The model of functioning of a set of small auto transport systems with unstable operation of vehicles

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Abstract. According to the results of the research, it has been found that the actual values of the execution time of the operations of the transport process differ from the planned ones. Consequently, the objective property of the transport process, besides discreteness, is the unevenness of the operation of auto vehicles. The need for accuracy of planned calculations determines the need to develop a descriptive model of the aggregate functioning of small-unsaturated auto transportation systems of freights, taking into account the indicated non-uniformity. The methodological basis of the research is the results of practical observations of the transportation process of construction freights dispatch by vehicles in Omsk. This descriptive model can be used in transport logistics when organizing transportation at the level of loading posts according to the “One to One” scheme.

1. Introduction.
A classification of auto transportation systems for freight transportation in cities has been developed in SibADI. The main purpose of this classification is to limit the choice of approaches to the mapping of systems observed in practice, to develop a description language that is suitable for the systems in question.

It follows from [1] that today construction cargo transportation in cities is carried out according to the “One to One” scheme – in the transport systems (micro) dispatch of freight.

According to the “One-to-Many” scheme, transportation is carried out in separate medium unsaturated transport systems of transportation of freight (first type), in the aggregate of freight dispatch of micro auto and small unsaturated transport systems.

According to the provisions of system analysis, all kinds of the model must be consistent with the environment. Otherwise, the model will not work. In modern conditions of the practice of freight transportation, the changes associated with the development of the Russian economy continue. It follows that the previously developed models are subject to verification or these models require the development of new models that would fit the practice. Automobile transport is a part of the Russian economy, therefore the solution of transport and logistics tasks allows us to formulate and solve more tasks that are complex. The study of scientific sources [2-11] suggests that the features of the practice of transporting construction materials in cities identified by the authors have already been noted in the works of scientists. But nothing else has been made. Studies in the theory of logistics lead the author to the conclusion that there have been no models and methods of transport logistics at the date of publication.
2. Materials and methods

Observations of the transportation of reinforced concrete products by vehicles made by ZAO “ZSZHB No.6” confirm the unevenness of the transport process due to the influence of loading time \( t_d \), unloading time \( t_u \), time of freight dispatch of auto transportation systems by movements of vehicles with freight \( t_{df} \), movement time without freight \( t_{du} \), which became the basis for developing the desired model.

According to the authors [2] the unevenness of the operation of the vehicle is characterized by:

1. different outputs (at the same time);
2. performing an equal volume of a task (at different times).

Also in [2], the following models were created:

1. separate micro model;
2. especially small model;
3. low unsaturated model.

These are the models of freight dispatch by vehicles of auto transportation systems (taking into account the work unevenness of the vehicles).

A set of small unsaturated vehicles \( \Sigma S_{\text{small}} \) is observed during transportation of mass construction, including transport-heterogeneous (freight dispatch of auto transportation systems with different bodies) freights in cities from different loading points of one consignor (CO) to multiple consignees \( (G_1P_1, G_2P_2, \ldots, G_nP_n) \).

An aggregate of small freight dispatch by vehicles of auto transportation systems \( \Sigma S_{\text{small}} \) should be understood as a situation where construction materials are transported in the city on several pendulum routes with a return unloaded mileage, each of which simultaneously and separately works a group of auto vehicles. Loading posts of the consignor are located on a separate territory of one consignor, and the unloading posts of each route are different and are located within the city. The unification of separately working groups of automatic telephone exchanges on pendulum routes with reverse unloaded mileage into a set of small unsaturated freight dispatch by vehicles of auto transportation systems takes place focused on fulfilling the contractual obligations of the parties as part of operational planning. To calculate the work results of one separate group of vehicles, a descriptive model of functioning of small unsaturated freight dispatch by vehicles of auto transportation systems can be applied.

