Operational planning of cargo transportation by motor vehicles used on hourly payment conditions

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Abstract. In the modern practice of transporting goods in cities, the use of motor vehicles on an hourly basis has become widespread, although it is known that their use is much less efficient. The purpose of this paper is to increase the efficiency of cargo transportation in cities by motor vehicles on an hourly payment basis by developing methods for operational planning of cargo transportation in cities by motor vehicles used on an hourly payment basis and practical recommendations for its use. The developed methodology considers the existing practice of cargo transportation. By default, it is assumed that a client who rents a car on an hourly basis has the competence to organize cargo transportation in cities. In an order application, the client indicates a car, body type and order time. Thus, it seems that the decision of the client when ordering always contributes to the positive satisfaction of his needs. However, the results of the study suggest that the use of cars on an hourly payment basis for the transportation of building or commercial goods at different distances in urban environments gives different results. Applying the results of this study allows assessing customer satisfaction and prevent undesirable outcomes prior to experience.

1. Introduction

Internet research carried out in 2013 and 2015 in the city of Omsk showed that a significant part of modern organizations (up to 46%), positioning themselves as motor transport enterprises, are not engaged in the organization of transportation of goods, but provide vehicles for use by the client on an hourly payment basis. The existing theory of freight transportation is stated for price-work transportation of goods [1, 2, 3]. Theory of logistics directly indicates the use of motor vehicles on an hourly basis as an alternative to the own vehicles [4, 5, 6, 7, 8]. In the theory of road and building vehicles the use of motor transport on hourly payment terms is provided to support production processes, however, the calculation of cost of the work involved is accomplished under specific conditions of production. One of the reasons for spreading the practice of the goods transportation by motor vehicles on an hourly payment basis serves the lack of organizations’ own fleet of vehicles, due to the high cost of its maintenance. According to the results of reviewing the theory of cargo road transport, logistics, road and building machines, the absence of such methods of operational planning is established.

Practical features of using the vehicles on an hourly payment basis:
- use in urban environments;
- building and production companies, representatives of small and medium sized businesses, and also individuals can act as clients;
satisfying client's need for one or more vehicles;
- delivering the vehicle of the type and modification selected by the client that is required for him to transport cargo;
- the client himself determines the movement route, working time, order of loading and unloading of goods;
- in most cases, motor vehicle fleet owners fix fare rates for the supply of the car to the customer,
- in most cases, motor vehicle fleet owners set minimum order time to compensate for the overhead;
- with increase in loading capacity of motor vehicles the fare rates for their use also increase;
- total paid time is rounded to within 0.5 hours, though some motor vehicle fleet owners provide for charging for every 10-15 minutes, etc.

Preliminary studies have shown that the small and medium-duty vehicles are most widely used in transporting building and commercial goods. Transportation of goods can be carried out both by a singular vehicle and by a group of vehicles. Cargo transportation route – pendulum with reverse unloaded mileage, as the most common one. To calculate the results of the work of motor vehicles on an hourly basis, a mathematical model of the work of vehicles on the pendulum route with reverse unloaded mileage, developed in SibADI by professor Nikolin V.I., was used.

2. Materials and methods
For the operational planning of cargo transportation by motor vehicles transferred to the client for the use on an hourly basis, a methodology has been developed consisting of the following steps:

Step 1. Acceptance of the application for a vehicle on an hourly basis. The client reports the time of order (hours or shift), body type (side or van), load capacity (1.5 t or 3 t or 5 t), the required number of vehicles (one or more).

Step 2. Information for the calculation of the plan for the carriage of goods by one or several cars on an hourly basis. If the client provides the necessary data for the development of an operational plan for a predefined volume of transportation, then go to Step 3. Otherwise, the owner organization provides the client with a specified number of serviceable vehicles payed at the existing hourly rate according to the price list, including the cost of supplying the car / vehicles to the place of loading (Step 2.1).

