trains breaking-up order control, railway traffic forecasting, stochastic programming

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INFLUENCE RESEARCH OF TRAFFIC PREDICTION ACCURACY ON EFFECTIVE MANAGEMENT OF THE TRAINS BREAKING-UP ORDER

Summary. The article presents the research results of management processes in order of trains breaking-up on marshalling yards. The objective of this article is determination the area of rational use of trains breaking-up order models. Model of trains breaking-up order selection is formalized in the form of stochastic programming task. With the help of simulation modeling was obtained the dependence, describing the impact of trains arrival forecasting error and sizes of car traffic processing on reducing operating costs of the marshalling yards through the management of trains breaking-up order. The investigations can establish the requirements for accuracy of information support of operational planning tasks necessary for achieving the desired economic effect of the management of trains breaking-up order.

ДОСЛІДЖЕННЯ ВПЛИВУ ТОЧНОСТІ ПРОГНОЗУВАННЯ РУХУ НА ЕФЕКТИВНІСТЬ КЕРУВАННЯ ЧЕРГОВІСТЮ РОЗФОРМУВАННЯ ПОЇЗДІВ

Анотація. В статті представлені результати дослідження процесів керування черговістю розформування поїздів на сортувальних станціях. Метою статті є визначення області раціонального застосування моделей керування черговістю розформування поїздів. Модель вибору черговості розформування поїздів формалізована у вигляді задачі стохастичного програмування. За допомогою методів імітаційного моделювання отримано залежність, яка описує вплив помилки прогнозування прибуття поїздів та розмірів вагонопотоків із переробкою на скорочення експлуатаційних витрат сортувальної станції за рахунок керування черговістю розформування поїздів. Виконані дослідження дозволяють встановити вимоги щодо точності інформаційного забезпечення задач оперативного планування, необхідної для отримання бажаного економічного ефекту від керування черговістю розформування поїздів.

1. INTRODUCTION

Trains breaking-up order control (TBOC) at sorting yards is one of the means of influence and efficiency of the processes of trains formation. At the present time specified instrument is almost never used by operational staff, due to the complexity of the task, as well as lack of appropriate automated systems for its solving. In addition, the ability to control effectively trains breaking-up order largely depends on the quality of information management, among which plays a particularly important is the trains arrival forecast. Thus, two necessary conditions for practical application of tasks of trains breaking-up order selection are imposing this feature on computerized systems of control and providing these systems with reliable and accurate forecast of the trains arrival.

2. STATEMENT OF RESEARCH PROBLEM

The papers of many scientists both in Ukraine and abroad are dedicated to the task of automated decision making support systems of operational staff. In paper [1] there was considered the possibility of creating such systems on the basis of the theory of fuzzy sets and fuzzy logic. Papers [2-3] are logical continuation of scientific research, which proposed when creating decision support systems use the artificial neural networks elements [4].

In the paper [5] there was noted that practical works on introduction of the station processes automated control systems should take into account a certain unreliability of prediction of the expected trains arrival. In the paper [6] there was described the trains breaking-up order control model, taking into account the stochastic nature of forecasting their arrival at the station. Even stochastic model may be ineffective in the absence of reliable information on the trains arrival. The accuracy of traffic forecasting is one of the main factors determining the appropriateness of trains breaking-up order control.

The main positive effects of changes in the trains breaking-up order control are achieved by reducing unproductive downtime of cars in breaking-up subsystem. The latter usually occur with increasing size of car traffic volume and improving the level of breaking-up subsystem load.

Thus, the area of effective control of the trains breaking-up order is determined primarily by two factors – accuracy of traffic forecasting and size of car traffic processing. The task of determining this area is important and solved in this paper.

