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DATA JUSTIFICATION FOR FORECASTING FUEL CONSUMPTION BY VEHICLES DURING THE GRAIN CROPS DELIVERY

The paper provides a justification of data for forecasting fuel consumption by vehicles during the transportation of grain crops from agricultural enterprises to the elevator. In order to obtain knowledge about the influence of the peculiarities of providing transport services and the conditions of using vehicles on the specific fuel consumption, regularities have been established and correlations between individual sets of data have been identified. To analyze data regarding the use of vehicles during the transportation of grain crops and to obtain additional information, a database containing 14140 instances of data on orders for the delivery of grain crops from agricultural enterprises to the elevator was used.

Factor analysis was performed and trends in the change of indicators characterizing these orders were identified. The analysis showed that the specific fuel consumption during the transportation processes of delivering grain crops from agricultural enterprises to the elevator is determined by a multitude of specific factors. Additionally, each order for the delivery of grain crops from agricultural enterprises to the elevator has its own specifics.

The results revealed the following relationships between specific fuel consumption and identified factors: the specific fuel consumption indicator is influenced by the location and method of vehicle loading, the vehicle model, the type of cargo, distance, cargo turnover and cargo volume. The identified dependencies allow for the preparation of a dataset and the correct interpretation of the results of machine learning models' work in order to increase the efficiency of their forecasting.

Key words: specific fuel consumption, transportation process, transportation of grain crops, factor analysis, machine learning

INTRODUCTION

Nowadays, transportation enterprises offer their services considering market conditions characterized by fuel shortages and high costs. Fuel expenses in the provision of transportation services during the delivery of grain crops from agricultural enterprises to the elevator are the primary resource determining the cost of these services [1-3]. Therefore, forecasting fuel consumption by vehicles during such deliveries is highly relevant today. Its resolution demands modern approaches that consider the factors and capabilities of individual transportation enterprises.

Some transportation enterprises providing cargo transportation services, including the delivery of grain crops from agricultural enterprises to the elevator, maintain their own databases regarding their activities in previous years [4]. Intelligent analysis of this data serves as one of the primary sources of knowledge about the peculiarities of providing transportation services and the conditions of vehicle usage.

ANALYSIS OF THE RECENT RESEARCH AND PROBLEM STATEMENT

There are numerous studies describing the influence of factors on the specific fuel consumption of cargo vehicles [1-3; 5-6]. Furthermore, there are studies reflecting the peculiarities of the transportation process of delivering grain crops [1; 6]. However, the use of modern approaches for forecasting specific fuel consumption involves the use of large databases describing transportation processes at specific enterprises. Among such approaches, machine learning methods are particularly relevant now [7-9]. Forecasting specific fuel consumption using machine learning methods allows for establishing regularities and identifying relationships between data. However, the application of these methods requires preprocessing and analysis of data, which involves identifying patterns and key influencing factors on the target variable (specific fuel consumption by vehicles in individual orders for the delivery of grain crops from agricultural enterprises to the elevator). This, in turn, significantly speeds up the process and allows more accurate forecasting results [10]. Therefore, there is a need to conduct an analysis of data characterizing the execution of individual orders for the delivery of grain crops from agricultural enterprises to the elevator regarding the provision of transportation services by the enterprise.

AIM AND THE TASKS OF THE RESEARCH

This study aims to establish patterns and identify relationships between individual data attributes to gain insights into the impact of the characteristics of providing transportation services and the conditions of vehicle use on specific fuel consumption.

The following tasks have been formulated to achieve the goal:

1)to conduct a statistical analysis of data characterizing the execution of individual orders for the delivery of grain crops from agricultural enterprises to the elevator regarding the provision of transportation services by the enterprise.

2)to perform factorial analysis and identify trends in the change of specific fuel consumption depending on the brand, cargo type, distance, and cargo turnover.