The necessary data for the development of the operational plan include the following:
- type of cargo and its transport characteristics;
- planned volume of transportation;
- method (technology) of loading and unloading;
- work schedule of loading and unloading points;
- existing restrictions at loading and unloading points (e.g. gate width for entering vehicles, parameters of loading and unloading mechanisms, permitted speed of movement on the territory of the point)
- defining the location of loading and unloading points;
- planning criteria (smallest number of vehicles, lowest cost of cargo transporting by one or several vehicles on an hourly basis, vehicle’s overall dimensions and weight restrictions, limit value of shipment accepted).

Step 3. Are transportations being centralized?
If Yes, then go to Step 4, Otherwise, the owner organization provides the client with a specified number of serviceable vehicles payed at the existing hourly rate according to the price list, including the cost of providing one or several cars to the place of loading.

Step 4. Need for vehicles >1?
If client needs vehicles >1, then go to step 5.1. If the client's need for vehicles = 1, then transition to step 5.2.

Step 5. Calculation of cargo transportation plan. At this stage, the cargo transportation plan, technical and operational performance indicators of vehicles are calculated separately for the group
(step 5.1) or one vehicle (step 5.2), the schedule of the group of vehicles or the schedule of one vehicle is being built.

Next, respectively, go to step 6.1 for a group of vehicles payed on an hourly basis and to step 6.2 for one vehicle payed on an hourly basis.

Step 6. The mileage of the vehicle / vehicles payed on an hourly basis per a shift exceeds the standard?

If in step 6.1, when calculating the cargo transportation plan for a group of vehicles on an hourly basis, the mileage of the vehicles per shift exceeds the standard, then go to step 7.1, otherwise - to step 8.2.

If in step 6.2, when calculating the cargo plan for the vehicle payed on an hourly basis, the mileage per shift exceeds the standard, then go to step 7.2, otherwise - to step 8.3.

Step 7. The client agrees to pay the cost of shipping at two fare rates at the same time?

The condition of applying two fare rates simultaneously means that in the case of excess vehicle mileage per shift, a combination of two rates is being included in the cost calculations: the rate for one hour of vehicle operation, and the rate (in this work, double), for the time of operation for a share of the run exceeding standard.

If during the operation of a group of vehicles payed on an hourly basis the client agrees to pay the cost of transporting cargo at two fare rates at the same time, then from step 7.1 we go to step 8.1, otherwise - we return to step 5.1.

If the client agrees to pay the cost of shipping at two rates at the same time during the operation of one vehicle payed on an hourly basis, then from step 7.2 we go to step 8.4, otherwise, we go to step 5.1, and calculate the plan of cargo transportation in the initial conditions, but for a group of cars.

Step 8. Calculation of the cost of goods transportation and the utilization rate of paid time:

Step 8.1. Calculation of costs for a group of vehicles at two rates simultaneously.

Step 8.2. Calculation of costs for a group of vehicles at a single-rate fare.

Step 8.3. Calculation of costs for one vehicle at a single-rate fare.

Step 8.4. Calculation of costs for one vehicle at two fare rates simultaneously.

After calculating the cost of goods transportation and the utilization rate of the paid time, go to step 9.

Step 9. Does the client agree with the plan?

If the client agrees with the plan, then go to step 10, otherwise return to step 2 and change the initial data and conditions, as advised by the client.

Step 10. Agreed work plan being hand over to the client for implementation.

Motor vehicle fleet owner provides the client with a developed cargo transportation plan and delivers serviced vehicles according to the agreed schedule. The client pays reasonable costs for goods transportation by vehicle payed on an hourly basis according to the approved transportation plan and the price list of the vehicle park owner.

3. Results

As one of the results of applying the developed operational planning methodology, we present an example.

Step 1. Acceptance of the application for a vehicle on an hourly basis. The client needs one onboard car with a carrying capacity of 3 tons for transporting the building cargo in urban operating conditions. Go to step 2.

