

# Application of the Bayes Theory Principles in Planning a Motor Transport Company Work

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**Abstract**— The Bayes approach allows obtaining a broader interpretation of the genuine parameters of the model of functioning of a motor transport company when transporting goods by specialized rolling stock for current planning, assuming that the technical and operational indicator – the haul distance with cargo is a probabilistic value. The aim of the research is to develop a theoretical and practical method for determining the planned volume of cargo transportation under contracts by specialized rolling stock with the use of the Bayes theorem. A probabilistic revision process to obtain new data when determining the output of specialized rolling stock has been carried out. A mathematical model for determining the probability transportation performance by each rolling stock unit under contracts at the stage of making a transportation plan has been developed. The application of the developed mathematical model in the practice of a motor transport company operation will allow obtaining the probability of transportation work performance by specialized rolling stock under contracts; the probability of transportation work performance by a certain unit of specialized rolling stock under the contract in question; the probability of using each unit of specialized rolling stock of a certain typical size when meeting the conditions of the contract and obtaining planned output, which depends on the haul distance with the carg

**Keyword**—motor transport company, the Bayes theorem, specialized rolling stock, transportation work.

## I. INTRODUCTION

Modern working conditions of the cargo motor transport enterprise (MTC) make additional requirements to the manager for the development of the annual transportation plan. Under such conditions it is necessary to have data about the demand for the transportation of a certain cargo type. In practice MTC make contracts on transportation of goods, which are classified according to physical, chemical and biological properties [1]. Goods differ in mass, volume and overall dimensions [2]. Moreover, goods are classified by methods of loading, unloading and storage, sanitation conditions that determine the rolling stock bodywork type for transportation [3]. With respect to goods transportation practice in the city, it has been determined that one of the most material-intensive fields of national economy is construction. Construction materials and structures constitute 60-65 % of the estimated cost of construction and installation work. The motor transport share accounts for more than 80 % of the overall scope of construction materials transportations, which is a component

element of the majority of technological processes during the construction of buildings and structures [4]. That is justified by the annual growth in cargo turnover in construction and a significant change in the array of consumable materials and constructions. The construction is characterized by the dispersion of places of manufacturing, recycling and consumption of materials. It influences the scope of work for their transfer to a large extent. Motor transport has its advantages for the construction manufacture conditions: mobility, maneuverability, the option of delivery of goods directly to an area of consumption at the time necessary for technological reasons, the option of self-unloading in some cases, as well as power-driven unloading [5]. Transportation of goods in the city is characterized by time unevenness, which is due to seasonal nature of the manufacturing or consumption of construction materials.

Today, construction is dominated by the technologies the implementation of which requires both single-piece and roll materials, including the materials that must be transported on specialized rolling stock (SRS) [6]. Goods, as a rule, are transported from one centre along pendulous routes with reverse with cargo mileage. According to the generally accepted classification of motor transport systems of cargo transfer, for operational planning such system is called an average motor transport network system (MTSN). Concluding a contract on the cargo transportation, the consumer proceeds from usefulness of the motor transport service and presents a demand for transportation of a certain type of cargo with the requirements established in the contract. In an environment of uncertain demand the managers face the problem of making a plan of transportation for the further calculation of indicators for the rolling stock exploitation and maintenance and repair of MTC rolling stock to meet the conditions of contracts. MTC is a complex system, while the transportation of construction goods by rolling stock is carried out along routes that are represented by MTSN, the use of the current planning of an average trip with cargo cannot comply with the MTC functioning practice in an environment of uncertain demand [5] and therefore with meeting the conditions of contracts. The MTC functioning model should reflect its state and behavior using complex, systematic approach that allows tracing both direct and reverse correlations between the direct objects of such decisions and other elements of the national economy [7].

## II. THEORY (RESEARCH DATA AND METHODS)

Both national and foreign authors pay much attention to cargo transportation planning. J. L. Cavinato [8] observes that these days in planning it is necessary to take into consideration the uncertainty, for competitiveness and viability of companies and organizations depend on it. Rational planning and control can significantly reduce the costs associated with the cargo transportation and delivery organization. S. M. Mochalin [9] as a result of his studies arrives at the conclusion that the uncertainty emerging in operational planning should be taken into consideration in the current MTC planning. In [10, 11] the emphasis is placed on the fact that taking into consideration the uncertainty influence the indicators of quality, efficiency and the level of logistic service and covers all part of the transportation chain. L. G. Reznik, O. Yu. Smirnova [12] proved that the results of the MTC activity are influenced by many heterogeneous factors which determine processes that are different by their nature but closely interact with each other. Freight motor transport system is a diffusive system, where a constant data exchange takes place. The essential characteristic of the external environment in the marketplace is its uncertainty and the variable nature of the demand for transportation.