RESULTS OF RESEARCH

For the intelligent analysis of data regarding the use of vehicles during the delivery of grain crops from agricultural enterprises to the elevator and extracting knowledge from them, we utilized a database of an enterprise that owns its own fleet and provides services for delivering grain crops from agricultural enterprises to elevators.

Factorial analysis was performed with a database of 14140 instances characterizing the execution of individual orders for the delivery of grain crops from agricultural enterprises to the elevator, and trends were identified. A histogram of the number of orders (Figure 1) for the delivery of grain crops from agricultural enterprises to the elevator by types of cargo was constructed (Figure 2). The majority of all orders have been established for transporting wheat – 7316 orders (51.74%). Additionally, rapeseed was transported in 4213 orders, which constitutes 29.79% of the total.

All other types of cargo, characterizing the sample for the delivery of grain crops from agricultural enterprises to the elevator, accounted for less than 5%.

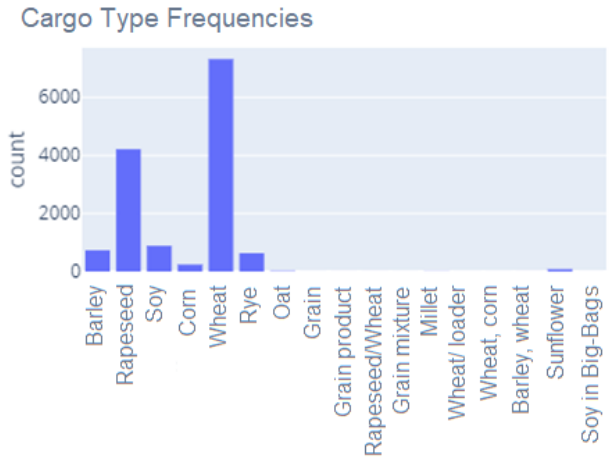

Figure 1 – Histogram of the number of orders for the delivery of grain crops from agricultural enterprises to the elevator by types of cargo

Based on the analysis of the obtained data, a histogram of specific fuel consumption by vehicles has been constructed for the execution of individual orders for the delivery of grain crops from agricultural enterprises to the elevator (Figure 3).

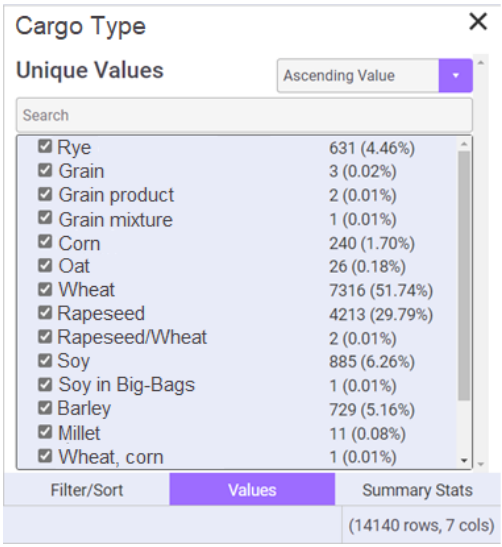

Figure 2 – Characteristics of orders for the delivery of grain crops from agricultural enterprises to the elevator by types of cargo

