Distribution method of different types of vehicles on the objects of internal works of the machine building enterprise

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Abstract. The process of distribution of vehicles of the machine-building enterprise for purpose of delivering goods from warehouses located on its production site is studied. A combined method of distribution of enterprise transport was proposed taking into account the joint transport work of different types of vehicles, which planned for shift delivery of goods declared by main and auxiliary divisions and the variability coordinates of cargo unloading points. The recommended method allows adjusting the joint operation of various types of vehicles, in order to choose a rational option for their operation in the current shift. It is preferable to choose a final option that reduces operating costs and provides traffic control in shifts.

1. Introduction

Transportation is an important part of logistics, which connects the current needs for material resources and tooling of the main and auxiliary production of a machine-building enterprise with their loading in warehouses of this enterprise and delivery to the end-use locations according to the current requests of divisions [1-4].

Transportation study process should be supported by number a divisions and services participation of machine building enterprise: planning department, motor pool, main and auxiliary machinery workshop, warehouse facilities, information technologies, communications infrastructure and checkpoints [5, 6].

Multistage solution of distribution issues of different types of vehicles on internal routes for delivery declared production cargo and mandatory connection of all interested specialists of the enterprise to solve the problems of transport and warehouse logistics, it is necessary to form a local control loop.

Each division (department, service) solves a number of specific tasks which are eventually integrated, it is contributes to adoption of effective management decisions in transport logistics field of enterprise [6].

The purpose of the study is to develop a method for combined distribution of vehicles, which takes into account the features of the functioning of a machine-building enterprise when combining internal flows of materials resource and instruments of enterprise, in addition to known variant [7, 8] of homogeneous distribution vehicles.
2. Work planning of different types of vehicles

The work planning process of different types of vehicles is based on the need for material resources and instruments, which specified at the request of main and auxiliary divisions of machine building enterprise. Cargo turnover planning based on a set of shift orders of the main and auxiliary divisions made taking into account the variety of cargo units involved in transportation (figure 1).

Planning of internal deliveries of goods by accumulated requests of production divisions enterprise begins with determining the total cargo turnover per shift \( TC_{\text{shift}} \) [6]:

\[
TC_{\text{shift}} = \sum_{i} V_{i}
\]  

(1)

All cargo delivery routes correspond to requests of i-department \( V_{i} \) with the following conditions:

\[
\text{Request} = \begin{cases} 
V_{i}, \text{ ton / shift}; \\
D_{i}, \text{ cargo volume corresponds to the vehicle capacity} 
\end{cases}
\]

(2)

In practice, indicator of planned number of trip per shift is calculated based on the time of one trip of i-th type of vehicle by the j-th route [7, 8]:

\[
t_{\text{tripij}} = t_{\text{movij}} + t_{\text{loadij}} + t_{\text{unloadij}} + t_{\text{checkij}}
\]

(3)

where \( t_{\text{tripij}} \) – estimated time of trip by one i-th type of vehicle by the j-th route;

\( t_{\text{movij}} \) – spent time on movement operations i-th type of vehicle by the j-th route;

\( t_{\text{loadij}} \) – spent time on loading operations i-th type of vehicle by the j-th route;

\( t_{\text{unloadij}} \) – spent time on unloader operations i-th type of vehicle by the j-th route;

\( t_{\text{checkij}} \) – spent time on passing checkpoints i-th type of vehicle by the j-th route.

In calculation of total number of trip uses the weighted average trip time \( t_{\text{tripi}} \) i-th type of vehicle (taking into account the load capacity of i-th vehicle and load utilization factor):
\[ t_{tripi} = \sum_{j=1}^{m} t_{tripij} \cdot L_j / \sum_{j=1}^{m} L_j \]  

(4)

where \( m \) – total number of routes requested by enterprise divisions; 
\( L_j \) – distance of transportation on the j-th route, km.

For the operating conditions of a machine-building enterprise, the weighted average trip time \( (t_{tripi}) \) i-th type of vehicle adjusted as the timekeeping and regulatory data of vehicles work, which involved in internal process of delivery declared goods by enterprise division.

Required total number of uniform vehicles \( i \)-th type (\( N_{\text{vehici}} \)), which are allocated for performing a shift cargo turnover of enterprise, taking into account the operational time \( (T_{op}) \) of vehicles working in a shift and the time of zero mileage defined by the multi storey fraction expression [4, 5]:

\[ N_{\text{vehici}} = \left( \frac{TC_{\text{shift}}}{c_i \times k_{lc}} \right) \left( \frac{T_{op} - t_{ici}}{t_{journeyi}} \right) \]  

(5)

where \( TC_{\text{shift}} \) – total cargo turnover per shift, ton/shift; 
\( c_i \) – lifting capacity the i-th vehicle, ton; 
\( k_{lc} \) – load capacity utilization factor, percentage of units; 
\( T_{op} \) – operational time of vehicles per shift, h. (\( T_{op} \approx 7 \) h.); 
\( t_{ici} \) – driving time on the route transport manufacturing department-warehouse-transport manufacturing department of the i-th type of vehicle (zero mileage); 
\( t_{tripi} \) – weighted average trip time i-th type of vehicle.