3. Results and discussion

Civil defense loading posts are located in a separate territory of the descriptive model of the aggregate functioning of small-unsaturated road transportation systems of freights, taking into account the irregularity of operation of vehicles:

\[
\Sigma S_{\text{small}} = \{F_1P_1F_1; F_2P_2F_2; \ldots, F_mP_mF_m; T_{c}; m; \text{of groups } A_{\text{auto}}>1; \text{SSD} \}
\]

where \( n \) – serial numbers of freight posts corresponding to the route number.

The number of pendulum routes \( (m) \) is equal to the total number of posts loading (unloading) in the work shift, if each consignor has one unloading post, and routes do not intersect in time and space (isolation). The number the group of vehicles in \( \Sigma S_{\text{small}} \) is equal to the number of pendulum routes \( (m) \).

The minimum number of routes in \( \Sigma S_{\text{small}} \) is two:

\[
m = n.
\]

The operating time of the aggregate of small-unsaturated road haulage systems for transportation of goods is determined by the operation mode of the freight center:

\[
T_c = \{t_1, t_2\}
\]

where \( t_1, t_2 \) is the time of the beginning and the end of the work of consignor.

**Stage 1.** For each pendulum route with inverse unloaded mileage, there are observational results that contain an array of \( t_n, t_p, t_{dp}, t_{du} \) values.
Stage 2. Calculation of the average value and standard deviation of the travel time with load, without load, idle time under loading, unloading using the procedure of testing the hypothesis about the distribution law of the random variable \( t_m, t_p, t_{dp}, t_{ds} \).

Stage 3. Calculation of technical and operational indicators work on the route.

The length of the route, \( km \):

\[
I_r = I_g + I_s,
\]

where \( I_s \) is the run with the load, \( km \); \( I_s \) – mileage without freight (vacant run), \( km \).

Riding time (turnover), \( h \):

\[
t_{s,o} = (t_n \pm \sigma_n) + (t_{dp} \pm \sigma_{dp}) + (t_p \pm \sigma_p) + (t_{ds} \pm \sigma_{ds}),
\]

where \( t_{ds} \) is the movement time of the vehicle with freight, \( km \); \( t_{ds} \) – movement time of vehicles without load, \( km \); \( t_n \) – loading time of the vehicle, \( h \); \( t_p \) – time of the unloading vehicle, \( h \); \( \pm \sigma \) is the standard deviation of \( t_m, t_p, t_{dp}, t_{ds} \).

Production in tons per ride, turn on the route:

\[
Q_{s,o} = q\gamma,
\]

where \( q \) is the load capacity of the vehicle, \( t \); \( \gamma \) – coefficient of static load capacity.

Production in ton-kilometers per ride, turn on the route:

\[
P_{s,o} = q\gamma \cdot I_g.
\]

Stage 4. Building a timetable for the group work of vehicles on a pendulum route with a return unloaded mileage.

The schedule is based on the recommendation of Dr. Sc., Professor Nikolin V. I. [2] to ensure the accuracy of calculations.

Coordinate axes are built. The ordinate axis is the number of vehicles operating on a separate route.

On the x-axis, there is successively the time of the operations of the transportation process (\( t_{p}, t_p, t_{dp}, t_{ds} \)), line by line for each vehicle. An example of the schedule construction is presented in Figure 1.

The specification of the \( t_p, t_p, t_{dp}, t_{ds} \) values in the range from \( -\sigma \) to \( +\sigma \) requires justification in each case of the application of the model. The values of \( t_{dp}, t_{ds} \) should be set using the average technical speed, ensuring road safety in accordance with the "Uniform time standards for transportation of goods by road and piecework rates for driver's wages" and the "Traffic Regulations of the Russian Federation".

Figure 1. Conditional timetable for the operation of vehicles on a separate pendulum route with a return unloaded mileage.

If \( t_{dp} - \sigma_{dp} < \frac{I_g}{V_T} \) or \( t_{ds} - \sigma_{ds} < \frac{I_g}{V_T} \), where \( V_T \) is the average technical standard speed (when working in the city – regardless of the type of road surface for cars and road trains with a carrying capacity of up to 7 tons – 25 km per hour, and for 7 tons and above – 24 km per hour), the planned values \( t_{dp} - \sigma_{dp} \) and \( t_{ds} - \sigma_{ds} \) are accepted in the calculations, \( \frac{I_g}{V_T} \), respectively.

