CONSISTENCY IN TRANSPORTATION PROCESS CONTROL

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ABSTRACT

The article discusses a system approach to organization of the railway transportation process and interaction of the structures and workers involved in this. The transport system has five main functions: management, organization, planning, regulation and control. In a dynamic and internally connected complex railway transport system, a change in only one position leads to a change in many other components. At the same time, the theory treats management of all objects of the process as a unity of goals at different hierarchical levels, united by strategic decisions, regulatory and operational planning, and through technology of dispatch management.

Keywords: system approach, transportation control, system theory, regulatory planning, adjustment measures, non-system management.

Background. *The transportation process control system is not limited to a simple set of its components. In order to increase the efficiency of the operational work of railways, it is necessary to cover all the components of a complex structure vertically and horizontally, all connections and «mediation». This is the fundamental, root idea of a systems approach.*

Modern control of the transportation process is associtated with control methods within the operation service, while a system approach to transportation requires the expansion of the concept of control, the inclusion in the scope of its responsibility of all that is involved in transportation. That is, control also becomes a theory of ways and means of harmonizing the transportation process in railway transport, achieving the level of organization of the system that is close to the ideal of a single mechanism.

At the same time, provision of independence to the infrastructure and rolling stock complexes bears a risk of destruction of the centralized control of the transportation process, as there are interests that conflict with industry-wide ones.

The transportation process control system should proceed from the fact that control is not an end in itself, but a set of production activities of enterprises and divisions, which unites and implements the creative efforts of all services of the industry.

There are five main functions in the transport system:

- *planning – developing ways to achieve the goal;*
- *management – defining strategies, goals, criteria;*
- *organization – joining forces and streamlining;*
- *regulation – direction, bringing to normal operation;*
- *control – actions to implement the strategy, goal, plan.*

Objective. *The objective of the author is to consider different aspects of the railway transportation process control through the system approach.*

Methods. *The author uses general scientific methods, comparative analysis, mathematical, engineering and specific traffic control methods.*

Results.

Planning. *It is necessary to start optimizing control of the transportation process at the planning stage of cargo transportation. The cargo plan is the initial information for distribution of resources and the use of railway transport vehicles, determining the need for fuel and electricity, preparing regulatory and technological documents, establishing standards and indicators of operational work.*

The effectiveness of planning is largely reduced due to the expert forecast of the amount of work, often far from the real one. In determining the volume of transportation, it is mainly based not so much on the capacity of railways, but on the needs of cargo owners [8].

With the increase in the volume of transportation, the number of shipments in violation of the normative terms of cargo delivery significantly increases [2]. This suggests that in order to include applications in the cargo transportation plan, it is necessary to check the throughput capacity of the infrastructure, the processing capacity of technical stations and the discharge capacity of consignees.

The quality of regulatory and technological documents and the efficiency of transportation activities are influenced by shortcomings in development of a loading plan. The share of transportation volumes, confirmed by the applications of shippers, does not exceed 50 %. As a result, the deviation of the actual loading from the planned size in some areas is more than 60 thousand cars per year. This requires additional measures to redeploy traction rolling stock and adjust the schedule of repair work on the infrastructure [2].

ETRAN system, which has been in operation since 2000, does not envisage verification of applications for compliance of cargo transportation needs with rail transport capabilities. An automated system for coordinating applications for carriage of goods and movement of empty cars, taking into account the transportation capabilities of roads, is proposed.

The statistical infrastructure model of the railway network is described by the graph:

$G_k = \{V_k; R_k\}$,

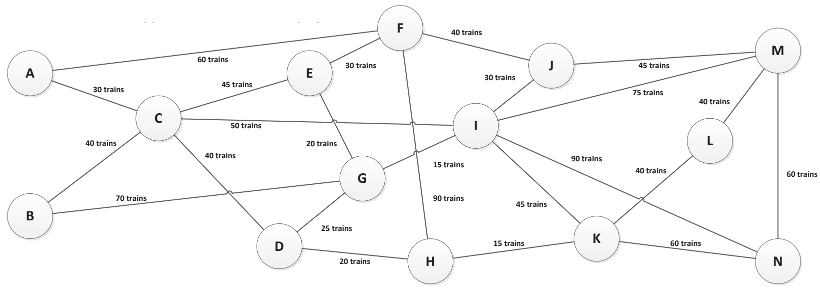
where V_k – all v_k-th vertices of the graph – stations; R_k – all r_k-th edges of the graph – sections; k – sequence number, or designation of the vertex/edge on the graph.

