DEVELOPMENT OF PROCEDURE OF SEARCH
OF RATIONAL VARIANT OF TECHNOLOGICAL TREATMENT
OF INCOMING CAR TRAFFIC VOLUME

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Summary. In the article we presented a principle and mathematical model of searching of the rational variant during the operative planning of technological treatment of incoming car traffic volume on industrial enterprises of rail mode.

Key words: Transport, railroads and railroad engineering, technological treatment, car traffic volume, planning, informational system.

INTRODUCTION

More than 80% of car traffic volume of railroads originates and retires on industrial enterprises. For these enterprises it is too important to improve the transport service on the area of connection station – access railroad where considerable part of current financial transport outlays of enterprise is made by payment of car-hours of using cars of "Ukrzaliznici" and private operator companies.

On main line transport enterprises poorly organized and unrhythmic traffic volumes are forthcoming that leads more often to overwhelming of the transport system of enterprise, in particular, of locomotives, station and exposition tracks. Thus the volume of work of locomotive brigades is increased, and the general index of efficiency of their use goes down. A traffic controller is often physically unable to analyze all car traffic volume that is forthcoming on an enterprise, and to define the optimum variant of a transport service. That is why for achieving more effective results on enterprises unmanned systems of planning and operating rail mode with the help of computers are more frequently used. It was discovered as a result of analysis of existing systems, that on enterprises the informative systems and systems of prognostication and planning are used separately. Informational systems are fulfilling next main functions:

-calculation of presence, distribution, use, and demurrage of the rolling stock;

-calculation of loads which are forthcoming and departed by type, deliveries and recipients;

-calculation and control of implementation of planned tasks;

- drafting of row of forms of the statistical reporting.

The existent systems of prognostication and planning do not take into account appearance of unplanned situations, and accordingly, cannot give out adjustment of prognosis which was made before.

Maximal efficiency in a management of work of transport is possible to achieve by integration of unmanned informational systems and systems of prognostication and planning. That means that there must be unmanned system which controls implementation of transport processes real-time and founded on received information plans transport processes. The final decision on forming of the plan must do a traffic controller that is why a system must have a structure of a system of support of making decisions (SSMD). In order to receive optimal result SSMD must "understand" principles of fulfilling those or other transport processes. Thus in order to receive a rational variant of technological treatment of incoming car traffic volume SSMD must solve next tasks:

Distributing of cars after homogeneous freight fronts (FF) with the purpose of implementation of freight operations (FO) with a minimum cost;

a choice of rational sequence of delivery of groups of cars to FF;

planning of shunting operation for reforming of rolling stock in different available places of enterprise;

complex estimation and choice of minimum cost variant of distributing of cars after FF, sequences of placing and plan of conduct of shunting operation.

A procedure was developed for the decision of set tasks: mathematical description of which is presented below.

A PROCEDURE OF SEARCHING OF THE RATIONAL VARIANT OF TECHNOLOGICAL TREATMENT OF INCOMING CAR TRAFFIC VOLUME

The process of feed, assembly and transportation of cars from freight fronts is suggested to be divided into the row of stages. For car feeds on freight fronts it will be:

-reforming of the rolling stock,

-successive delivery of feed and arrangement on FF,

-freight operations.

The state of the transport system on each stage is characterized by the range of points $\varphi^1_p, \varphi^2_p,.. \varphi^n_p$, collection of which is vector $\varphi(p)=(\varphi^1_p, \varphi^2_p,.. \varphi^n_p)$, it is a vector of the state of a system. The state of the system on the prime stage $p=0$ is considered predetermined $\varphi(0)=\varphi_0$.

