# Mathematical Model of the Process of Transportation of Construction Goods by Automobiles

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ABSTRACT

A study of construction shipments to customers by means of Motor Vehicles shows that each sender carries out transportation on the basis of their own interests, not taking into account the interests of other senders, especially the population in the service sector. This leads to overuse of vehicles and, accordingly, to an increase in the cost of delivery of cargo.
The article aims to increase the efficiency of transportation by applying mathematical methods to the delivery of their cargo to the destination.

**Keywords:** automobile, construction cargo transportation, independent transportation, lost time, mathematical model, cost.

The use of modern technologies in the effective organization and management of flows in the global supply chain attaches particular importance to the timely provision of consumer needs for finished products and raw materials. In this regard, in developed foreign countries, special attention is paid to the development of new scientific and technical solutions for the delivery of goods to consumers in the right volume, at the right time, in the right place, with good quality and reasonable prices. Increasing the volume of traffic, timely guaranteed satisfaction of the needs of consumers in the transportation of cargo flows and ensuring economic efficiency is the most important task today [1, 2, 4].

A transport process is a random discrete process with a discrete state and continuous time [6].

When analyzing random processes with discrete states and with continuous time, it is convenient to use a variant of a schematic description of the possible states of gross service systems [3, 5] (Fig.1).

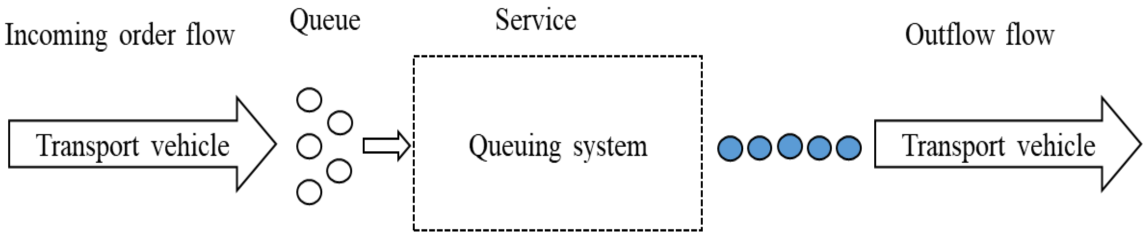


**Figure 1. Diagram of possible states of gross service systems.**

The states of gross service systems are usually represented by rectangular or round shapes, and the possible directions of transition from one state to another are oriented by oriented arrows connecting these states. For example, the indicated graph of the states of a single-channel system of a random service process at the point of departure of the cargo is shown in Figure 2.

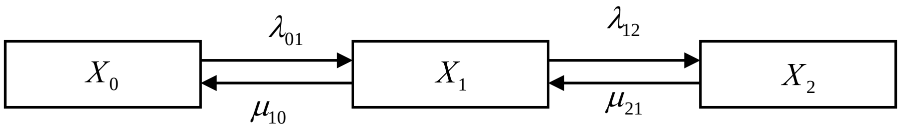


**Figure 2. Single-channel random service process system graphical state.**

In this case, the system can be in one of three states: let channel $X_0$ (waiting); channel $X_1$ is busy with maintenance; channel $X_2$ is busy with maintenance, and there is one order in the queue.

The transition of the system from state $X_0$ to state $X_1$ occurs under the action of the simplest application current with an intensity of $\lambda_{01}$, and the system is transferred from state $X_1$ to state $X_0$ through a service current with an intensity of $\lambda_{10}$.

Since the probability that the system will remain in one state or another is probabilistic, the probability that the system will be in state $X_i$ during $t$ is called the probability of the $i$ state of queue systems $X_i(t)$ and is determined by the number of services received.

A random process that occurs in the system at random points in time $t_0, t_1, t_2, ..., t_k, ..., t_n$ the system is in one or another discrete state known sequentially.

Such a random sequence of events is called a Markov chain, if for each step there is a probability of transition from one state $X_i$ to another independent $X_j$ due to when and how the system moved to the state $X_i$, then the Markov chain is described using the probabilities of states, and they form a complete group of events, so their sum is one.

A mathematical model of the problem of transportation of dispersed construction goods is presented (Table.1). This mathematical model [1, 2] is presented in the source for general transfer processes. In this dissertation, they were applied to solving the issue on the basis of concrete examples of transportation of construction materials (scattered cargo). It is known that when obtaining solutions to transportation optimization problems, optimality criteria are adopted. The efficiency of the gross service system is also assessed on the basis of various criteria.