Stage 5. Calculation of the results of a separate vehicle on the schedule.
The calculation of the operational plan for the vehicles, taking into account the unevenness of their work with a minimum volume of freight transportation on each individual pendulum route with a return unloaded mileage in the city.

With a minimum plan for the transport of goods, only two exchanges work, the second one in the plan has one ride.

For the first vehicle.
The number of riders of the first vehicle in the group per shift is calculated from the first line of the schedule; the number of riders \(Z_e\) is equal to the number of unloadings \(k_p\) performed before the end of the shift of the vehicle.

The operating time of the first vehicle (index 1) on the route \(T_{m1}\) is determined from the time of the beginning of the first loading to the time of the end of the last unloading on the schedule (Figure 1).

Production in tons of the first vehicle during the work on the route is determined by the amount of workings for each ride on the schedule (Figure 1):

\[
Q_1 = \sum q \cdot \gamma.
\]  

The production in ton-kilometers of the first vehicle during the work on the route is determined by the amount of workings for each trip on the schedule (Figure 1):

\[
P_1 = \sum \gamma \cdot l_y.
\]  

Run of the first vehicle during the work on the route (Figure 1):

\[
L_1 = l_y \cdot Z_{e1} - l_y.
\]  

The actual time in the outfit of the actual second vehicle \(T_{n1f}\) is determined by summing \(T_{m1}\) according to the schedule (Figure 1) and the run times of zero runs:

\[
T_{n1f} = t_{n1} + T_{m1} + t_{n2}
\]  

The total mileage of the first vehicle is determined by summing \(L_1\) on the schedule (Figure 1) and zero mileage:

\[
L_{sum1} = l_{n1} + L_1 + l_{n2}.
\]

For the second vehicle.
The number of riders of the second vehicle \(Z_{e2}\) in the group per shift is determined by the condition of one ride when the minimum traffic plan on the route.

The operating time of the second vehicle on the route \(T_{m2}\) is determined from the time of the start of loading to the time of the end of unloading on the schedule (Figure 2):

\[
T_{m2} = t_v \cdot (t_{v2} \pm \sigma^{v2}).
\]  

The output in tons of the second vehicle during the work on the route is determined by the output for a single ride:

\[
Q_2 = q \cdot \gamma.
\]  

The development in ton-kilometers of the vehicle during the work on the route is determined by the output for a single ride:

\[
P_2 = q \cdot \gamma \cdot l_y.
\]  

Run of a second vehicle during the work on the route:

\[
L_2 = l_y.
\]  

The time in the outfit of the actual second vehicle \(T_{n2f}\) is determined by summing \(T_{m2}\) and the execution times of zero runs on the schedule (Figure 2):
\[ T_{n2f} = t_{u1} + T_{m2} + t_{u2} \] (17)

The total mileage of the second vehicle is determined by summing \( L_2 \) and zero mileage:

\[ L_{\text{sum}2} = l_{u1} + L_2 + l_{u2}. \] (18)

The calculation of the operational plan for the group of vehicles, taking into account the unevenness of their work with the maximum volume of freight transportation, on a separate pendulum route with a return unloaded city mileage.

With a maximum freight transportation plan, the freight dispatch by vehicles of auto transportation systems, the group works without downtime for loading and unloading, since the vehicle supply interval for loading or unloading is greater than the rhythm of the freight post.

The arrival interval of the vehicle for loading and the rhythm of the freight item:

\[ I > R, \] (19)

where \( I \) – interval, i.e. time between two consecutive vehicles (vehicles arriving one after another), h; \( R \) – rhythm, i.e. time after which another car may take the post of loading or unloading, h.