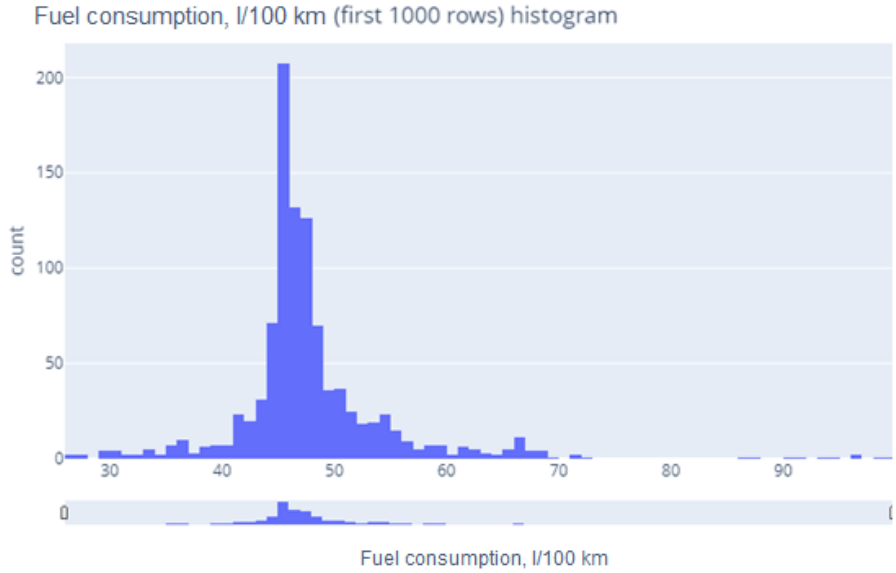

Figure 3 – Histogram of specific fuel consumption by vehicles for the execution of individual orders for the delivery of grain crops from agricultural enterprises to the elevator

Based on the obtained histogram, it can be observed that the specific fuel consumption by vehicles for the execution of individual orders for the delivery of grain crops from agricultural enterprises to the elevator varies in a wide range – from 16.9 liters/100 km to 99.7 liters/100 km. Although according to the technical specifications of the vehicles used, this range should be from 18.2 liters/100 km to 29.7 liters/100 km.

In the vast majority of cases, during the execution of individual orders for the delivery of grain crops, this indicator is significantly higher. The indicators of normative and actual specific fuel consumption by vehicles have been compared for the execution of individual orders for the delivery of grain crops from agricultural enterprises to the elevator (Table 1).

Table 1 – Comparative indicators of normative and actual specific fuel consumption by vehicles during the execution of individual orders for the delivery of grain crops from agricultural enterprises to the elevator

№	Brand and model of vehicle (engine)	Specific fuel consumption, liters/100 km		
		Normative	Actual	
			minimum	maximum
1	DAF 85.300 (WS295M)	21,8	29,5	96,2
2	DAF 95.380 (279 kW)	21,4	27,8	89,8
3	DAF CF85 (316 kW)	20,0	27,1	93,75
4	DAF CF85.410 (301 KW)	21,0	27,4	71,7
5	DAF CF85.430 (316 kW)	20,0	18,4	73,14
6	DAF FT CF 85.410 (301 KW)	21,0	21,97	98,8
7	DAF FT XF 105 (340 kW)	22,4	16,8	97,7
8	DAF FT XF 105.410 FTXF (300 kW)	22,3	45,5	60,8
9	DAF FT XF 105.460 (340 kW, 12 automatic transmission)	20,6	20,3	98,2
10	DAF FT95.430 (W5315M)	24,7	34,97	82,4
11	DAF XF 105.460 FTXF (340 kW)	22,4	30,2	88,5
12	DAF XF95.480 (355 kW)	22,9	32,4	99,7
13	Freightliner FLC-120 (Detroit Diesel S60, 351 kW)	29,7	35,1	69,3
14	Mercedes-Benz Atego818 (175 kW)	18,2	17,1	23,3
15	KAMAZ 45143-012-15 (KamAZ 740.31 240, 176 kW)	26,0	27,8	98,6
16	MAZ 543205-020 (6581.10)	24,4	23,7	67,8
Range of variation		18,2…29,7	16,8…45,5	23,3…99,7
Exceeds normative values, times		–	0,75…2,04	1,28…4,76

The obtained indicators provided in Table 1 indicate that the minimum actual specific fuel consumption by vehicles ranges from 16.8 to 45.5 liters per 100 km, while the maximum actual specific fuel consumption during the execution of individual orders for the delivery of grain crops from agricultural enterprises to the elevator ranges from 23.3 to 99.7 liters per 100 km. In the majority of cases, the minimum actual specific fuel consumption by vehicles exceeds the normative values, while the maximum values exceed them by 1.28 to 4.76 times. However, there are individual orders where the actual minimum specific fuel consumption by vehicles (DAF FT XF 105, Mercedes-Benz Atego818, and DAF FT XF 105.460) is lower than the normative values.

