Simulation Model for Assessment of the Effect of Modernization of Transport Complex on Freight Delay in Multimodal Traffic

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Abstract. The article is aimed at solving the issue of assessing the influence of various factors affecting the processing capacity of transport nodes. The leading approach to investigating this problem is to create a simulation model for software to assess the impact of changing infrastructure parameters. Article materials can be useful for all participants in the transportation process of any type of transport.

1. Introduction
In the modern transport market conditions, it is necessary to involve different types of transport for transportation of goods or passengers. Therefore, one of the perspective types of directions is mixed transportation. Mixed transportation by type of interaction and coordination can be divided into intermodal, multimodal, direct and unloaded. Multimodal transportation is one of the most common types of mixed transportation used for cargo delivery at the present time. Their implementation involves the use of complex logistic systems that coordinate the interaction of several types of transport [1, p.7].

Technical and technological complexes with sufficient throughput and processing capacity are necessary for rational and optimal interaction between them.

In the direction of the Far East region, a large number of multimodal transport hubs carry out their activities for the processing and delivery of cargo (Vanino, Nakhodka, Vladivostok, Posyet, etc.). In the conditions of the growing volume of traffic in the direction of these transport hubs, there are problems in receiving and processing of incoming cargo. These problems are related to insufficient throughput and processing capacity of technical and technological complexes [3, p.118].

The solution to this problem can be the modernization of complexes using capital investments: the reconstruction of infrastructure, innovative technologies, and the use of modern technological methods of operations. Application of these solutions causes a problem of choosing the best method from the initial set of possible design directions and alternatives. To select the proper one it is necessary:

- the establishment of estimation and selection parameters;
- carrying out a detailed analysis of the work of a particular hub;
- processing of multiple data;
- doing a number of calculations [10, p.58,61].
These operations can lead to the costs of temporal and financial nature, and also to obtaining inaccurate data because of the appearance of unaccounted factors. Changing the parameters using various techniques, described in the scientific and educational literature, may not always lead to the desired result. It is due to the fact that the most visible problems are not of primary importance [4, p.120].

Today, to assess the impact of technological and technical complexes on the operation of transport hubs, qualitative and quantitative performance indicators are required, which can be determined by calculating the duration of the main operations and building daily and contact schedules. Their construction can be called a creative process, but it does not allow evaluating the work in a given period of time, for example every day of the month. Thus, to assess the impact of the modernization of the complex on the change in the performance of the node, it is proposed to use the initial simulation model, which will be an intelligent transport system [2, p.25; 6, p.5].

This term currently describes a set of integrated management tools of traffic and transport, used to solve all kinds of transport problems on the basis of high technologies, methods of modeling of transport processes, software, organization of information flows in real-time [8, p. 6; 5, p.54].

The simulation model is aimed at determining the primary parameter, the change of which will give the greatest result and will determine the limits of changes in technological parameters at the constancy of the technical infrastructure and vice versa. [9, p. 97; 10].

The primary simulation model software is devided into elements of a transport hub such as a railway station (JS), a seaport (MP) and a road junction (AP). Each element consists of individual subsystems of a temporary nature (t), serving the vehicle with the load. These subsystems for each kind of transport are:

- on a train station: car yard, sorting device, sorting yard, departure yard;
- on a marine transport: reception and dispatch yard, load operation yard, berth;
- on an automobile transport: receiving points, place of delivery and loading of goods.

In case of multimodal transportation, cargo is delivered to each of the listed subsystems to perform various operations. Each of these operations has its own duration, in this regard, the goods will be under the so-called productive downtime $t_{pd}$. In some cases, during reception of the goods in the subsystem, the necessary operation can not be performed due to a number of technical or technological reasons. This kind of downtime is called not productive $t_{npd}$ (picture 1). Thus, the time of cargo being in the subsystems is one of the main criteria for multimodal transportation.