The fact was taken into consideration by the author of the presented article and using the classical methods of probability theory, the following results were obtained:

- the hypothesis about the logarithmic-normal distribution of a random value – the length of the trip with a cargo in the city was put forward and confirmed;
- the hypothesis about the logarithmic-normal distribution of a random value – the length of the trip with a cargo in an intercity traffic was put forward and confirmed;
- the hypothesis about the normal distribution of the mass of cargo shipment in intercity traffic was put forward and confirmed.

The confidence intervals of the length of trip with the cargo in the city and the intercity traffic of the MTC rolling stock have been established with a probability of 0.95. The confidence intervals of mass of the cargo shipment in intercity traffic of MTC rolling stock have been established with a probability of 0.95.

Mathematical models of dependences of the influence of the length of a trip with a cargo in the city on the MTC operation results are found out. Mathematical models of dependences of the influence of the length of a trip with a cargo and the mass of the cargo shipment in an intercity traffic on the MTC operation results are found out.

One of the mathematic modeling limitations is to take into consideration the correspondence of output in tones for the found rolling stock combination to the volume, which is determined by the demand for cargo transportation for each contract. Particular attention should be given to information about the planned amount of freight transportation in the city by specialized rolling stock (SRS) at each time step of the calculation, inasmuch as at the preliminary stage this information will allow evaluating the MTC production capacity for each typical size of SRS. It is difficult to obtain such

information using the classical theory of probability, inasmuch as it suggests implementing certain essentially reproduced any unlimited number of times the set of conditions in order to determine the probabilities of a certain contract execution. In this case it is advisable to use the methods of subjective probabilities. These methods include the Bayes method, which differs from the classical methods in its approach to the interpretation of the true parameters of the model.

Approximate Bayes calculations in planning is a universal approach to solving the problem of likelihood function associated with numerical evaluation, where synthetic blocks of data with established parameters are designed and in which the combined data of this data set are compared with the corresponding experimental values [13]. This allowed the use of the Bayes methods in solving some problems in motor transport. J.A. Moscoso-López, I. Turias, M.J. Jiménez-Come, J.J. Ruiz-Aguilar, M.D.M. Cerbán [14] suggested using the Bayes neural networks as a decision-making tool in the management and planning the transportation operations on the stage of preliminary processing of databases on the actual mass of the cargo. The research proved the adequacy of the obtained data of the real intermodal transport processes in the sea ports supply chains. The need to consider safety indicators during container transportation in practical activities in sea ports justified the appliance of a new approach using the Bayes method [15].

Thanks to the constant improvement of the railroad freight transportations network an efficient estimate can guarantee that the railroad remains competitive on the competitive cargo transportation market [16]. In a pattern of an event tree is presented in compliance with logical interdependence between factors, which is later reflected in the Bayes network pattern. The method of probability calculation using the Bayes network has found application in the calibration of probability value of the major events affecting the quality of degree of service of railroad cargo transportations network of the region Chengdu-Chongqing [16].

The Bayes network approach is used to forecast the scope of motor cargo transportations [17]. The authors [17] proved that the Bayes network approach can take into consideration historical data on the scope of cargo transportations; data related to the general state of the national economy; the tendencies in the field when big and small motor transport companies make decisions. It is demonstrated that the use of the method can increase the accuracy of forecasts.

An analysis of economic tendencies in the scope of railway cargo transportations in Poland based on the analysis of data for 2009-2013 year, presented in [18], allowed developing a decision-making method about the investment attractiveness of the sector of the national economy under consideration. The forecasts are accurately presented for chosen transport parameters made by the Bayes network method and the double exponential smoothing by Holt-Winters using an artificial immune system to determine the parameters and initial conditions.

The wide range of application of the Bayes method in transport reaffirms the relevance of the conducted study, and

also allows making a conclusion about the lack of development of the issue of planning the scope of MTC cargo transportations.

### III. RESEARCH RESULTS

To apply Bayes theorem to the planning of MTC operation, the process of probability revision for obtaining new data is presented (fig. 1).