The carrying capacity of the freight point in the vehicle (the number of vehicles operating on a separate route) is determined by the integer ratio \( t_{f, n} \) the maximum time of the freight operation (loading or unloading) because there can be no fractional cars and rounding down. It is planned to run the vehicle without idle waiting for loading (unloading):

\[ A'_{\text{auto}} = \left\lfloor \frac{t_{f, n}}{R_{\text{max}}} \right\rfloor, \] (20)

where \( R_{\text{max}} \) – the maximum time freight operation (loading or unloading), h.

An example of a schedule for a group of vehicles is presented in Figure 2.

![Figure 2](image)

**Figure 2.** Conditional timetable for the operation of vehicles on a pendulum route with a return unloaded mileage with the maximum planned traffic.

The calculation for each vehicle is similar to the above presented calculation of the plan for the first vehicle using formulas 4 – 12.

**Stage 6.** Calculation of the results of the work the group of vehicles on the route.

The results of the work of the group of vehicles on a separate route (regardless of the planned traffic volume) are determined by summing up the work results for each vehicle on the schedule (Figure 2).

Working time is the actual group of vehicles on the route:

\[ T_{ag} = \sum_{1}^{A_{\text{auto}} \text{,'}} T_{m}, \] (21)

where \( A_{\text{auto}} \) is the number group of vehicles on a separate route from two to \( A'_{\text{auto}} \), units.

Production in tons of the group of vehicles on the route:

\[ Q_{ag} = \sum_{1}^{A_{\text{auto}}} Q. \] (22)
Production in ton-kilometers of the group of vehicles on the route:

\[ P_{ag} = \sum_{1}^{A_{ag}} P. \]  

(23)

The group of vehicles’ mileage per shift (day) on the route:

\[ L_{ag} = \sum_{1}^{A_{ag}} L. \]  

(24)

The total mileage of the group of vehicles per shift (day):

\[ L_{s,ag} = \sum_{1}^{A_{ag}} L_{summ}. \]  

(25)

The complexity of the work of the group of vehicles for the shift (day):

\[ T_{of,ag} = \sum_{1}^{A_{ag}} T_{of}. \]  

(26)

Stage 7. Construction of the summary sheet of the dispatcher in \( \Sigma \text{Small} \). The summary sheet of the dispatcher serves as a tool for use in operational planning, transport organization and dispatching regulation, and analysis of the results of the performed work. The summary sheet of the dispatcher is built by combining the previously built schedules of work of all groups of exchanges with different planned traffic volumes (Figures 1 and 2). An example of the summary sheet of the dispatcher is shown in Figure 3.

Stage 8. Calculation of the results of the work of the group of vehicles in \( \Sigma \text{Small} \) with the summary sheet of the dispatcher (Figure 3).

The number of vehicles in \( \Sigma \text{Small} \) is equal to the number of lines of the summary sheet of the dispatcher (\( E \)):

\[ A_{\text{auto} \Sigma \text{Small}} = E. \]  

(27)

Development of the group of vehicles in tons in \( \Sigma \text{Small} \):

\[ Q_{\Sigma \text{Small}} = \sum_{1}^{m} Q_{ag}. \]  

(28)

Development of the group of vehicles in ton-kilometers in \( \Sigma \text{Small} \):

\[ P_{\Sigma \text{Small}} = \sum_{1}^{m} P_{ag}. \]  

(29)

Run of the group of vehicles per shift (day) in \( \Sigma \text{Small} \):
The complexity of the implementation of the transportation plan of the groups of vehicles per shift (day) in $\Sigma$Small:

$$L_{\Sigma\text{Small}} = \sum_{i}^{m} L_{s agi}.$$  

(30)

$$T_{\Sigma\text{Small}} = \sum_{i}^{m} T_{s agi}.$$  

(31)

4. Conclusion

The developed descriptive model can be used as a transport logistics tool in organizing transportation at the level of loading posts according to the “One to One” scheme. The legitimacy of the latter statement is ensured by the work of the groups of vehicles isolated from each other.

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