**Figure 1.** The productive and non-productive idle times of the transport means in the system.

The target function of downtime $F(t)$ will have the form shown in formula (1):

$$F(t) = \{JS; MP; AP\} \rightarrow \min,$$
Therefore, the subsystems of the elements are represented as the total time of the cargo and the vehicle being in the hub (formula 2):

$$JS = \sum_{j=1}^{n} t_j; \quad MP = \sum_{m=1}^{n} t_m; \quad AP = \sum_{a=1}^{n} t_a,$$

(2)

The duration of stay of goods in each subsystem can be determined by means of standard formulas or the set of known values. The specified values or the resulting formulas can be changed by changing the technological and technical factors. Changes of these factors, in combination or alone, can increase, decrease, or not change the downtime of cargo in the subsystem. To assess the impact of changes of the factors on the cargo downtime in the route and finding the dependence, it is necessary to create a simulation model.

To describe the process of determining the primary factor, we introduce the symbols of the technological group of factors as $Th$ and technical group as $T$. Thus, the dependence of downtime $F(t)$ on two groups of factors is reduced to the target function, the main task of which will be to find the optimal parameters of groups of factors to bring the downtime value to a minimum (formula 3):

$$F(t) = f : \{Th; T\} \rightarrow \{JS; MP; AP\} \rightarrow \min,$$

(3)

The parameters of factor groups are the values of variables $Xi$-technological group and $Yj$-technical group for one or more modes of transport (formula 4):

$$Th = \{x_1, x_2, x_3, ..., x_i\} \quad \text{and} \quad T = \{y_1, y_2, y_3, ..., y_j\},$$

(4)

The following variables can be used as technical and technological parameters for each element of the transport hub:

- **railway transport:**

  $X_i$ – the value of the interval between trains, the plan of formation of trains, the technology of processing of trains of different categories, types of maneuvers with the disbanding of trains, change of specialization of railways, the technology of implementation of shunting movements at the stations, the order of the cars in the local points of work;

  $Y_j$ – extension and addition of station tracks, introduction of productive sorting devices, the use of more powerful traction means, the use of productive technical means of loading, reconstruction of the neck of the station yard.

- **military transport:**

  $X_i$ – interval between vessels, coordination of supply of the vessel with railway transport, priority of giving points of local work;

  $Y_j$ - modernization of mooring fronts for the maneuverability and capacity, the introduction of the productive devices of loading, the availability of storage facilities.

- **automobile transport:**

  $X_i$ – interval between cars, coordination of supply of vehicles with other types of transport, the order of submission to the points of local work, rational technology of working with documents;

  $Y_j$ – capacity and load-carrying capacity of the vehicle, the availability of storage facilities, the use of productive technical means of loading, the length of the unloading fronts.

The restriction conditions for this type of target function will be the change of any parameter from any group of factors to a value less than or equal to the maximum value of the power reserve of the transport hub under specified conditions. Thus, the minimum downtime will be achieved under the following restriction conditions:

$$\begin{align*}
  Th_{\text{min}} & \leq Th \leq Th_{\text{max}} \\
  T & = \text{const}
\end{align*},$$

(5)
The effectiveness of the event when changing the parameters will be determined by the least downtime, as well as technical-operational and economic performance. The dependence between parameters and indicators needs to be established to determine effectiveness. The efficiency will be determined as the difference between the existing and future performance of the hub.

Let us consider the calculation of cargo downtime in the subsystem of the receiving yard element of the transport hub of the railway station JS. Variable Xi of the technological group will be the only parameter - the number of teams (B). This factor will affect the duration of processing of the cargo in the reception yard. The variables of the Yj technical group are constant. With the introduction of the amount of teams and the schedule of train arrivals, the initial simulation model performs the automatic calculation of the necessary number of teams, and also reflects the change in the value of downtime of the cargo in the yard.

The function of the reception yard subsystem will have following form:

\[
F(t_j) = \begin{cases} 
1; & 0 \leq t \leq 2,275 \\
2; & 0 \leq t \leq 1.90 
\end{cases}
\]

The unit of simulation time of the model is minute. It is possible to see the work of the station in any period of time because finding the cargo at a certain stage of processing during the day is split with a precision of minutes, you can see the work station in any period of time [7, p. 55]. The detailed calculation of parameters of a subsystem in the initial simulation model is presented in picture 2.

**Figure 2.** Calculation of cargo downtime in the subsystem of the reception yard with the change of the technological parameter «number of teams».
At the minimum value of the original data the initial simulation model was able to assess the effect of changing the process parameter "cargo downtime" in the subsystem.