By varying the load capacity and load utilization factor, we can change one vehicle to another. The formula (5) will automatically recalculate the required number of similar vehicles for different types of vehicles. That is, instead of the i-th index (formula 5), we can put (d-th or s-th), which will correspond to attracting other types of vehicles for the case of their joint transport work. At the same time, the number of vehicle units required to replace the i-th type of vehicle with a d-s-g when two types work together (\( N_{\text{vehici}} \)) can be determined:

\[ K_{\text{ repli} - d} = \frac{N_{\text{vehici}}}{N_{\text{vehicid}}} \]  

(6)

\[ N_{\text{vehici} - d} = N_{\text{vehici}} - l_i + \frac{l_i}{K_{\text{ repli} - d}} \]  

(7)

where \( K_{\text{ repli} - d} \) – replacement rate i-th type of vehicle on d-th type; 
\( N_{\text{vehici}} \) (\( N_{\text{vehicid}} \)) – the number of vehicles of i-th (d-th) type allocated by transport manufacturing department during the scheduled shift, units; 
\( l_i \) – actual reduction of the planned demand for type i vehicles (for technical readiness of transport, distraction to other types of work of enterprise, etc.) per shift (\( l_i \leq N_{\text{vehici}} \)), units.
By changing the values of parameters (load capacity and load utilization factor), we can replace one vehicle with another.

The simultaneous operation of vehicles of 3 types \( N_{\text{vehicd-s}} \) in the transport and warehouse model is proposed to be determined by a set of expressions:

\[
N_{\text{vehicd-s}} = N_{\text{vehici}} - l_i + \frac{l_d}{k_{\text{repli-d}}} - l_d + \frac{l_d}{k_{\text{repld-s}}} \tag{8}
\]

\[
l_i \leq N_{\text{vehici}} \tag{9}
\]

\[
l_d \leq \frac{l_d}{k_{\text{repli-d}}} \tag{10}
\]

\[
k_{\text{repli-d}} = \frac{N_{\text{vehici}}}{N_{\text{vehicd}}} \tag{11}
\]

\[
k_{\text{repld-s}} = \frac{N_{\text{vehici}}}{N_{\text{vehics}}} \tag{12}
\]

\[
c_l \leq c_d \leq c_s \tag{13}
\]

where \( l_i, l_d \) – actual decrease in planned demand for vehicles of the i-th (d-th) type per shift, units;

\( k_{\text{repli-d}}, k_{\text{repld-s}} \) – replacement rate i-th type of vehicles to d-th type (d-th type vehicles on s-th type);

\( c_i \) – lifting capacity the i-th vehicle (d-th type or s-th type), ton.

At the moment, the studied machine-building enterprise has 3 types of vehicles that cover internal needs for cargo delivery. The weighted average trip time for the types of vehicles involved in transportation along the cargo delivery routes (according to formula 4) was calculated experimentally (using time-based observations), and the time of zero mileage for each type of vehicle was determined.

The performed calculations allow adjusting the joint operation of various types of vehicles, in order to choose a rational option for their operation in the current shift [2]. It is preferable to choose a final option which reduces the drivers labor cost and fuel consumption.

3. Adjusting of vehicles distribution for non-stationary unloading points

For working conditions with non-stationary unloading points (for example, construction or repair of internal roads of the enterprise (on industrial site of enterprise)) the average time of trip \( t_{\text{tripi}} \) of i-th vehicle type adjusted (formula 4) with the changes of coordinates the discharge points, i.e. distances to discharge points (to a larger or smaller size) on objects of the enterprise:

\[
\bar{t}_{\text{tripi}} = \tilde{t}_{\text{tripi}} \pm \tilde{l}_\Delta / V_i \tag{14}
\]

where \( t_{\text{tripi}} \) - average trip time in subsequent scheduled shifts of the enterprise, taking into account the increase (or reduction) of distances to the points of vehicles unloading on the objects of the enterprises work, h.;

\( \tilde{l}_\Delta \) – average distance by which the distance is adjusted (increased or decreased) in subsequent planned shifts of the enterprise (this is due to changes in the coordinates of the place of unloading of transport units on the objects of work of the enterprise), km.
\( \bar{V}_i \) – average speed of i-th vehicle serving the objects (sections) of the enterprises work, km/h (index i takes the values d or s, depending on type of vehicle involved in transport work).

For this option, the transport and warehouse model is adjusted (formula 8-13), which is adjusted based on the results of calculation using formula 14.

4. Conclusions
As a result, the advantages of the proposed distribution of different types of vehicles for delivery of goods a machine-building enterprise is as follows:

- using the combined method of vehicles distribution allows to ensure a fairly full load of allocated vehicles when combining internal flows of material resources and tooling of machine building enterprise divisions;
- reduce deviations risk from the plan of internal cargo transportation a machine-building enterprise, which is formed based on the replacement requests of its divisions;
- preparation and acceptance of requests for supply of material resources and tooling by divisions a machine building enterprise must be completed one day before their execution;
- the proposed rational planning of transport process provides for the release up to 30-35 % of vehicles;
- vehicle traffic monitoring is configured in shift mode, which detects possible cases of vehicle downtime or overloading.

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