Each edge of the calculated graph corresponds to a set of parameters (from the Network-3 system):

$$R_k = \left\{ L_R, v_R^{\mu}, D_R^{\mu} \right\},$$

where L_R – length of the section bounded by stations (vertices) V_k, km; v_R^{μ} – section speed of cargo trains of a μ category along the section, km/h; D_R^{μ} – technological time of travel on the section R_k of trains of the category μ, h $\left(D_R^{\mu} = L_R / v_R^{\mu} \right)$.

The algorithm scans the tables of applications made at stations V_i and forms the set S in the form of a table of orders, ordered by time. In accordance with the album, the shortest distances of the application are «superimposed» on the graph of the network of railways. At each section applications (cars), «passing» on it, are summarized. The amount of cars is divided by the average composition of trains. The resulting number is compared with the available capacity of the section n_i (Pic. 1).



Pic. 1. A network of railways with transit capacity of sections.

When $N_{rj} > n_{rj}$, transportation in a round-trip (bypassing the section that has exhausted the available capacity) is offered to a consignor. If the consignor refuses to realize the application in a circle, the application is rejected.

For $N_{rj} > n_{rj}$ the application is included in the cargo transportation plan.

The long-term system at the stage of receiving applications for transportation of goods consists in maximizing the transportation capacity of the railway network and is decided by the criteria:

1) receiving the maximum number of applications (cars);

2) obtaining the highest fare (profit);

3) performance of the maximum turnover (t•km);

4) transportation of the greatest weight of goods (t).

The set of applications S is presented in the form of a list, ranked according to the corresponding criterion in descending order. This list determines the sequence of consideration of applications.

The options differ by different criteria for selecting an application for inclusion in the transportation plan, but at the same time they have the same limitation – the carrying capacity of sections. Let's consider them in more detail.

The objective function of the problem for its first variant is represented as follows (1):

$$f_1 = \Sigma p_s = max. \qquad (1)$$

At the same time, restrictions can be expressed in another form (2):

$$\forall l_j : \frac{t_j}{m_j} \le n_j . \qquad (2)$$

Let's disclose restriction. The current number of cars t_j for section j, resulting from the summation of the number of applications accepted for processing, should be related to the norm of cars m_j for this section, as a result the train flow N_j for this section will be calculated. It is compared to the available capacity of n_j section. Thus, the expression (2) takes the form:

$$\frac{p_1 + p_2 + \dots p_s}{m_j} \le n_j . \qquad (3)$$

To solve the problem defined by expressions (1) and (3), one should perform a recurrent procedure, which, in turn, requires the following to be borne in mind:

1. Stage i is put in compliance with the application s, including p = 1, 2, 3 ..., s_p cars.

2. The solution at the stage i describes the number of applications s and the corresponding number of cars P_i in each section l_j. The number of trains N in each section j is equal to

$$N_j = \frac{\sum p_j}{m_j} .$$

3. The state x_i at the stage i expresses the total number of cars, the decision to include in the plan of which was taken at the stage i, i+1, ..., s. This definition reflects the fact that the limit on the number of cars is the only one that binds s stages together.

Let $f(x_i)$ be the maximum number of cars at the stage i, i+1, ..., s for a given state of the railway network x_i. Then the solution to the problem will be found by performing the following two-step procedure.

Step 1. We express $f_i(x_i)$ as a function $f_{i+1}(x_{i+1})$:

$$f_i(x_i) = \max_{\substack{p=p_1,\dots,p_s \\ x=0,1,\dots,P}} \{p_i + f_{i+1}(x_{i+1})\}, i = 1,2,\dots,s . \qquad (4)$$

Step 2. We express x_{i+1} as a function to ensure that the left side of the equation (4) is a function of only x_i. That is, $x_i - x_{i+1} = p_i$, or $x_{i+1} = x_i - p_i$. Consequently, the recurrent equation for each state takes the form:

$$f_i(x_i) = \max_{\substack{p=p1,\dots,p_s \\ x=0,1,\dots,P}} \{p_i + f_{i+1}(x_i - p_i)\}, i = 1,2,\dots,s . \qquad (5)$$

For each stage, when calculating the maximum number of cars in sections, an algorithm is used, the block diagram of which is shown in Pic. 2