Development of the system consists of successive transition from one state to another. It is possible to influence it on every transition through the stage p by a certain operation $u(p)$ which was chosen from the range of possible operations. Thus, the state of a system $\varphi(p+1)$ is determined from one side by the vector $\varphi(p)$ and from the other side by operation $u(p)$:

$$\varphi(p+1) = f\{\varphi(p); u(p)\}$$

(1)

Function f set the rule of transition from the state $\varphi(p)$ into the state $\varphi(p+1)$ depending on the option of $u(p)$. The range of options each of which may be chosen on the stage $p=m$ we will indicate as U_m. Development of the system is determined by the succession $\varphi = \{\varphi(0), \varphi(1),..., \varphi(P)\}$, where $\varphi(p) \in \varphi_m$ is the vector of state of the system for $p=m$.

We will name the presented sequence as a strategy. Admission of a strategy is conditioned by the possibility of existence of the option that allows making a transition out of any state on the certain stage in the following on other. Each strategy is described by the target function $F(\varphi)$. Thus, the development of the system is described:

-by the range of admissible states of the system φ_m;

-by the range of admissible options U_m;

-by rules of transition from the one state into another after chosen option:

$$\varphi(p+1) = f\{\varphi(p); u(p)\}_,$$

(2)

by the target function $F(\varphi)$.

The task of the searching of rational variant of technological treatment of car traffic volume comes to the finding of admissible strategy which guarantees the minimum of the target function. The last one in the general case is set by the sum of criterion functions $Q_m\{\varphi(m), \varphi(m+1)\}$ which were received during the transition from the state $\varphi(m)$ to the state $\varphi(m+1)$:

$$F(\varphi) = \sum_{m=0}^{P-1} Q_m\{\varphi(m); \varphi(m+1)\}$$

(3)

The target function must be considered the function from option because any admissible strategy φ is absolutely determined by the sequence of admissible options $u=(u_0, u_1,..u_{p-1})$. Thus, the task comes to the necessity of determination of options $u^*=(u^*_0, u^*_1,..u^*_{p-1})$ which minimize the target function:

$$F(\varphi(u)) = \sum_{m=0}^{P-1} Q_m\{\varphi(m); \varphi(m+1)\} \to \min$$

(4)

on condition that

$$\begin{cases} \varphi(p+1) = f\{\varphi(p); u(p)\}; \\ \varphi(m) \in \varphi_m; \varphi(0) \in \varphi_0; \\ u(m) \in U_m; m = 0,1,...,P-1. \end{cases}$$

(5)

Computing process of car feed on FF after the end of receive-return operations should be divided into several stages.

At the primary stage $(p=0)$ we should collect and analyze information about the current status of the system, especially those elements which may be involved in the process which is planned.

Technological treatment for the case of car feed on FF will have 5 stages, $p = \overline{0,4}$. Examination of stages we will start from the last one $(p=4)$. This stage determines all possible variants of arrangement of cars after FF taking into account the

duration of freight operations for car groups. *φ(4)* is a vector which describes variants of arrangement of cars after FF:

$$\varphi(4) = (\varphi_4^1, \varphi_4^2, \varphi_4^3, ..., \varphi_4^{k_4}) \tag{6}$$

where: every variant φ_4^v, $v = \overline{1, k_4}$ in its turn describes parameters of freight work with cars after the end of their arrangement after FF, namely: cost and duration of fulfillment of FO on every FF, locomotive hours and car hours spent on FO on every FF, cost of work of freight-unload mechanisms and shunting equipment on every FF.

On the next stage of the system, *(p=3)*, it is offered to examine all possible variants of delivery of car groups to FF:

$$\varphi(3) = \left\{\varphi_3^{(v;\tau;\eta)}\right\}, \ v = \overline{1, k_4}, \ \tau = \overline{1, g_v!}, \ \eta = \overline{1, k_1}, \tag{7}$$

where: $\varphi_3^{(v,\tau;\eta)}$ is a vector which describes parameters of delivery of cars to FF, v is a number of variant of arrangement of cars after FF, τ is a number of variant of sequence of delivery of cars to FF for the chosen variant of arrangement (v), g_v is the amount of FF where FO is performed for v variant of arrangement, η is the index of the shunting zone where the delivery to FF starts, k_1 is the amount of shunting zones.