Step 2. Information for calculating the plan for goods transportation by road on an hourly basis. The client provides the following additional information:

- type of cargo: pallets with paving slabs;
- volume of transported cargo \( Q_{\text{plan}} \) = 15.3 tons (17 pallets);
- dispatch value is 3 pallets (gross mass of one pallet is 900 kg, pallet dimensions are 800 × 1200 × 144 mm);
mechanized loading and unloading (according to the reference manual «Uniform standards of time for the transportation of goods by road and piece rates for payment of drivers», time for loading (unloading) at full capacity $t_{(\text{un})}=0.19$ h, at partial capacity (2 pallets) – $t_{(\text{un})}=0.13$ h); distance of cargo transportation by car on an hourly basis $l_{\text{with}} = 13$ km.

Go to step 3.

Step 3. Are transportations being centralized? In this case, cargo is loaded by the manufacturer of paving slabs, i.e. building cargo is transported centrally. Go to step 4.

Step 4: Need a car > 1? Client need for a car = 1. Go to step 5.2.

Step 5.2. Calculation of a cargo transportation plan for one car along a pendulum route with a return unloaded mileage.

We take “standard” vehicle mileage for building cargo transportation as 140 km per shift (according to experience), and take the average technical vehicle speed ($V_t$) in urban mode as 25 km/h.

Route mileage ($l_r$, km) per ride:

$$l_r = l_{\text{with}} + l_{\text{without}},$$  \hspace{1cm} (1)

where $l_{\text{with}}$ – mileage with load, km; $l_{\text{without}}$ – mileage without load, km.

Run time, vehicle turnover ($t_{r,t}$, h):

$$t_{r,t} = \frac{l_r}{V_t} + t_{\text{(un)}},$$  \hspace{1cm} (2)

Vehicle tonnage carried per ride ($Q_{r,t}$, t):

$$Q_{r,t} = q \cdot r,$$  \hspace{1cm} (3)

where $q$ – vehicle load capacity, t.

Vehicle tonnage-mileage per ride ($P_{r,t}$, t·km):

$$P_{r,t} = q \cdot r \cdot l_{\text{with}},$$  \hspace{1cm} (4)

Number of rides, vehicle turn-around, is determined by the ratio of transportation volume on request and the vehicle productivity in tons per ride (set based on the body dimensions of the vehicle on an hourly basis) ($Z_{r,t}$, N):

$$z_{r,t} = \left[ \frac{Q_{\text{plan}}}{Q_{r,t}} \right] + z_{r,t},$$  \hspace{1cm} (5)

Ride performed for the time remainder, after performing a whole number of turn-arounds ($z'_{r,t}$, N):

$$z'_{r,t} = \begin{cases} 1, & \text{if} \quad \frac{\Delta T_r}{l_{\text{with}} + t_{\text{un}}} \geq 1, \\ 0, & \text{alternatively}. \end{cases}$$  \hspace{1cm} (6)

Vehicle mileage on a pendulum route with reverse unloaded mileage ($l_{\text{day}}$, km):

$$l_{\text{day}} = l_r \cdot z_{r,t} - l_{\text{without}},$$  \hspace{1cm} (7)

Actual vehicle operation time on a pendulum route with reverse unloaded mileage ($T_{r,a}$, h):
The results of the calculation of technical and operational performance of the vehicle on an hourly basis on the pendulum route with reverse unloaded mileage are shown in Table 1.