Further analysis of the data describing orders with maximum specific fuel consumption by vehicles revealed that the main reasons for the significant increase in specific fuel consumption by several times include the prolonged operation of the vehicle during direct harvesting from the field and the minimal distance for order execution (up to 17 km).

Regarding the specific fuel consumption by individual brands and models of vehicles during the execution of individual orders for the delivery of grain crops from agricultural enterprises to the elevator, it also varies (Figure 4).

The variation in specific fuel consumption has been observed among different brands and models of vehicles involved in the transportation processes during the execution of orders for delivering grain crops from agricultural enterprises to the elevator. Specifically, the smallest range of variation in specific fuel consumption is observed for deliveries of grain crops by Mercedes-Benz Atego818 trucks, amounting to 6.2 liters per 100 km or 36.25%. Meanwhile, for deliveries of grain crops by DAF FT XF 105 trucks, the largest range of variation in specific fuel consumption is observed, amounting to 80.9 liters per 100 km or 481.5%.

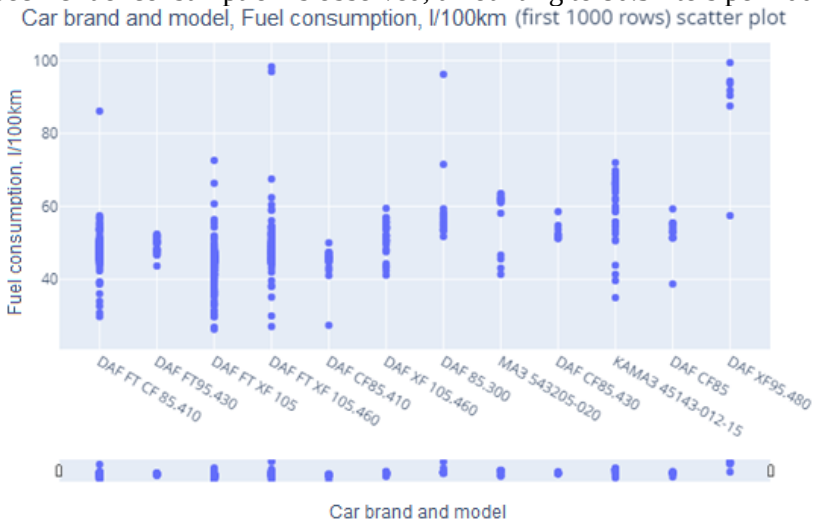

Figure 4 – Range of variation in specific fuel consumption by different brands and models of vehicles during the execution of individual orders for the delivery of grain crops from agricultural enterprises to the elevator

The trends in specific fuel consumption by vehicles during the delivery of various grain crops from agricultural enterprises to the elevator have been analyzed (Figure 5).

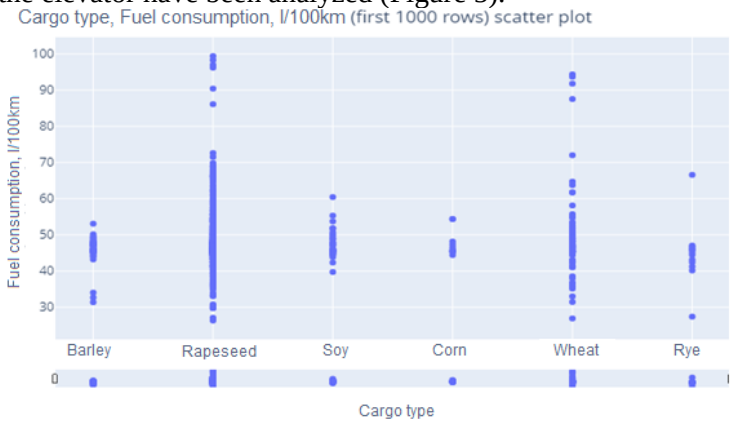

Figure 5 – Range of variation in specific fuel consumption by vehicles during the delivery of different grain crops from agricultural enterprises to the elevator