On the next stage *(p=2)* parameters of shunting work for reforming the rolling stock are calculated and brought forward. Here we should take into the consideration that the process of reforming may be fulfilled in different ways and in different places of the enterprise. As ways of leading a classification work there are singled out 3 types: classification on vertical climbs and half vertical climbs; classification on tracks in parks and necks by means of deposition and pulling out cars; classification by pushes (the fulfillment is possible only if there is electrical centralized point in the park).

Main parameters of carrying of shunting work, which is fulfilled for reforming of the rolling stock under v variant of distributing of cars after FF and τ variant of the sequence of delivery, are reflected in the vector $\varphi_2^{(v,\tau,\eta)}$:

$$\varphi(2) = \left\{\varphi_2^{(v;\tau;\eta)}\right\}, \ v = \overline{1, k_4}, \ \tau = \overline{1, g_v!}, \ \eta = \overline{1, k_1}, \tag{8}$$

where η is the index which indicates the amount of necks of the enterprise or station for which parameters of shunting work are calculated, k_1 is the amount of shunting zones at the enterprise which are suitable at that moment for carrying shunting classification work.

At the end the delivery of the rolling stock from the initial point to the shunting zone for further reforming is examined:

$$\varphi(1) = \left\{\varphi_1^1; \varphi_1^2; \varphi_1^3; ...; \varphi_1^{k_1}\right\} \tag{9}$$

where φ_1^η is a vector which characterizes the delivery of the rolling stock with n cars to the shunting zone η, $\eta = \overline{1, k_1}$.

The process of searching variants of technological treatment of car traffic volume may be shown as a graph. The example of such graph is shown on pic. 1. Conditional

denotations: $C(\varphi_n^i)$ is the cost of fulfilling i variant for n stage of technological treatment, $C_{m.s.z.}$ is the cost of moving to the shunting zone, C_{shun} is the cost of fulfilling shunting works, C_{moveFF} is the cost of moving to FF, C_{FO} is the cost of fulfilling freight operations.

EXPERIMENTAL RESEARCH

Let's look through the example of the searching for rational variant of technological treatment of incoming car traffic volume. Let on the enterprise came empty cars feed: 2 boxcars (BC) for freighting sackful of cement on FF 1 or FF2 with a maximum feed 10 cars and 2 gondola cars (GC) for freighting sand on FF with a maximum feed 5 cars. Cars in a rolling stock are placed in the next sequence: BC1, GC1, BC2, and GC2. We see that there no formed groups in a rolling stock that is why the first stage of technological treatment will be the delivery of cars to the shunting zone. Let there is only one zone available for shunting work at the moment then the cost of fulfillment of the first stage will be the same for all cases and will be equal to $C_{m.s.z.}=C(\varphi_1^1)=P_{mz}^1$.

On the second stage the shunting wok is performed. For its planning each car must have a sequence number of a group. As a result of the shunting work we should receive a rolling stock where cars are located in downwards numbering of groups. All variants of the shunting work for the given example are given in the table 1.

Table 1. **Initial data for planning of the shunting work and its cost**

Variants of the shunting work	Initial sequence	Final sequence	Cost $(Cshunt.)$
φ_2^1	1,2,1,2	2,2,1,1	M_1
φ_2^2	2,1,2,1	2,2,1,1	M_2
φ_2^3	1,3,2,3	3,3,2,1	M_3
φ_2^4	2,3,1,3	3,3,2,1	M_4
φ_2^5	1,2,3,2	3,2,2,1	M_5
φ_2^6	3,2,1,2	3,2,2,1	M_6
φ_2^7	2,1,3,1	3,2,1,1	M_7
φ_2^8	3,1,2,1	3,2,1,1	M_8

On the third stage the delivery of cars to FF is performed. All variants of delivery sequences for the given example are shown in the table 3.