To perform calculations in the other subsystems of the hub, in addition to the train schedule and entering the number of teams, it is necessary to enter data on the characteristics of the station at the initial stage. For example, when calculating the location of the cargo in the disband subsystem, the technological parameter can be the methods of disbandment (picture 3). This requires the introduction of additional data such as the nature of the work of the station, the sorting device, the useful length of paths, etc.

**Figure 3.** Calculation of cargo downtime in the disband subsystem when changing the technological parameter "method of disbandment".

To simplicity and reduce the time criterion for the use of the initial simulation model by the user, the system initially requires the clarification of some parameters with the help of five steps:

Step 1. **Classification of the station.**

At this stage, the system offers the classification of separate items according to the following parameters: technical or cargo. According to the selected parameter, the initial simulation model begins to use the calculation algorithm that corresponds to a separate point.

Step 2. **The tasks of station parameters.**

The system displays fields for specifying parameters. For example: the number of yards, the number of paths in the yard, the presence of sorting devices, the useful length of the path in the station yard, the plan of formation of trains, the presence of the shunting means.

Step 3. **Introduction the schedule of train arrivals.**

The specified fields include the arrival time of the train, the number of cars in the train, the category of each train or the system determines the category of numbering of the Russian Railways database.

Step 4. **Definition of areas of local work.**

The user enters the number of areas of local work with the name, the duration of loading and unloading. The system calculates the duration of operations on supply and cleaning of wagons according to the option selected by the user. There are three options:

1. If the user knows the time of placing and removing of cars, data is brought in the corresponding fields;
2. If the user does not know the duration of placing and removing of cars, then it is possible to make technological maps of shunting work;
3. If the user does not know the duration of placing and removing of cars, then the calculation is performed on the given formulas using the necessary data requested by the system from the user.

Step 5. Selection of parameters for changing the operation of technological and technical systems.
The program gives out all possible technical and technological parameters, which change, can affect processing ability of station, and also on cargo downtime and the load in the hub.

After completing the five steps of the simulation model, the system displays the result of the change in the downtime for the selected user options.

The initial simulation model allows:
- to assess the impact of changes in technological and technical parameters on the operation of the transport hub;
- reduce the evaluation time of changing parameters;
- to evaluate the change of parameters for any period of time of the transport hub;
- will assess the economic efficiency of the adopted technological or technical solutions to increase the processing capacity of transport hub.

2. Conclusion
Thus, the initial simulation model is the basis for the development of software for the calculation of cargo downtime in transit under different operating conditions of transport hubs. This software will be aimed at the participants of the transportation process to create optimal logistic conditions for cargo traffic.

3. References
[1] Apatcev V I 2000 Problems of optimization of transport production in railway junctions Monograph RGOTUPS 244
[2] Golubeva E V 2004 Statistical modeling of the operation of a near-shore station Perfection of the technology of rail transportation: International, interiv. Sat. Scientific Tr., Rostov-on-Don, RGUPS 20-29
[3] Eremenko E A, Shirokov A P 2015 The technology of operation of the port station with local cars Actual questions of engineering science: materials III Intern. sci. Conf. (Perm, April 2015) 118-122
[4] Intellectual technologies and technology in production and industry Collected papers on the results of the international scientific and practical conference (Omsk, October 18, 2017) 152
[5] Kel’ton V, Lou A 2004 Simulation modeling 847
[6] Kozlov P A 2013 Automated construction of simulation models of large transport objects Transport of the Urals 2 (37) 3-6
[7] Korol’ R G 2014 Simulation modeling of the operation of a railway station near a railway station with a probability-statistical approach to changing the parameters of the incoming car-stream Transport of the Urals 3 (42) 53-58
[8] Kocherga V G 2001 Forms of integration of intelligent transport systems «Construction 2001» Proceedings of the International NPC 58-60
[9] Logistical transport-cargo systems: the Textbook for the stud. supreme. textbooks, institutions Publishing Center «Academy» 304
[10] Tashlykova A I 2017 On the Plainty of a Local Car at a Port Station Effective Studies of the Present: A Collection of Articles of 32 International Scientific Conference. - Moscow: EO 58
[11] Excerpt of the Quartet Plus Publication “Validation of User Behavioural changes due to Multimodal Traffic Information and related impacts on the Transport System” 1998 Editor Dr. Antony Stathopoulos, Nat. Techn. Univ. of Athens