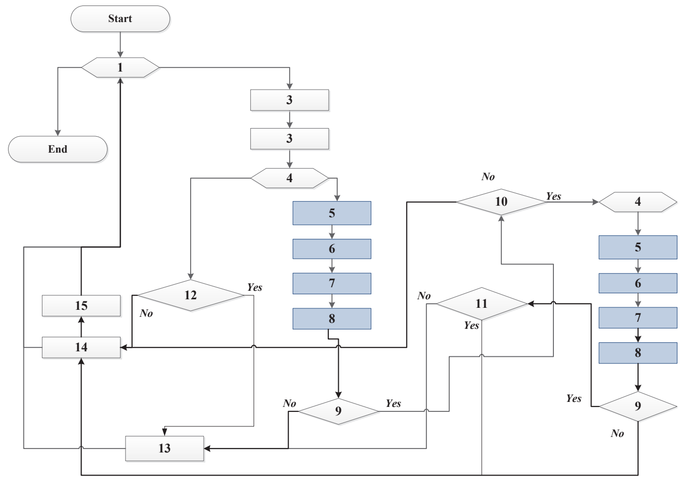
All actions assumed by the algorithm fit into fifteen blocks (in this case we omit their versions). As a result, a combination of received applications will be found, in which the number of cars in the sections is maximum and the carrying capacity is not exceeded, which is what the first version of the task required. To solve each of the remaining variants, it is necessary to change the objective function (1) and the calculations accordingly.

In the operational management system of railways, technical rationing of operational work plays a crucial role. At the stage of technical regulation, the strategy of the transportation process control is implemented on the basis of regulatory and technological documents (traffic schedule, train formation plan, technological processes at the station).

The technical plan must take into account the real possibilities of railways and contain not only indicators, but the technology and conditions for their achievement. The mode of operation of sorting stations allows to create and maintain optimal conditions. Similarly, the mode of operation of the sections allows to maintain optimal conditions for train operation [3].

In order to really manage train work, it is necessary, first, to foresee difficulties in advance and, second, to start from the moment of the origin of trains: planning of train formation, providing trains with locomotives, crews, «threads» of a traffic schedule with accompanying adjustment measures, planning an upcoming pass and supply trains to the nodal points (Pic. 3). After that it is necessary to plan transfer of trains between the roads.

The output information of each of these tasks is the input to the other task. Their joint iterative solution



Pic. 2. The block diagram of the algorithm for drawing up a transportation plan according to the criterion of the maximum number of cars in the sections.

significantly extends the timeframe of operational planning of train work.

Management. *The effectiveness of management of the transportation process depends largely on the correct management strategy. This issue is not resolved by the dispatcher on duty. Strategy (goal, program, doctrine) is set by the leadership of the industry.*

Strategic decisions should be reflected in technological and regulatory documents, in particular, traffic schedule, train formation plan, technological processes, technical plans, budget assignments, etc.

Regulatory planning is intended to fulfill the goals of a strategic decision. Traditional regulatory planning (technical plan, budget assignments) «based on the achieved level» [6, 9], by the increment method of actually fulfilled indicators is illegal, since it does not take into account feedbacks, that is, real possibilities. For example, a sorting station provides for formation of additional train appointments and, with constant technical equipment, tighten the rate of idle cars at the station. We must strive to ensure that the planned targets correspond to the strategic decisions and the real capabilities of the enterprises.

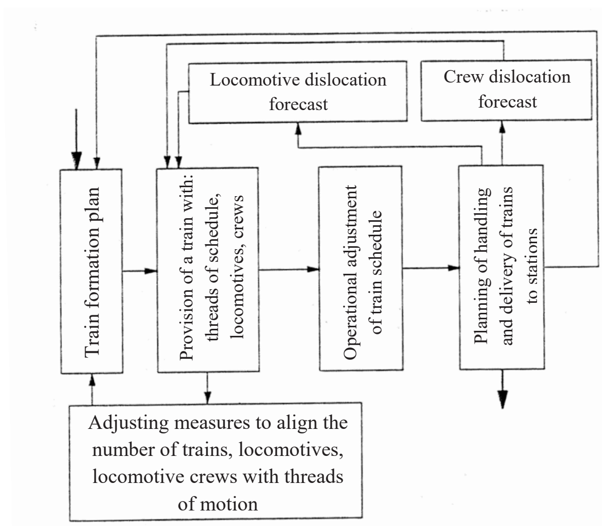
The existing analysis of real possibilities does not reveal the true reserves. These reserves can be divided into two groups: regulatory and deep.