**Table 1.** Results of calculation of technical and operational performance of the vehicle on an hourly basis on pendulum route with reverse unloaded mileage.

| Parameter                                      | Symbol | Value |
|------------------------------------------------|--------|-------|
| Route length per ride, km                      | \( l_{r} \) | 26    |
| Turn-around time, h                            | \( t_{r,t} \) | 1.42  |
| Vehicle tonnage carried per ride, t            | \( Q_{r,t} \) | 2.7   |
| Vehicle tonnage-mileage per ride, turn-around, t-km | \( P_{r,t} \) | 35.1  |
| Number of rides, vehicle turn-around N         | \( N_{r,t} \) | 6     |
| Ride performed for the time remainder, after performing a whole number of turn-arounds, N | \( Z'_{t} \) | 1     |
| Vehicle mileage on a pendulum route with reverse unloaded mileage, km | \( l_{day} \) | 143   |
| Actual vehicle operation time on a pendulum route with reverse unloaded mileage, h | \( T_{r,a} \) | 7.88  |

The result of the developed plan of cargo transportation is the operation schedule of the vehicle used on an hourly basis (Figure 1).

Next, go to step 6.2.

**Step 6.2.** Car mileage per shift exceeds the standard? When calculating the cargo transportation plan for a vehicle on an hourly basis, the mileage per shift exceeds the standard \( (l_{day} = 143 \text{ km}) \), therefore, go to step 7.2.

**Step 7.2.** Does the client agree to pay costs for one vehicle at two rates? If yes, then go to step 8.4.

**Step 8.4.** Calculation of costs for one vehicle at two rates at the same time, utilization rate of paid time.

The vehicle’s operating time on an hourly basis is rounded up to 0.5 hours, i.e. \( T_{r,a} = 8.0 \text{ hours} \). The cost of cargo transportation by vehicle on an hourly basis under the conditions of applying two fare rates is calculated according to formula 9 (\( C_{th} \), rub.):

\[
C_{th}^2 = \Delta T_{r,a,1} \cdot C_{1h} + \Delta T_{r,a,2} \cdot 2 \cdot C_{1h} + C_{del},
\]

\[ (9) \]
wherein $\Delta T_{r.a.1}$ – actual vehicle operating time without taking into account excess mileage, h; $\Delta T_{r.a.2}$ – actual vehicle operating time for a fraction of mileage exceeding standard (in our case, for an excess mileage of 3 km), h:

$$\Delta T_{r.a.2} = \frac{\Delta l}{v}$$  \hspace{1cm} (10)

$$\Delta T_{r.a.2} = \frac{3}{25} = 0.12$$

$$\Delta T_{r.a.1} = T_{r.a.} \cdot \Delta T_{r.a.2}$$  \hspace{1cm} (11)

$$\Delta T_{r.a.1} = 8.0 \cdot 0.12 = 7.88$$

$$C_{th}^2 = 7.88 \cdot 500.00 + \frac{3}{25} \cdot 2 \cdot 500.00 + 100.00 = 3940 + 120 + 100 = 4160,00$$

Cost of transporting one ton of cargo by vehicle on an hourly basis is ($S_t^2$, Rub./t):

$$S_t^2 = \frac{C_{th}^2}{Q_{plan}}$$  \hspace{1cm} (12)

$$S_t^2 = \frac{4160}{15.3} = 271.9$$

Utilization rate of paid time ($K_{upt}^2$):

$$K_{upt}^2 = \frac{T_{r.a}}{T_r}$$  \hspace{1cm} (13)

$$K_{upt}^2 = \frac{7.88}{8.0} = 0.985$$

Step 9. Does the client agree with the plan?
If the client agrees with the plan, then go to step 10.
Step 10. The agreed operating plan is submitted to the client for implementation.

4. Discussion and conclusion
Application of the developed methodology for operational planning of vehicle operation on an hourly basis will allow the client long before the experience:
1) to establish a correspondence between the desired and possible results;
2) to determine how much the paid time is used to transport cargo in cities;
3) to cancel the order that does not meet his needs.
Providing vehicles, along with the plan for their use, significantly reduces the requirements for the training of client personnel in organizing cargo transportation.
The results of the study positively affect the competitiveness of both the motor vehicle fleet owner and its clientele, which determines the practical significance of the results.

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