The smallest range of variation in specific fuel consumption is noted for corn delivery, whereas the largest range is observed for rapeseed and wheat delivery. This is mainly associated with the harvesting technologies of these grain crops. Specifically, the delivery of these grain crops from grain flows at agricultural enterprises to the elevator results in the lowest specific fuel consumption. However, when vehicles transport grain crops directly from the fields after harvesting, these fuel consumption rates significantly increase. This is due to multiple loading of vehicles in various parts of the fields and the operation of vehicles in low gears. In some cases, vehicles operate full shifts in fields with periodic relocations, leading to a significant increase in fuel consumption. Additionally, the condition of roads, which are often in poor condition in field conditions, also significantly affects fuel consumption.

The trends in specific fuel consumption by vehicles over different distances for the delivery of grain crops from agricultural enterprises to the elevator have been analyzed (Figure 6).

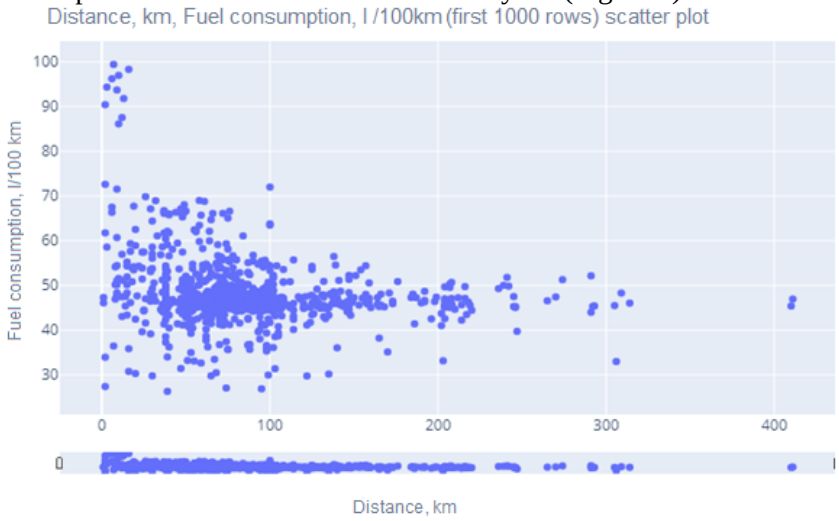

Figure 6 – Trends in the variation of specific fuel consumption by vehicles for different total delivery distances of grain crops from agricultural enterprises to the elevator

The analysis of various total delivery distances revealed that the highest specific fuel consumption by vehicles occurs for orders with short delivery distances of different grain crops from agricultural fields to the elevator. In general, all transport orders are executed within a distance of up to 100 km. As the transportation distance of grain crops increases, the range of variation in specific fuel consumption by vehicles decreases. For total distances of 150 km and more, the range of variation in specific fuel consumption by vehicles remains unchanged, indicating that the distance has no influence on fuel consumption.

Similar trends are observed regarding the variation in specific fuel consumption by vehicles for different cargo turnover rates during the delivery of grain crops from agricultural enterprises to the elevator (Figure 7).