The initial information is theoretical, preliminary and related to the probability of demand for the carriage of goods in the MTSN SRS for the quarters of the year  $P(H_{i,t})$  (formula (1), fig. 1)). The probability  $P(H_{i,t})$  is described by the influence of many different factors. One of the parameters that determines  $P(H_{i,t})$  (formula (1), fig. 1) is the regional competitiveness coefficient of the carrier associated with the description of both its transportation capabilities and the characteristics of cargo transportation reliability, the availability of the necessary SRS fleet to ensure the technological process (load capacity, vehicle size), as well as the level of customer focus, the quality of transport services and other components. Indicator  $P(H_{i,t})$  takes into account intraregional factors that determine the potential and the demand for MTC services: technological, technical, organizational, and economic. Technical and technological factors are determined by the presence of MTC, the required number and characteristics to perform the transportation processes taking into account the technology (schemes and conditions of routes, types of cargo, etc.). Organizational and economic factors are associated with the peculiarities of the organization and efficiency of cargo transportation, which has a significant impact on the quality and reliability of the carriers services.

A priori information suggests that the implementation of the  $i$ -th contract will be involved in the work of the  $j$ -th typical size of SRS in MTSN on the  $t$ -th time step of the calculation (formula (2), fig. 1). Subjective probabilities the Manager sets on the basis of his individual experience or a priori information obtained in situations similar, but different from it in the sense that the complex external conditions cannot be considered unchanged. This information is preliminary generalized in the individual experience and then is quantitatively assessed.

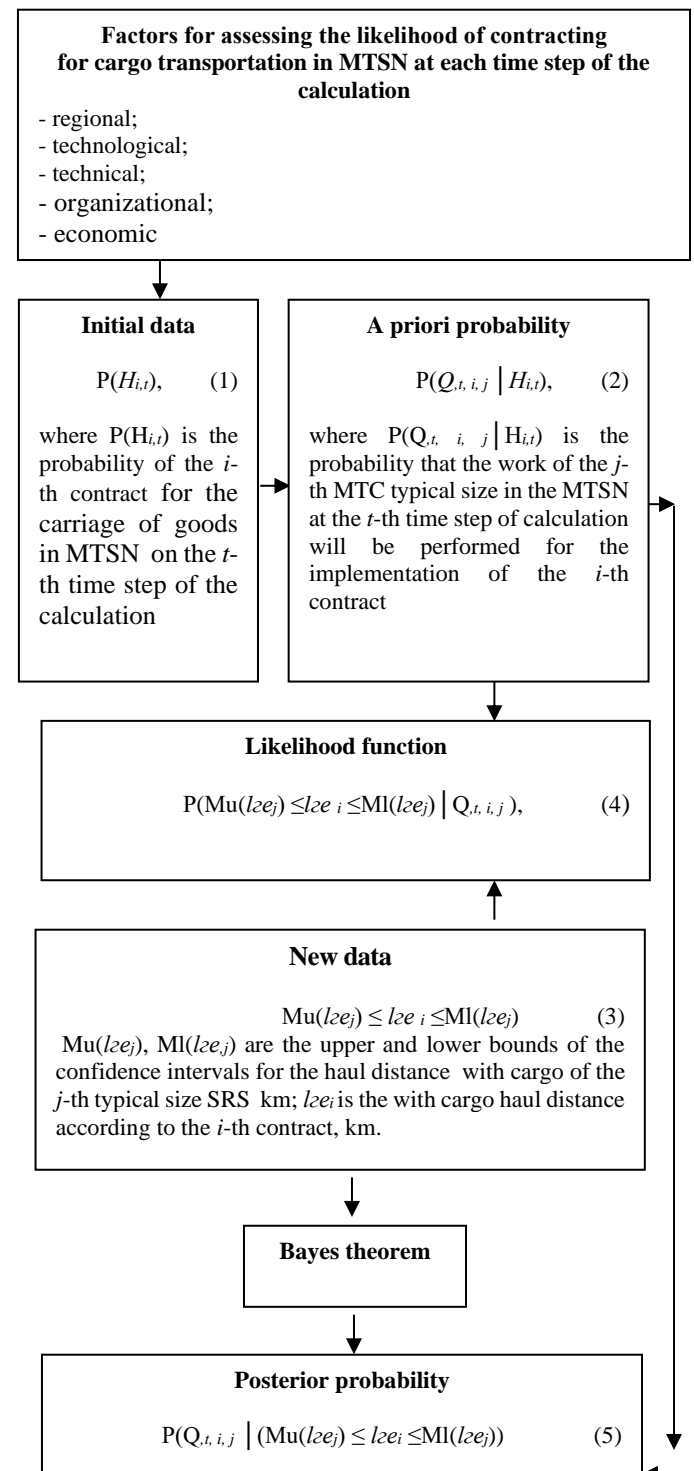


Fig 1. Process of reviewing probabilities to obtain new data in determining output of MTC rolling stock

The new information includes the results of studies that allow to establish the values of the upper and lower limits of the confidence intervals of the haul distance with the load for the  $j$ -th size SRS (formula (3), fig. 1). Because the likelihood function includes all sample information, the a posteriori

probability density function includes all available information, both a priori and sample.