On the fourth stage freight operations are performed. All variants of freight operations for the given example are shown in the table 2.

Table 2. **Initial data for planning of freight operations and their cost**

Variant of FO	The arrangement of cars on FF			Cost (C_{FO})
	FF1	FF2	FF3	
φ_4^1	BC1, BC2	-	GC1, GC2	FO_1
φ_4^2	BC1	BC2	GC1, GC2	FO_2
φ_4^3	BC2	BC1	GC1, GC2	FO_2
φ_4^4	-	BC1, BC2	GC1, GC2	FO_3

We should note that variants φ_4^2 and φ_4^3 have the same cost of their performing but they are examined separately because the choice of one of them influences the cost of shunting work.

Based upon the received data from table 1 and table 2 we may write down all variants of technological treatment of the rolling stock for the given example (table 3).

Table 3**. Initial data of variants of technological treatment of the rolling stock and cost of the each stage of treatment**

Variant	The delivery sequence			The amount of cars on FF			$C_{MOVIE.S.Z}$	C_{SHUN}	$C_{move.F.F}$	C_{FF}	$C_{general}$
	1	2	3	FF1	FF2	FF3					
1	FF1	FF3	FF3	2	0	2	P_{sz}^1	M_1	P_{FF}^1	FO_1	C_{gn}^1
2	FF3	FF1	FF3	2	0	2	P_{sz}^1	M_2	P_{FF}^2	FO_1	C_{gn}^2
3	FF2	FF3	FF3	0	2	2	P_{sz}^1	M_1	P_{FF}^3	FO_3	C_{gn}^3
4	FF3	FF2	FF3	0	2	2	P_{sz}^1	M_2	$P4_{FF}$	FO_3	C_{gn}^4
5	FF1	FF2	FF2	1	1	2	P_{sz}^1	M_3	$P5_{FF}$	FO_2	C_{gn}^5
6	FF1	FF2	FF2	1	1	2	P_{sz}^1	M_4	$P5_{FF}$	FO_2	C_{gn}^6
7	FF2	FF1	FF1	1	1	2	P^1sz	M_3	$P6_{FF}$	FO_2	C_{gn}^7
8	FF2	FF1	FF1	1	1	2	P_{sz}^1	M_4	P_{FF}^1	FO_2	C_{gn}^8
9	FF1	FF3	FF2	1	1	2	P_{sz}^1	M_5	P_{FF}^1	FO_2	C_{gn}^9
10	FF1	FF3	FF2	1	1	2	P_{sz}^1	M_6	P_{FF}^7	FO_2	C_{gn}^{10}
11	FF2	FF3	FF1	1	1	2	P_{sz}^1	M_5	P_{FF}^8	FO_2	C_{gn}^{11}
12	FF2	FF3	FF1	1	1	2	P_{sz}^1	M_6	P_{FF}^8	FO_2	C_{gn}^{12}
13	FF3	FF1	FF3	1	1	2	P_{sz}^1	M_7	P_{FF}^9	FO_2	C_{gn}^{13}
14	FF3	FF1	FF3	1	1	2	P_{sz}^1	M_8	P_{FF}^9	FO_2	C_{gn}^{14}
15	FF3	FF2	FF3	1	1	2	P_{sz}^1	M_7	P_{FF}^{10}	FO_2	C_{gn}^{15}
16	FF3	FF2	FF3	1	1	2	P_{sz}^1	M_8	P_{FF}^{10}	FO_2	C_{gn}^{16}

Let's note that there are variants with the same delivery sequence and the amount of cars on FF in the table 3. Such variants differ by numbers of cars which are planned to be disposed on FF. Cars receive different numbers of groups that leads to different principle of leading the shunting work and, accordingly, to its different cost. Received results are shown as a graph (fig. 1).

