Improved method for calculating performance parameters of vehicles before conclusion of a cargo transportation contract

T V Markelova¹, E E Vitvitskiy¹ and A Kh Tolebaeva²

¹Siberian State Automobile and Highway University, 5, Mira Avenue, Omsk, 644080, Russia
²Company Poligrafiya, 36, Shukhov Street, Petropavlovsk, 150013, Republic of Kazakhstan

E-mail: mim9007@mail.ru

Abstract. Fulfillment of contractual obligations for cargo transportation, as shown by the results of practical observations, can be hindered by inaccurate or incomplete knowledge of features of cargo transportation by road transport in cities. These drawbacks in preparation of contracts for cargo transportation may cause a situation where the carrier assumes obligations inherently impossible in specific operating conditions. This can lead to unexpected freight charges.

1. Introduction.

In economic practice in the Russian Federation, relationships are built based on contracts, and each party must determine the parameters since the parties are responsible for non-fulfillment of a contract. This requires a practical tool to calculate executable (or not feasible) obligations under the Contract of transportation in specific operating conditions on scientific basis.

Practice shows a simultaneous multidirectional change that occurs daily in the average road speed \(V_r\) and the time of loading and unloading \(t_{lu}\), which can hinder fulfillment of transportation obligations by the provider.

Scientists from SibADI proved that vehicles in cities work not only on routes, but in various road transportation systems (RTS). The pendulum vehicle with dead return mileage is related to functioning of micro RTS.

The review of the theory of road transportation showed the absence of mathematical models and methods allowed to determine the warranty of cargo transportation by micro RTS. In order to guarantee cargo transportation, today the provider overestimates the time of its execution and (or) underestimates the planned vehicle performance, which increases the required number of vehicles, time and cost of shipping. The economy, on the contrary, requires reduction in the cost of goods and services through the reduced cost of transporting goods, which can improve the competitiveness of the national economy. This contradiction is a practical and scientific goal, which allowed formulation of the working hypothesis 1 – the cargo transportation warranty is violated as the actual simultaneously differently varying \(V_r\) and \(t_{lu}\) are not taken into account; working hypothesis 2 – it is required to determine the conditions under which the obligations of the transport provider calculated on the average \(V_r\) and \(t_{lu}\) can be untenable due to ignored simultaneously differently varying actual \(V_r\) and \(t_{lu}\).
2. Materials and methods

Prof. L L Afanasyeva, DScTech, one of the founders of the road transportation theory, [4] put forward a well known idea that:

- there is a wrong decision on the impact of individual meters and operating conditions on performance of cars and the car park due to the lack of identified dependencies of this performance on the components of the transportation process and the impact of interdependent meters;

- in many cases, the methods of counting meters are incorrect.

Prof. V I Nikolin, DScTech, [2] formulated the need and concept of the development of the road transportation theory. In his opinion, the subsystems of primary research are those (although under certain conditions, they can be considered as independent systems) where transportation is directly carried out. The schedule for transportation by micro RTS is developed in accordance with the model, taking into account the features of cargo transportation on a pendulum route with dead return mileage [2].

Prof. B I Shafirkina, DScTech, [3] and prof. V I Nikolina, DScTech, [2] note that in contrast to other industries, resource savings in transportation can be basically obtained if measures are taken to save these at the stage of transportation scheduling, because if transportation is completed, it is simultaneously consumed, and hence transportation is inefficient [3].

According to prof. B L Geronimus, class A (in terms of reliability of calculations – almost reliable, the confidence interval (±) exceeds 3σ) should be used for calculations, in cases when deviation of the results can lead to catastrophic consequences (for example, non-fulfillment of the contract for cargo transportation). These recommendations are preliminary. In practical application, they should be specified based on critical assessment of the results obtained [7].

In [2, 4 and others], the transport process is indicated as a probabilistic one, and the need to take it into account in cargo transportation scheduling is highlighted. The theory of probability is the science that studies patterns in random processes. Random are phenomena that proceed a little differently each time in a repeated experiment. In road cargo transportation, this phenomenon is a trip – an elementary cycle of transportation [2, 4]. It is proved that the probabilistic nature of the transportation process is determined by Vr and tlu. Driving time consists of periods in movement and downtime under loading and unloading and depends on Vr and tlu among other things [3, 5].