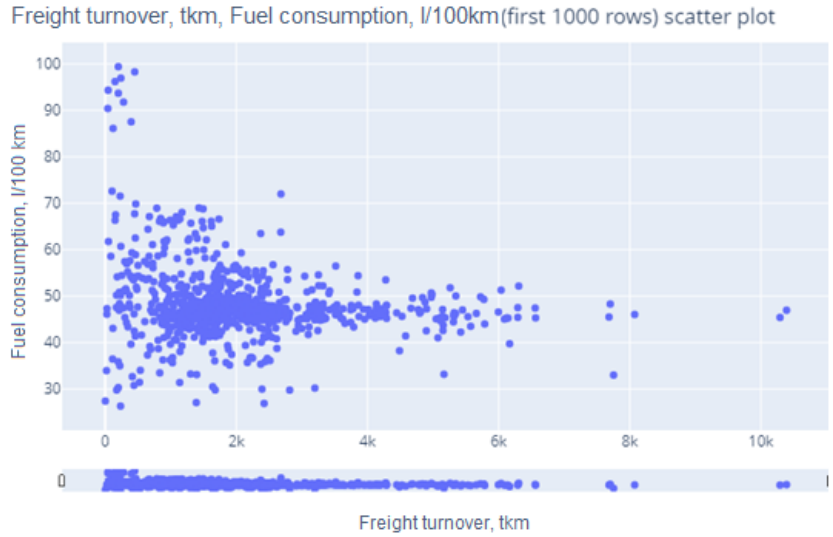

Figure 7 – Trends in the variation of specific fuel consumption by vehicles for different cargo turnover during the delivery of grain crops from agricultural enterprises to the elevator

The trends in the variation of specific fuel consumption have been analyzed by vehicles for different cargo volumes in individual orders for the delivery of grain crops from agricultural enterprises to the elevator (Figure 8).

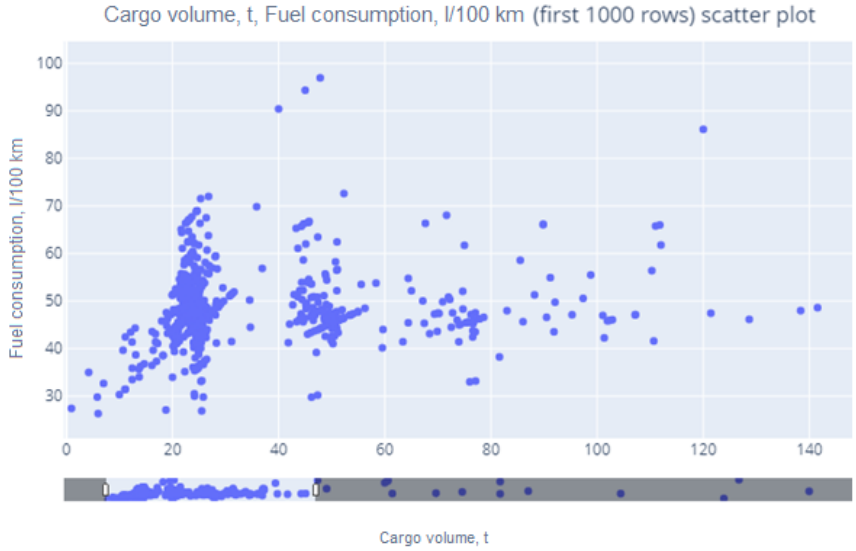

Figure 8 – Trends in the variation of specific fuel consumption by vehicles for different cargo volumes in individual orders for the delivery of grain crops from agricultural enterprises to the elevator

The specific fuel consumption by vehicles can be divided into three clusters, which are determined by the volumes of grain crop delivery from agricultural enterprises to the elevator. The first cluster corresponds to cargo volumes up to 30 tons and is characterized by requiring only one trip since the cargo volume does not exceed the load capacity of the vehicles. It also has a range of specific fuel consumption between 20 and 70 liters per 100 km. Cargo volumes exceeding the load capacity of the vehicles characterize the second and third clusters. The second cluster corresponds to cargo volumes from 30 to 60 tons and has the widest range of specific fuel consumption, between 30 and 99 liters per 100 km. The third cluster corresponds to cargo volumes exceeding 60 tons and has the narrowest range of specific fuel consumption, between 40 and 70 liters per 100 km.