The probability density distribution function (likelihood function, formula (4)) assumes the probability that the value of the haul distance with the cargo under the  $i$ -th contract is between the upper and lower limits of the confidence intervals of the haul distance with the cargo for the  $j$ -th typical size of SRS and can be obtained for the  $j$ -th typical size of SRS under the  $i$ -th contract at the  $t$ -th time step of calculation. According to formula (5), the a posteriori probability indicates that transport work will be performed by the  $j$ -th SRS typical size in the MTSN under the  $i$ -th contract at the  $t$ -th time step of calculation, provided that the haul distance with the cargo under the  $i$ -th contract is between the upper and lower limits of the confidence intervals of the haul distance with the cargo for the  $j$ -th SRS typical size. The a posteriori probability density function obtained in this way is an exact function for the case of a finite volume sample, and it can be used to obtain the corresponding a posteriori probabilistic statements about the probabilistic parameters of the MTC functioning model for the current planning.

The Bayes approach allows to obtain a broader interpretation of the true parameters of the MTC functioning model for the transportation of MTC goods for the current planning, based on the fact that the technical and operational indicator that is the haul distance with the load is a probabilistic value. Randomness is considered as an imminent property of the real physical world, assuming that the physical object itself is subject to continuous random changes.

The use of Bayes theorem allows determining the probability of executing transportation work by the  $j$ -th typical size of SRS in MTSN under the  $i$ -th contract at the  $t$ -th time step of the calculation under the condition of  $Mu(l_{zej}) \leq l_{zei} \leq Ml(l_{zej})$  (formula (6)). Formula (7) makes it possible to determine the probability that the transport work was performed by the  $j$ -th typical size of SRS at the conclusion of the  $i$ -th contract for the carriage of goods in the MTSN at the  $t$ -th time step of calculation under additional conditions.

$$\begin{aligned} P(Q_{t,i,j} | Mu(l_{zej}) \leq l_{zei} \leq Ml(l_{zej})) &= \\ = P(Mu(l_{zej}) \leq l_{zei} \leq Ml(l_{zej}) | Q_{t,i,j}) \times & \quad (6) \\ \times \frac{P(Q_{t,i,j})}{P(Mu(l_{zej}) \leq l_{zei} \leq Ml(l_{zej}))} \end{aligned}$$

$$\begin{aligned} P(Q_{t,i,j} | Mu(l_{zej}) \leq l_{zei} \leq Ml(l_{zej})) &= \\ = P(Mu(l_{zej}) \leq l_{zei} \leq Ml(l_{zej}) | Q_{t,i,j}) \times & \\ \times \frac{P(Q_{t,i,j})}{P(Mu(l_{zej}) \leq l_{zei} \leq Ml(l_{zej}) | Q_{t,i,j})} \cdot P(Q_{t,i,j}) + & \quad (7) \\ + P(Mu(l_{zej}) \leq l_{zei} \leq Ml(l_{zej}) | \neg Q_{t,i,j}) \cdot P(\neg Q_{t,i,j}) \end{aligned}$$

where  $Q_{t,i,j}$  is the output of the  $j$ -th typical size of SRS in MTSN under the  $i$ -th contract the  $t$ -th time step of the calculation,  $t$ ;  $l_{zei}$  is the haul distance for the  $i$ -th contract, km;  $M_u(l_{zej}), M_l(l_{zej})$  are the upper and lower bounds of the confidence intervals for haul distances with a load of the  $j$ -th typical size of the SRS, km;

$P(Q_{t,i,j} | Mu(l_{zej}) \leq l_{zei} \leq Ml(l_{zej}))$  is the probability that transport job of the  $j$ -th typical size SRS in MTSN will be executed under the  $i$ -th contract the  $t$ -th time step of the calculation, provided that the value of the haul distance with cargo by the  $i$ -th contract is between the upper and lower boundaries of the confidence intervals for haul distances with cargo for the  $j$ -th typical size, of SRS;  $P(Mu(l_{zej}) \leq l_{zei} \leq Ml(l_{zej}) | Q_{t,i,j})$  is the probability that the value of the haul distance with cargo under the  $i$ -th contract is between the upper and lower boundaries of the confidence intervals for length of runs with a load for the  $j$ -th typical size of the SRS and can be obtained for the development of the  $j$ -th typical size of SRS in MTSN under the  $i$ -th contract the  $t$ -th time step of the calculation;  $P(Mu(l_{zej}) \leq l_{zei} \leq Ml(l_{zej}) | \neg Q_{t,i,j})$  is the probability that the value of the haul distance with cargo under the  $i$ -th contract is between the upper and lower boundaries of the confidence intervals for the haul distance with a load for the  $j$ -th typical size of the SRS, but could not be obtained for the development of the  $j$ -th typical size of SRS in MTSN under the  $i$ -th contract the  $t$ -th time step calculation.

