Model for selecting transportation option based on an analysis characteristics of the freight system

J O Poltavskaya* and O A Lebedeva
Angarsk State Technical University, Russian Federation, 665835, Angarsk
*juliapoltavskaya@mail.ru

Abstract. The stable economic situation of the enterprise is determined not only by the minimum process costs, but also by the ability to effectively ensure production distribution. When implementing the distribution of goods, it is necessary to solve issues related to delivery, including choosing the option of transportation to the final consumer. The aim of this study is to establish the influence of the characteristics of freight system on the choice of transportation, which is carried out by participants in the transport process, namely, shippers and carriers. The logit model used to assess the need for transportation of goods based on disaggregated data is analyzed. The utility function includes time, cost of transportation and level of service. The evaluation results showed that the main characteristics of the freight system are of statistical significance and allow to determine the main parameters necessary for the decision-making process at the micro level.

1. Introduction
Transport plays a system-forming role that links the elements of economy and social sphere, which contributes to the further development of the country, the expansion of its internal and external transport and economic ties, the growth of production volumes and the improvement of living standards of the population. The transport complex of cargo transportation in Russia is represented by all types of transport, each of which performs certain functions within the transport system, based on the technical, economic, geographical and historical features of its development.

The transportation network of roads accounts for about 63% of the total length of communication lines in Russia as of 2017. In the structure of the volume of transported cargo, 67% falls on road transport, which amounts to 5404 million tons [1]. Due to the extremely high share of road transport in the process of freight transportation, problems arise with the organization of movement in agglomerations. The increase in domestic transportation costs, the occurrence of traffic congestion, air pollution, pavement repair, reconstruction of the road network, road traffic accidents involving freight vehicles necessitate the development of an intermodal automated freight transportation system taking into account its characteristics.

In technically developed countries (USA, Germany, the Netherlands, Japan), various automated freight transportation systems are currently used for assembly cargo between logistics centers and final consumers [2–4]. However, there is a lack of information and data for making management decisions, taking into account forecasting of changes in the characteristics of transport system and the distribution of cargo flows by mode of transport.
Thus, the aim of the study is to analyze the characteristics of the freight transportation system using the transportation option selection model, and to determine the statistically significant difference in the results obtained depending on the distance of freight in the case of introducing an intermodal automated transportation system. Therefore, this study discusses changes in the characteristics of the transport system due to the introduction of a new option for the transport of goods (intermodal automated freight transport system), taking into account transport demand in the freight market.

2. Determination of the demand for freight
Since the choice of transportation option is based on an analysis of the characteristics of the cargo transportation system, it has been established that the declared demand will be preferable to the identified or actual one [5, 6].

The determination of declared demand is focused on building a model for choosing a mode of transport after applying the new freight transportation system (Figure 1).

![Diagram](image)

**Figure 1.** Process for determining declared transportation demand [7].

In the course of modeling a specific situation, alternative transportation options are considered, each of which is characterized by parameters such as cost and time costs of delivery, which for the most part affect the choice of transportation method. Further, the analyzed options are evaluated and ranked according to the method of expert evaluations, and the more preferable one that meets the criterion of minimum total costs is selected. A survey of potential respondents in order to establish the
declared demand is carried out taking into account the acceptable level of errors during the survey due to the comparison (consideration) of hypothetical scenarios.

Figure 2 shows the transportation options, between which the most frequently selected shippers and carriers [7, 8].

Figure 2. Comparison of an automated intermodal transport system with a traditional logistics process organization.

In addition, other transportation options including rail, air and water modes of transport were analyzed. However, since the delivery to the final consumer in the intermodal automated system of freight transportation is carried out by road transport, which allows transportation from the logistics center to the surrounding areas, other modes of transport are not involved in this procedure [9–11]. Thus, in this study, only two alternatives were considered.

The choice of transportation option varies depending on the distance of transportation of goods from the production facility to the regional distribution center.

3. Model Description

In order to determine the significant characteristics of the transport system that affect the choice of transportation option, an individual behavior model is used. The main advantage of the model is the fact that it reflects the characteristics of the choice of transportation relative to the particular shipper in question, since disaggregated data are used as the initial parameters. In addition, it is worth noting the possibility of applying logistic regression, or the logit model, which is widely used in practice to determine the transportation option. As input variables, we chose the cost, transportation time, and level of service (a qualitative indicator of the freight transportation process), since they play an important role in the models for choosing the transportation option [7, 12, 13]:

\[
V_i = \beta_0 + \beta_1 T_t + \beta_2 T_c + \beta_3 LS, \tag{1}
\]

where \(V_i\) – utility function, \(\beta_0\) – dummy variable, \(\beta_1, \beta_2, \beta_3\) – parameter of the linear function, \(T_t\) and \(T_c\) – time and cost of transportation, respectively; \(LS\) – level of service.

The level of service is defined as the reliability of arrival at the destination at a given time, without damage or loss of cargo, with the possibility of providing information about the location or arrival of the cargo during transportation [14, 15].

The statistical significance of the results is estimated by testing the hypothesis: zero \((H_0)\) and alternative hypotheses \((H_1)\) were established in order to compare the results of the model assessment depending on the distance of cargo transportation:

\[
H_0: \beta_1 = \beta_2 = \ldots = \beta_x,
\]

\[
H_1: \beta_1 \neq \beta_2 \neq \ldots \neq \beta_x,
\]

where \(\beta_x\) – vector of coefficients for a certain segment \(x\) by distance.

The equation of test statistics used to test a hypothesis is as follows:
\[ X^2 = -2 \left[ L_N(\hat{\beta}) - \sum_{x=1}^{2} L_{nx}(\hat{\beta}^x) \right], \]  
(2)

where \( L_N(\hat{\beta}) \) – value of the logarithmic likelihood function when using integer data, \( L_{nx}(\hat{\beta}^x) \) – value of the logarithmic likelihood function when using sample data of market segmented subgroups [7].

Checking the likelihood statistics \( (X^2) \), which was calculated from a hypothesis test to compare the entire model in segmentation by transportation distance, the null hypothesis was rejected at a significance level of \( p = 0.5\% \) with a degree of freedom \( n = 4 \), which confirms a statistically significant difference in the calculated coefficients.

4. Conclusion

The solution to the problem of choosing a transportation option is based on the characteristics of the freight system. On this basis, the declared demand of shippers and carriers who carry out transportation is investigated.

An individual demand model is considered, in which the variables are time, cost of transportation, and level of service. It has been established that reducing transportation costs is a more effective tool for increasing transportation demand than reducing transportation time or increasing the level of service. In the case of transformation of the traditional organization of transportation into an automated system of freight transportation, it is necessary to take into account changes in the structure of cargo flows and transportation time for each type of transport separately.

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