Regulatory reserves are associated with more efficient use of established values. For example, running time is calculated on the accepted estimated weight of the train on the critical element of the track profile. In fact, many trains follow the full length of the station tracks, but not with the full weight. Consequently, such trains have reserves to reduce time they spend on the section. The situation is similar with the average downtime of cars at technical stations. It is known that the rate of average idle time is derived on the basis of certain sizes of transit car passes with and without processing. This means that with an increase in transit car flows without processing at the station, there are reserves to reduce the average idle time of cars.

Deep reserves are associated with a reduction in technological standards. It is the rise and use of these reserves that is of great interest to increase the economic efficiency of the industry.

The management of the transportation process is a continuous chain of decision-making, the choice of

Pic. 3. A block diagram of the process of planning and control of train work.



the order of work, ways of action. And here it is always important to know what we want to achieve by making this or that decision.

Setting a goal to be pursued is not as easy as it may seem. Let's take an example of technical rationing of the operational work of railways, which determines the guidelines for operational control of the transportation process. For a long time, on the one hand, it requires an increase in train average weight, and on the other, it is necessary to increase section speed. Both indicators are included in the budget production tasks. The execution of tasks for both is under the scrutiny of the management. But their goals are contradictory. There is an inversely proportional dependence between the indicators. With constant technical equipment, increasing the weight of trains causes the need to reduce section speed and vice versa. At the same time, an increase in the average weight of trains and an increase in section speed can be achieved only if the power of locomotives increases, the track state improves, etc., that is, the technical equipment changes.

The problem of multiple goals, alas, is most often solved by «administrative-command methods» [5]. Whereas goals must be prioritized. In our case, train weight should take precedence when the capacity of sections is exhausted or high. As it was in the 1980s. In the absence of construction of new unloading lines and a high level of capacity utilization, the increase in the average weight of trains then allowed to increase the volume of cargo transported annually. In modern conditions, when after reducing the volume of transportation in 1991, there were reserves of capacity, but there is a shortage of certain types of cars, priority should be given to section speed, which allows to speed up the car turnover, reduce the shortage of rolling stock and the existing fleet of cars to transport more cargo.

In order to achieve improvement of one of the indicators, to give preference to one of the goals, you will have to sacrifice other indicators. It is advisable to choose a «victim» by ranking the targets. The ranking of this kind in the technical regulation and operational control of the transportation process should be conducted according to financial and economic indicators. The optimum weight norm is designed to meet the minimum operating costs. This approach allows us to establish the impact of performance indicators on the transportation capacity and the final financial results of railways.

Organization. Because of the frequent use of the concepts «organization of car flows», «organization of movement of trains», etc. people stopped paying attention to the word «organization». It is believed that it is enough to develop a formation plan for organization of car flows, and a timetable for organizing movement of trains. And these «guidelines» themselves realize their capabilities and automatically streamline car flows and train traffic. But the development of regulatory and technological documents for the transportation process is not enough.

Regulatory and technological documents mean a reference point (compass) in a boundless sea of possibilities (options).

The regulatory schedule of motion and the adopted plan for formation of trains is only one of the options obtained for the values of the average daily size of trains and car traffic flows. And since they fluctuate in a sufficiently large range, every day, a shift, different sizes of train and car traffic flows are actually born and other variants of the schedule and formation of trains are effective.

That is, to comply with the regulatory schedule, it is necessary to organize (create and maintain) conditions for the train to go «from green to green light». The organization of this condition requires regulation of the saturation of the section with trains.

In order for the formation plan to be effective and the train assignments to comply with the conditions so that the savings from handling through the passing stations without processing exceed the cost of accumulation, it is necessary to control the fluctuations of car flows of allocated and unassigned train assignments and timely adjust the formation plan.

The transportation process has a dual nature. On the one hand, a planned basis, regulatory and technological documents, on the other – irregularity, uncertainty. And just the right organization allows you to successfully deal with unevenness and uncertainty.

Train dispatchers manage the movement of trains on the sections. We emphasize that they should also manage the operational organization of car flows. As the train schedule developed for the year is of a normative nature (the schedule of the performed movement differs significantly from the normative one), the operational organization of car flows must be based on the current formation plan, but take into account the current situation.