3. RESEARCH OF ECONOMIC EFFICIENCY CONTROL OF TRAINS BREAKING-UP ORDER

Initial data for scheduling trains formation and trains departure are:

– Telegram-car list on all trains arriving in full or partial processing (excluding assorted, export and transfer ones);

– plan of supply trains to station;

– data on presence at the station tracks of trains and cars on the purpose of formation plan at the beginning of planning period;

– data on availability and expected arrival of locomotives and locomotive crews for trains removal;

– data on the quantity, destination and estimated time of cars cleaning on the station track after the cargo handling operations;

– technological standard time for operations of trains and cars.

A planning operator provides calculation of operational plans of train formation of 4-6 hour period. The operator receives data on the number, purpose and a planned rearrangement of local cars on the station track from shunting dispatcher.

Calculation of the train formation, that is the definition of preparedness moments of trains departure, is determined on the basis of established process of technological norms of the residence time of trains in receiving and departure yard and time on trains formation and breaking-up and their transposition to the departure yard.

After developing a plan of train formation (based on the accepted order of breaking-up) the operator informs the station (shunting) dispatcher the expected completion time of trains formation as per plan of trains formation.

Then shunting dispatcher determines the procedure for preparing the existing trains for departure. When planning departure trains there is carried number-specific assignment of its formation and transit by trains schedule threads. There is indicated number of train, departure, destination station, number of the locomotive. In some cases, when the number of threads per schedule planning period is less than the number of planned to dispatch trains, departure of additional trains for the dispatch schedule is expected. In practice, the portion of the trains that go by the dispatch schedule, reaches up to 50%.

Planning a train formation to date actually is performed "in manual mode". Given the large amount of information that must be processed in a short time, making by operational staff of economically feasible decisions is an extremely difficult task. Automated systems can facilitate decision-making procedures and improve management of trains breaking-up order.

The automated control system of trains breaking-up order should rely on reliable forecast of trains arrival. At the present time in the Ukrainian automated control system ACS VP UZ-E there in information only about performed railway traffic. Thus, the operating personnel can receive the actual points of arrival and departure of trains passing the stations. At that, ACS VP UZ-E doesn't provide railway traffic forecasting. Therefore, during current planning of stations work operational personnel can only manually specify the expected time of arrival of trains, based on normative duration of the train's movement between stations and personnel's experience.

The absence of automated forecasting of trains in ACS VP UZ-E complicates use by operational staff of many levers of influence on train formation processes, including control of trains breaking-up order.

To ensure the reliability of the forecast, traffic forecasting system should be based on modern mathematical and technical means. A powerful tool for creating models is forecasting mathematical device of artificial neural networks. The possibilities of its application in forecasting of train are investigated in the paper [7]. In the paper [8] it was proposed to perform prediction based on consideration of a wide range of factors that affect the conditions of following trains on station. By modern technical means of predicting the traffic include satellite-positioning system [9], possibility of which is considered in the paper [10].

Since even the most reliable forecast is characterized by some random error, it is important to know what the requirements makes the task of choosing the order of dissolution trains for precision forecasting their arrival. In other words, it's necessary to determine how the efficacy of this task implementation changes by changing the characteristics of stochastic forecasting error.

The random variable forecasting error for sufficiently adequate and reliable forecasting model is described by normal distribution with zero expectation and a certain standard deviation, depending on the traffic conditions on stations. This view is confirmed by studies [11], performed in DNURT. Therefore, the study of trains breaking-up order control efficiency in the paper was made based on the assumption that the random variable forecasting error is described by normal distribution with expectation zero. This random variable is determined by the standard deviation.

For research model there was used TBOC presented in [12]. Each option of train processing is characterized by selected trains train breaking-up order

$$X^{(t)} = \{N_1, N_2, ..., N_k\}, \tag{1}$$

where $N_1, N_2, ..., N_k$ – train number, which is breaking-up, respectively, first, second, *k*;

t – number of priority trains breaking-up, $t = 1...k!$.

