tg} \cdot i_{o'q} \cdot P_i \cdot K \quad (5)$$

Where: $i_{o'q}$ – The number of axles of the vehicle (TV) with the same excessive load;

P_i – The amount of damage caused as a result of exceeding the permitted axle loads of the vehicle (TV), determined for the chosen road section.

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