As criteria of practical importance in solving such issues, the amount of costs attributable to the volume of transported (sent or received) cargo per ton or per hour of operation of service points and vehicles is taken.

**Table 1.**
**Description of gross service theory indicators**

| Specification | Calculation formula | Description |
|---|---|---|
| $\lambda$ –the flow rate of vehicles entering service | $\lambda = \frac{1}{\bar{t}_k}$, $\bar{t}_k$ –average time elapsed from the moment the vehicle is loaded to the next load | Average number of automobiles arriving at the loading point per unit of time |
| $\mu$ – intensity of maintenance of automobiles by loaders | $\mu = \frac{1}{\mu(t_x)} = \frac{1}{t_x}$, $t_x$ – service time | The inverse of the average service time of one vehicle |
| $n$ – service posts | Number of vehicle loading stations at service points | |
| $\psi$ – load factor of service tools | $\psi = \frac{\lambda}{\mu}$ | Determines the loading level of all service channels at the loading point |

| | | |
|---|---|---|
| $m$ – number of automobiles waiting in line | The number of automobiles standing in line waiting for service at loading points | |
| $P_0$ – probability of waiting for vehicles by loaders | $P_0 = \frac{1}{\sum_{k=0}^{n} \frac{m!\psi^k}{k!(m-k)!n^{k-n}}}$ | Shows the efficiency of the service system |
| $\overline{m}_{queue}$ – average number of automobiles waiting for service | $\overline{m}_{queue} = \sum_{k=k+1}^{m}(k-n)P_k$ | Average number of vehicles awaiting service at loading points |
| $\bar{t}_{wait}$ – average automobile waiting time | $\bar{t}_{wait} = \frac{\overline{m}_{\text{queue}}}{\lambda}$ | Average waiting time for a loader of automobiles |
| $\overline{n}_{empty}$ – average number of idle loading tools | $\overline{n}_{empty} = \sum_{k=0}^{n}(n-k)P_k$ | The average number of idle loading vehicles waiting for the arrival of automobiles at service points |
| $\sum C_{\text{common}} = (C^{T}_{auto} \cdot \overline{m}_{queue} + C^{\kappa}_{\text{loader}} \cdot \overline{n}_{empty})T_{work} \to \min$ | Let the sum of the economic losses arising from the mutual waiting times of the means of automobile transport and the points serving them be the smallest value. $C^{T}_{auto}$ – hourly rate of the vehicle. $C^{\kappa}_{loader}$ – one hour cost of the service vehicle. | |

The amount of economic losses from loading and unloading operations and unproductive waiting for each other's vehicles is determined as an efficiency criterion as follows [1, 2]:

$$\Delta S_{hour} = C^{T}_{wait} \cdot \overline{m}_{\text{queue}} + C^{\kappa}_{wait} \cdot \overline{n}_{\text{empty}} \quad (1)$$

The sum of costs corresponding to each service (loading, unloading) process is defined as $\sum S_x$ or loss estimate ($\Delta S_x$) as [1, 2]:

$$\sum S_x = \frac{\sum S_{hour}}{n}\left(\bar{t}^{\kappa}_{wait} + \bar{t}_{service}\right) \quad (2)$$

$$\Delta S_x = \frac{\Delta S_{hour}}{n}\left(\bar{t}^{\kappa}_{wait} + \bar{t}_{service}\right) \quad (3)$$

The sum of the costs corresponding to the volume of cargo transported per ton $\sum S_m$ or the cost of $\Delta S_m$ is determined as follows [1, 2]:

$$\sum S_m = \frac{\sum S_x}{q_{\text{н}} \cdot \gamma_{cm}} \quad (4)$$

$$\Delta S_m = \frac{\Delta S_x}{q_{\text{н}} \cdot \gamma_{cm}} \quad (5)$$

As a conclusion, we can say that when delivering goods to consumers in the right volume, at the right time, in the right place, of good quality and at reasonable prices, it is necessary to pay attention to the effective organization of the transportation process using mathematical models and the development and practical application of new scientific and technical solutions for it. Thanks to this, cargo transportation increases, the needs of consumers for goods are guaranteed to be get on time, and economic efficiency is achieved.

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