Under step of task we mean the train breaking-up. In equation (1) there are imposed restrictions on the number of trains that can be considered in the step of solving the problem:

$$k \le h \tag{2}$$

where h – the number of tracks in arrival yard of sorting station.

The whole set of options of the trains breaking-up we denote as $X = \{X^{(t)}\}$. Among all the options $X^{(t)}$ it's necessary to select the one that provides the minimum overall operating costs of sorting station. In this case, the objective function of the TBOC task is formulated as follows:

$$C(X^{(t)}) = C_{wh}(X^{(t)}) + C_{th}(X^{(t)}) + C_{lh}(X^{(t)}) + C_{man}(X^{(t)}) \longrightarrow \min_{\forall X^{(t)} \in X}, \tag{3}$$

where $C_{wh}(X^{(t)})$ – costs associated with downtime of cars at the station in the implementation of the breaking-up order $X^{(t)}$;

$C_{th}(X^{(t)})$ – costs associated with downtime of trains in case of impossibility of receiving at station in the implementation of breaking-up order $X^{(t)}$;

$C_{lh}(X^{(t)})$ – costs associated with downtime of locomotives at the station in the implementation of breaking-up order $X^{(t)}$;

$C_{ман}(X^{(t)})$ – costs associated with additional shuntingon station in the implementation of breaking-up order (this part of the costs arising for example when overflow of sorting tracks).

Let us assume that $\{\theta_i\}=\{\theta_1,\theta_2,...,\theta_f\}$ – set of possible states of the system „Station – Adjunct station-to-station block", that is defined by moments the ability of trains arrival to the station – $\theta_i=\{T_1,T_2,...,T_k\}$. A set $\{\theta_i\}$ is based on statistical forecasting error on trains. Probability $P(\theta_i)$ of each state is known.

Given the possibility of deviation of the actual arrival of trains from the forecast, we get the stochastic programming task [13]. Under these conditions, solving the problem of choosing the breaking-up order involves the choice of schedule, which provides consistency dissolution to the expectation of total operating costs related to the processes of trains formation was minimal. This expectation of operating costs is determined by considering all possible states, in which may be the station in case of deviation of the actual moments of arrival of trains from projected ones:

$$C'(X^{(t)})=\sum_{i=1}^{f}(C(X^{(t)};\theta_i)\cdot P(\theta_i))\rightarrow \min_{\forall X^{(t)}\in X} \quad (4)$$

where $C(X^{(t)};\theta_i)$ – total operating cost of the breaking-up order $X^{(t)}$ in terms θ_i.

The model TBOC was investigated in terms of economic efficiency. The study was performed by simulation modelling using the model developed at the Department of stations and junctions of DNURT. For this purpose, the universal simulation model has been adapted to track development scheme and technology of Nizhnedneprovsk-Node sorting yard odd system.

In the paper there was explored the impact of the accuracy of the forecast arrival of trains on the efficiency of trains breaking-up order management. Management efficiency is understood here as a relative reduction of operating costs of sorting station, achieved by changing the trains breaking-up order. Accuracy of the forecasting was determined by standard deviation of forecasting error and varied ranging from 5 minutes to 25 minutes in steps of 5 minutes.

The main economic effect of trains breaking-up order management is achieved by reducing the unproductive downtime of trains, which complete forming of new trains on the marshalling yard. Such downtime is largely dependent on the size of traffic volume and processing load of the breaking-up subsystem. Therefore, the studies of effect the accuracy forecasting on TBOC efficiency were performed for different car traffic volume processing.

Besides that, studies were performed at different depths of planning, i.e. with different number of trains to be included in the count of breaking-up order variants. Simulation has showed that it's enough to fulfil planning of 4-5 trains. Further increasing the depth of planning does not improve the performance of the station. Test results for the depth of planning on 4 trains are shown in Fig. 1.