The study of the practice of cargo transportation revealed:

a) during a driving time, several indicators can change simultaneously, for example Vr and tlu, rather than separately and isolated, as previously believed by researchers, who used a single-factor test [2, 4];

b) in practice, there is an equally possible combination of different one-time changes of several indicators (hereinafter, events), for example: "plus Vr and plus tlu"; "minus Vr and minus tlu"; "plus Vr and minus tlu"; "minus Vr and plus tlu".

The basis is the deterministic approach and the scientific concept of the development of the theory of road cargo transportation developed at SibADI [2]. Scientists from SibADI have established discrete dependences of the impact of performance parameters (PP) on functioning of RTS, and developed description models, planning and analysis methods, and algorithms to determine the need for vehicles in RTS to be used in practice [2]. Previously, scientists used a verbal formulation in their research – a study of productivity (output) under an increase or decrease in any single PP. This verbal formulation cannot be used since it is necessary to know the output in the range of possible values of simultaneously changing a number of performance parameters in the range from minus 3σ to plus 3σ [5 and others]. Therefore, we use the verbal formulation – the calculation of the output of vehicle under simultaneous change of PP towards plus (minus) 3σ.

Cargo transportation of goods is carried out by vehicle of different capacity and at different distances in cities. This indicates that the impact of the factors "vehicle capacity" and "distance of cargo transportation" on the warranty should also be studied.

In order to calculate executable (or unrealizable) obligations under the Contract of transportation, an improved methodology is developed described below.
3. Results

3.1. Improved method of calculating the vehicle performance before conclusion of the contract for cargo transportation by micro RTS

Warranty of cargo transportation [6] is a concept in practice and theory that appeared in Russia in the 80s of the last century, which essentially reflects the interest of the parties of the contract in performance of obligations by the transport provider. On the other hand, it was found that at the time specified by the providers of transportation the contract calculated using the average PP may not be objectively performed. The research results showed a significant complexity of the formulation and laboriousness of assessing the guaranteed implementation of the cargo transportation schedule calculated using the average PP. This showed the need and relevance of improving the method for calculation of vehicle performance before conclusion of the contract. The scheme of the improved methodology is presented in Figure 1.

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**Figure 1.** Flowchart of the improved method for calculating vehicle operation hours prior to making a contract for cargo transportation by micro RTS: where the dotted line indicates the developed procedure for checking implementation of the scheduled cargo transportation calculated by the average PP.
Consider individual blocks of the diagram illustrating the proposed method (Figure 1) in detail:

Block 1. Finding, preparing and checking the source data: commercial offer for cargo transportation, transport characteristics of goods, PP statistics (if available).

Specified: scheme of the transportation route (pendulum route with dead return mileage); $T_{oh}$ is vehicle operation hours, h; $l_c$, $l_s$ are mileage values with and without cargo, respectively, km; $l_d$ is values dead return mileage, km; $q$ is vehicle capacity, t; $t_{lu}$ is time of vehicle loading and unloading, h; $V_r$ is average road speed, km/h. Transition to Block 2.

Block 2. Calculation of the cargo transportation schedule with average $V_r$ and $t_{lu}$, and given $l_c$. Comparison of the parameters of the operational schedule for cargo transportation and the request, RTS identification.

Based on the micro RTS model, the cargo transportation schedule is calculated with average (specified, standard) PP values and given $l_c$ on days of the scheduled period. Examples of calculation are presented in the chapter on micro RTS. Transition to Block 2.1. Is it micro RTS?

If the declared transportation load is less than or equal to the scheduled (standard) one per shift, then the transportation will be performed by the micro RTS. Transition to Block 3. Otherwise, transition to Block 2.2 – Stop.

Block 3. Comparison of specified (standard) and actual average $V_r$ and $t_{lu}$ by days of the scheduled period to determine the signs of the realized "sign, sign" event.

Based on $V_r$ and $t_{lu}$ statistics, compare (specified, standard) and actual average values of $V_r$ and $t_{lu}$, and thus determine one of the four events "sign, sign" on each day of the scheduled period. Transition to Block 4.

Block 4. Calculation of the cargo transportation schedule by the micro RTS with actual $V_r$ and $t_{lu}$ and given $l_c$ on each day of the scheduled period of the realized "sign, sign" event.