The optimal variant may be found as a minimum of the target function:

$$F(\varphi(u)) = C_{general} = C_{m.s.z.} + C_{shun.} + C_{moveFF} + C_{FO} \rightarrow \min \tag{9}$$

that means that we find: $C_{general}^{x} = \min\left(C_{general}^{n}\right)$, $n = \overline{1,16}$ where x - is the number of the optimal variant of technological treatment of the rolling stock.

The given principle of searching of the rational variant of technological treatment of car traffic volume is implemented as a software product. Combinatorial algorithms were developed with the help of which the search was implemented. In the software product next stages of technological treatment of car traffic volume are taken into account: delivery to the shunting zone of the feed which came to the enterprise; performance of shunting operations; delivery of formed car groups from the shunting zone to according FF; performance of freight operations with each car group.
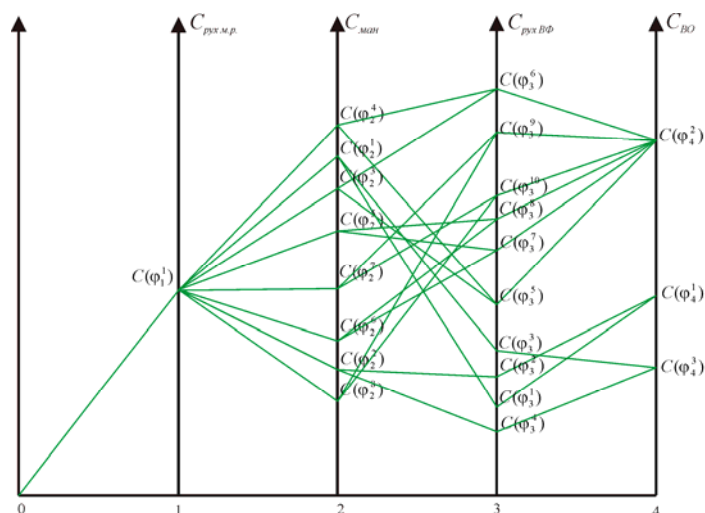
Fig. 1 The graph of defining the rational variant of technological treatment
of car traffic volume after the cost criterion

Here is the interface unit of the software product. The main window of the program (fig. 2) is used for information input about the rolling stock for which we should find the rational variant of technological treatment.

Results of the work of the program are shown on the fig. 3. Namely: sequence of delivery of car groups to FF, the list of car numbers on every FF, time of fulfilling of technological operations on every stage which are mentioned above and the general cost of each variant.

Fig. 2 The main window of the program

Fig. 3 The window of results of the program work

CONCLUSION

In the process of investigation of the problem of searching of rational variant of technological treatment of car traffic volume existing systems of computer aided planning and transport processes control were analyzed. The expedience of unmanned system of car traffic volume control which would unite functions of calculation and planning of transport work was shown. For realization of planning functions the technology of car traffic volume treatment was formalized and the principle with the help of which the search for the rational variant is performed was shown. After this principle combinatorial algorithms were built and realized in the form of software product which allows processing and analyzing of big amount of information and offer the rational variant of treatment of incoming car traffic volume.

The derived software product may be used separately or as a part of unmanned control system on industrial enterprises of rail mode. Its use will increase the effectiveness of traffic dispatcher and locomotive brigades work as a result of relatively quick receipt of some rational variants of leading the technological treatment of car traffic volume plan.

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РАЗРАБОТКА МЕТОДИКИ ПОИСКА РАЦИОНАЛЬНОГО ВАРИАНТА ТЕХНОЛОГИЧЕСКОЙ ОБРАБОТКИ ВХОДЯЩЕГО ВАГОНОПОТОКА

Короп Г.В., Заверкин А.В., Шикун О.В.

Аннотация. В статье представлены принцип и математическая модель поиска рационального варианта при оперативном планировании технологической обработки входящего вагонопотока на промышленном железнодорожном транспорте.

Ключевые слова: транспорт, железные дороги, железнодорожная техника, технологическая обработка, вагонопоток, планирование, информационная система.