During the mathematical modeling of SRS of the MTC is formed from units, each of which has an individual number, it is also possible to assign a certain typical size to each unit of MTC to fulfill the conditions of a particular contract. In this regard, formula (8) makes it possible to determine the probability that the transport work will be performed by the  $x$ -th unit of the  $j$ -th typical size of SRS in the MTSN under the  $i$ -th contract at the  $t$ -th time step of calculation provided  $Q_{t,i,j}$ . In the formula (9) takes into account the probability that if will be executed transport work  $j$ -th typical size of SRS in MTSN under the  $i$ -th contract at the  $t$ -th time step of the calculation, the output for the  $x$ -th unit of the  $j$ -th typical size of SRS in MTSN under the  $i$ -th contract at the  $t$ -th time step of the calculation cannot be obtained.

$$P(Q_{ci,x,j,t} | Q_{t,i,j}) = P(Q_{t,i,j} | Q_{ci,x,j,t}) \cdot \frac{P(Q_{ci,x,j,t})}{P(Q_{t,i,j})} \quad (8)$$

$$\begin{aligned} P(Q_{ci,x,j,t} | Q_{t,i,j}) &= P(Q_{t,i,j} | Q_{ci,x,j,t}) \cdot \frac{P(Q_{ci,x,j,t})}{P(Q_{t,i,j}) \cdot P(Q_{ci,x,j,t})} + \\ + P(Q_{t,i,j} | \neg Q_{ci,x,j,t}) \cdot P(\neg Q_{ci,x,j,t}) & \quad (9) \end{aligned}$$

where  $Q_{ci,x,j,t}$  is the output of the  $x$ -th unit of the  $j$ -th typical size of SRS in MTSN for the  $i$ -th contract the  $t$ -th time



step of the calculation,  $t$ ;  $P(Q_{ci,x,j,t} | Q_{t,i,j})$  is the probability that a vehicle will fail the  $x$ -th unit of the  $j$ -th typical size of SRS in MTSN under the  $i$ -th contract the  $t$ -th time step of the calculation under the condition  $Q_{t,i,j}$ ;  $P(Q_{t,i,j} | Q_{ci,x,j,t})$  is the probability that it will be executed transport work  $j$ -th typical size MTC MTSN under the  $i$ -th contract the  $t$ -th temporal step of the calculation, this will give the output of the  $x$ -th unit of the  $j$ -th typical size of SRS in MTSN under the  $i$ -th contract the  $t$ -th time step of the calculation;  $P(Q_{t,i,j} | Q_{ci,x,j,t})$  is the probability what if the transport work  $j - m$  typical size MTC MTSN under the  $i$ -th contract the  $t$ -th temporal step of the calculation will be executed, the output for the  $x$ -th unit of the  $j$ -th typical size of SRS in MTSN under the  $i$ -th contract the  $t$ -th time step of the calculation cannot be obtained. In the mathematical model, the values of the following indicators are known:  $Q_{t,i,j}$ ;  $l_{rei,j}$ ;  $MB(l_{rei,j})$  и  $MH(l_{rei,j})$ ;  $Q_{ci,x,j,t}$ .

#### IV CONCLUSION

A mathematical model of determining the probability of execution of the transport operation of each SRS unit in MTSN contracts at the stage of preparation of the MTC transportation plan is developed. For the first time, a theoretical and practical method is proposed, which is based on the subjective probability of performing transport work with a specific size of SRS in MTSN for each contract at the planned time step of calculation. The mathematical model takes into account the haul distance with the load, which are obtained as a result of the use of classical methods of probability theory. According to the research, it is concluded that the application of Bayes theorem at the step of drawing up a transportation plan in the practical work of MTC will allow to obtain:

- the probability of performing a certain size SRS transportation work in MTSN under the contract, provided that the value of the haul distance with a cargo under this contract is located between the upper and lower boundaries of the confidence intervals for haul distance with a load for this MTC size;
- probabilities of transport service performance by a certain unit of SRS, under the considered contract on condition that development for the MTC of the typical size of SRS used in practice can be received.
- the probability of using each unit of a particular typical size SRS under the conditions of the agreement and obtaining a planned development, which depends on the haul distance with a load in MTSN.

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