The schedule is calculated for cargo transportation by micro RTS with actual $V_r$ and $t_{lu}$ and given $l_c$ in the realized "sign, sign" event based on the micro RTS model on each day of the scheduled period. Transition to Block 5.

Block 5. Determination of transportation of the declared volume of cargo by micro RTS through identification of its location on each day of the scheduled period of the "sign, sign" event.

If the declared volume of cargo is more than the actual one, an "additional" vehicle will be required to transport the volume of cargo calculated by subtraction of the actual volume transported by one vehicle from the declared volume. Transition to Block 6.

If the declared volume of cargo is equal to or less than the actual one, the declared volume of cargo is transported by one vehicle. Transition to Block 6.

Block 6. Decision making on each day of the scheduled period.

An authorized person makes possible decisions based on the results of calculations. Transition to Block 7.

Block 7. Signing the contract for transportation of cargo with reasonable parameters.

Based on the results of calculations of operational schedules for cargo transportation on each day of the scheduled period, the values corresponding to the performance of the declared cargo volume are included in the contract, i.e. the results of daily transportation by vehicle during a month are summed, and the contract is to be concluded.

Calculate the possible effect ($E$) by the formula: $E=C_1-C_2$, where $C_1$ is the vehicle rentals per shift to transport the declared volume of cargo, rubles; $C_2$ is the vehicle rentals per workshift calculated with the actual average $V_r$ and $t_{lu}$.

Since transportation of the declared volume of cargo can require renting an "additional" vehicle, the vehicle rentals per shift include the sum of the vehicle rentals calculated using the actual average $V_r$ and $t_{lu}$ ($C_2$) and the possible cost of renting an "additional" vehicle ($C_{ad}$). In this case, $E=C_{ad}$. Calculate the possible rentals of an "additional" vehicle ($C_{ad}$) in the micro RTS based on the rates of the operating company. Based on the results of previously performed calculations for each value of the distance of cargo transportation and for each loading capacity of the vehicle employed, the number of cancelled trips and hours worked were calculated, and the results are presented in Table 1.
Table 1. Results of calculation of the possible rentals of “additional” vehicles (\(C_{ad}\)) in the micro RTS in the event (fragment)

| Event | Vehicle capacity | 1 ton | 9 tons | 20 tons |
|-------|------------------|-------|--------|---------|
|       |                  | min   | max    | min     | max     |
| PP    | l, km            | 1–41  | 61     | 1–60    | 66      | 1–59    | 66      |
| Z_0, unit | t_{eo, h}         | 7–1   | 1      | 1       | 1       | 1       | 1       |
|       | 3.96             |       |        |         |         |         |         |
| minus V_l and minus t_{lu} | T_a, h | 0.62–1.99 | 1.97 | 0.62–2.99 | 3.28 | 0.19–2.97 | 3.31 |
|       | rate, rub        | 500   | 500    | 1000    | 1000    | 1500    | 1500    |
|       | C_{ad}, rub      | 1100  | 1100   | 3300    | 3580    | 5000    | 5465    |

| Event | Vehicle capacity | 1 ton | 9 tons | 20 tons |
|-------|------------------|-------|--------|---------|
|       |                  | min   | max    | min     | max     |
|       | l, km            | 1–41  | 61     | 1–59    | 66      | 1–58    | 66      |
| Z_0, unit | t_{eo, h}         | 7–1   | 1      | 5–1     | 5–1     | 1       | 1       |
| minus V_l and plus t_{lu} | T_a, h | 0.62–2.00 | 1.97 | 1.23–2.99 | 3.33 | 1.44–2.98 | 3.37 |
|       | rate, rub        | 500   | 500    | 1000    | 1000    | 1500    | 1500    |
|       | C_{ad}, rub      | 1100  | 1100   | 3300    | 3830    | 5000    | 5555    |

where \(l\) is loaded mileage; \(Z_0\) is the number of trips; \(t_{eo}\) is time of the trip (turnover); \(T_a\) is time from the moment the vehicle leaves the park to its return.

4. Conclusion
The improved method enables guaranteed transportation of the declared volume of cargo, calculation of the daily demand for vehicles and necessary expenses. Determination of the effect showed that implementation of the developed theoretical provisions and the improved method for calculating the performance of vehicles prior to the conclusion of a contract for cargo transportation allows elimination of possible losses in the amount of 1100 rubles (26.83%) to 5555 rubles (44.44%) per workshift.

References
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