It is proposed to introduce special positions of dispatchers in charge of organization of car flows at railroads' traffic control centers. Their main responsibility will be to adapt the formation plan to the real operational environment. This is achieved by an early adjustment of the train formation plan even before the cars arrive at the station.

Adjustment. No matter what they say, adjustment measures are the most effective way to systematically manage the transportation process. Regulation in a sense is synonymous with management [10]. The word «regulate» comes from the Latin «regulare», which means to streamline, adjust, direct development, the movement of something with the aim of putting it in order, into the system [12].

The existing set of adjustment measures does not have a technological basis; therefore, it is not always clear in which cases it is advisable to apply certain measures, what needs to be done and what results will be obtained. Sometimes adjustment measures acquire the nature of a slogan. For example, the use of empty run of cars for transportation of goods in interchangeable rolling stock, increasing the size of unloading, train traffic; unloading part of the cars at the stations en route. Many adjustment measures are rather slogans because the dispatcher on-duty unit spends a lot of time on fixing ongoing or past events.

In order for regulation to become an effective lever in control of the transportation process, it is necessary to accelerate the transition of dispatch centers from information to control mode. This will provide an opportunity to identify in advance the disparity of needs and possibilities in transportation and to bring them into compliance. By the way, the discrepancy between needs and capabilities suggests non-system planning and control and is the main cause of difficulties in operational work, for elimination of which adjustment measures should be applied [4].

Improving the quality of control of the transportation process is associated with the effective use of adjustment measures, which allow:

• to identify and use hidden reserves in technological units;

• to increase revenues by increasing reliability and timeliness of delivery of goods and passengers, satisfying the requests of shippers, maintaining a high carrying capacity of railways;

• to reduce the cost of transportation on the basis of creating optimal working conditions for stations, sections and cargo loading fronts; strengthening the role of the schedule and train formation plan; application of economic criteria in control of train and cargo work; increasing the completeness and reliability of information on the progress of the transportation process, the state of the infrastructure and rolling stock; implementation of the system of economic relations within a division reducing unproductive losses.

In order to accomplish the assigned tasks, the adjustment measures should be determined by criteria reflecting the quality of the transportation process both from the consumers of the services (clients) and the efficiency of organization of the transportation activity and the company itself.

The main «external» criteria for assessing the quality of the transportation process for consumers of services are:

• satisfaction of customer requests for transportation;

• fulfillment of the terms of cargo delivery;

• implementation of the schedule of passenger trains;

• ensuring the safety of goods;

• ensuring traffic safety;

• timely informing the client about the transportation process.

The high level of quality and economic efficiency, profitability of the transportation process is supported with the use of «internal» criteria:

• implementation of the consolidated order for transportation of goods;

• cost of transportation;

• car performance;

• locomotive performance;

• level of traffic safety.

An important purpose of operational regulation is creation of optimal conditions for operational work.

However, the presence of such conditions is not the same as rhythmic work. We must strive for it, but we cannot make it the goal of the regulatory activities of all railway divisions. The unevenness of cargo and train work exists objectively (for example, unloading onto railway networks in the first half of the day does not exceed 20 % of the total per day) and we must not fight this, but find the opportunity to create conditions in which maximum results are achieved at minimum cost.

Why the purpose of regulation should not become the creation of rhythmic work, but optimal conditions? Because the result of distribution of local cars is the size of unloading, and the greatest unloading is achieved by maximizing the use of unloading abilities of cargo fronts by optimizing their working conditions for the timely supply of cars. Hence, the main purpose of local car distribution should not be rhythm and acceleration, but timeliness.

Similarly, the result of train formation control should not be rhythm, but timeliness of providing trains with locomotives and locomotive crews, departures according to their «threads» of the schedule.

And again, the result of regulation of train flows should be the optimal working conditions of the sections at which the greatest dimensions of train movement and fulfillment of traffic schedule standards are achieved.

Conclusion. *Operational planning, management and regulation form a coherent whole in the overall process of transportation control [13]. We should not separate them, and even more oppose them. Each of the components is not an end in itself; they are designed to complement each other and obey a common goal which is optimization of the current system.*

The efficiency of railway transport is achieved when the transportation process is considered as its main purpose, and railways represent the reliably organized and regulated integrity of the system elements.

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