The results of simulation modelling can formulate the following conclusions:

–increase in the standard deviation of error prediction and reduction in size of car traffic volume processing significantly reduce the effectiveness of trains breaking-up order control;

–with the amount of car traffic volume daily processing in 3,000 car/day and standard deviation of forecasting error to 5 minutes, operating costs, depending on the trains breaking-up order are reduced by up to 6.7%;

–with the amount of car traffic volume daily processing 2,500 car/day and standard deviation of forecasting error for about 25 minutes, the appropriateness of trains breaking-up order control almost disappears;

– increasing of economic efficiency of TBOC by increasing the size of the car traffic volume with processing is explained due to an increase in unproductive downtime of trains in rail receiving yard.

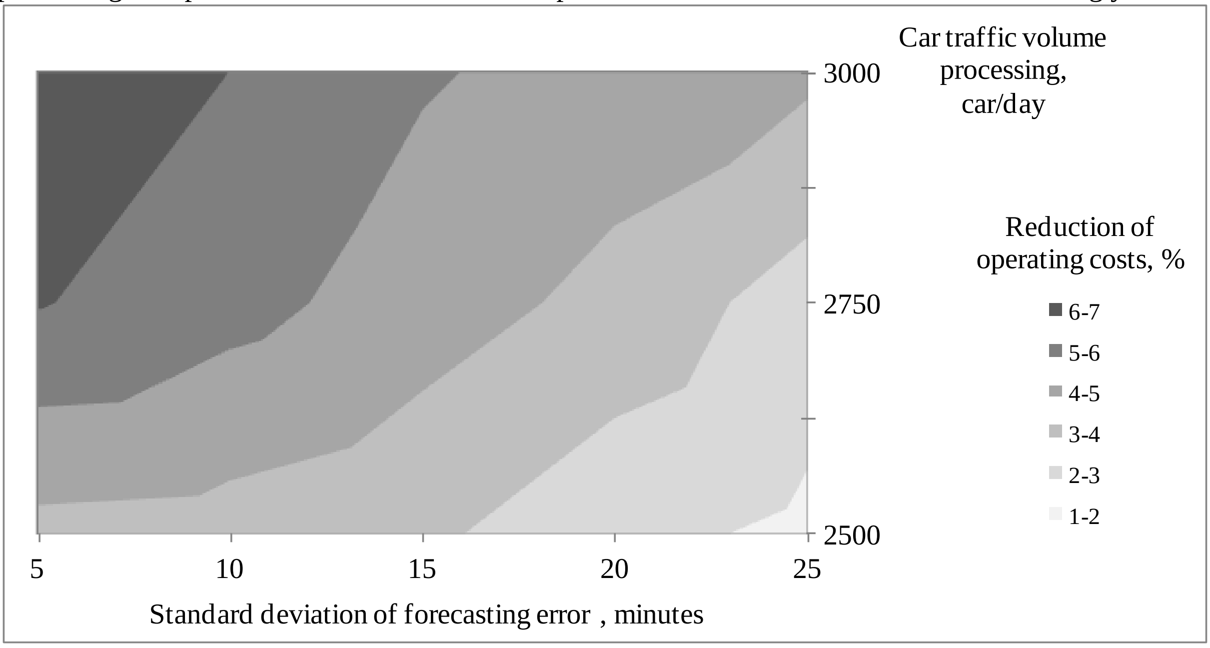

Fig. 1. Dependency of breaking-up order control efficiency from forecasting error
Рис. 1. Залежність ефективності керування черговістю розформування від похибки прогнозування

4. CONCLUSIONS

The feasibility of implementing technologies of trains breaking-up order control for sorting stations largely determined by the accuracy of traffic forecasting on nearby stations. Besides a reliable basis for the implementation of these technologies are the large size of the processing of car traffic and high load of sorting station breaking-up subsystem.

For feasibility of practical use of trains breaking-up order models, it is necessary to ensure two conditions:

– imposition of this function on automated control systems;

– providing an automated system with sufficiently reliable and accurate prediction of trains arrival.

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