DISCUSSION OF RESEARCH RESULTS

The analysis of the data indicates that the specific fuel consumption during the transportation processes of delivering grain crops from agricultural enterprises to the elevator is influenced by a multitude of specific factors. Fully considering them using analytical models is impossible because fuel consumption has a stochastic nature and depends on a variety of variable production conditions during the transportation process. Additionally, each order for the delivery of grain crops from agricultural enterprises to the elevator has its own specificity.

The obtained results reflect the following relationships: the indicator of specific fuel consumption is influenced by the location and method of loading the vehicle; the vehicle model (engine type); the type of cargo, which determines the method of harvest collection; distance and cargo turnover (an increase in these indicators leads to a tendency to decrease the target indicator); cargo volume. The identified dependencies allow for the preparation of a dataset and the correct interpretation of the results of machine learning models to enhance the efficiency of their forecasting.

CONCLUSIONS

1. The database concerning the execution of orders by the enterprise responsible for grain crop delivery was used for the analysis of data regarding the use of vehicles during the transportation of grain crops from agricultural enterprises to the elevator and obtaining additional information. Factorial analysis was conducted to identify trends in the indicators characterizing these orders based on 14,140 instances of data regarding executed orders for the delivery of grain crops from agricultural enterprises to the elevator.

2. The analysis of the number of orders for the delivery of grain crops from agricultural enterprises to the elevator by cargo type was performed. Trends in specific fuel consumption by vehicles were analyzed: for the execution of individual orders, by specific vehicle makes and models, by varying total delivery distances, by varying cargo turnover, and by varying cargo volume in individual orders during the delivery of grain crops from agricultural enterprises to the elevator. It was found that specific fuel consumption during the execution of transportation processes for delivering grain crops from agricultural enterprises to the

elevator is influenced by the location and method of loading the vehicle, the vehicle model, the type of cargo determining the method of harvest collection, distance and cargo turnover, and cargo volume.

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В. Котенко. **Обґрунтування даних для прогнозування витрат палива транспортними засобами під час доставки зернових культур.**

У статті проведено обґрунтування даних для прогнозування витрат палива транспортними засобами під час доставки зернових культур від сільськогосподарських підприємств до елеватора. З метою отримання знань щодо впливу особливостей надання транспортних послуг та умов використання транспортних засобів на питому витрату палива встановлено закономірності та виявлено взаємозв'язки між окремими наборами даних. Для аналізу даних стосовно використання транспортних засобів під час доставки зернових культур та отримання додаткової інформації використано базу даних, що налічує 14140 екземплярів даних виконаних замовлень із доставки зернових культур від сільськогосподарських підприємств до елеватора.

Виконано факторний аналіз та встановлено тенденції зміни показників, що характеризують ці замовлення. Проведений аналіз показав, що питомі витрати палива під час виконання транспортних процесів доставки зернових культур від сільськогосподарських підприємств до елеватора зумовлюються множиною специфічних чинників. Окрім того, кожне із замовлень на доставку зернових культур від сільськогосподарських підприємств до елеватора має свою специфіку.

Отримано результати, що відображають наступні взаємозв'язки між питомими витратами палива та виявленими чинниками: показник питомої витрати палива зумовлений місцем і способом навантаження транспортного засобу; моделлю транспортного засобу (типом двигуна); типом вантажу, який визначає спосіб збору врожаю; відстанню та вантажообігом (із зростанням цих показників спостерігаємо тенденцію до зниження цільового показника); обсягом вантажу. Виявлені залежності дозволяють провести підготовку набору даних та правильно інтерпретувати результати роботи моделей машинного навчання з метою підвищення ефективності їх прогнозування.

Ключові слова: питома витрата палива, транспортний процес, перевезення зернових культур, факторний аналіз, машинне навчання.

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