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MODELING THE MOVEMENT OF LOCAL CARS AT A MARSHALLING YARD USING DIFFERENT NETWORKS

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Introduction

The principles of systems analysis and logistics methodology allow us to develop some theoretical provisions that are responsible for improving the efficiency of the transportation process. An important element in the development and functioning of the logistics of transport and logistics services is a combination of factors such as: the choice of a rational method of transport services; search for the optimal form and method of organizing transport processes; study of alternatives and compromise options for a set of parameters of the logistics function of delivery, to highlight the logistics functions of marshalling yards for the formation of technological schemes for the supply chain of goods in the area of gravity. [1,2].

To increase the reliability of local work plans, reference, technical and technological parameters of the management of organization of shunting work to form local trains at the marshalling yard [3]; planning the work of local trains between the marshalling yard and the freight station, freight terminals; planning of supply, placement and cleaning of wagons from cargo objects.

The developed methods for determining the size of transfer trains do not fully take into account the costs that occur when moving car flows from the marshalling yard to the freight station.

When determining the parameters of the movement of transfer trains, a more detailed study of the process of movement of local cars at the junction is necessary, which will allow more reasonably planning the size of the trains of transfer trains and ensure a minimum of the reduced costs.

With this approach, the number of parameters to be optimized increases. In this regard, it is necessary to develop a method for optimizing parameters, taking into account the nonlinear relationship and discreteness of individual parameters.

Obviously, the feasibility of implementing the results obtained should be cost-effective for all participants in the supply chain. This was a prerequisite for the choice of research issues to improve the planning of the local operation of the marshalling yard and adjacent areas. They are aimed at ensuring rhythmic freight and train operation of stations and the hub as a whole at the lowest cost.

Main part. Based on the general requirements of transport logistics for the delivery of the desired product (G), to the required place (A) and at the right time (T), in the required quantity (N) and condition (Q), to the required consumer (R) with the lowest possible logistics costs on the movement of goods (C), it is possible to formulate the problem of delivery of goods using the principles of transport logistics (providing transport and service services), as a search for a set of optimal values in the objective function (F) of the above parameters [1]:

$$\boldsymbol{F_{G,A,T,N,Q,R}\,(C) \rightarrow min} \qquad \textbf{(1)}$$

at

$$\boldsymbol{f\,(G, A, T, N, Q, R) = 1}$$

In this case, the following condition must be met:

The target value of function (1) will be the optimal value of the set of parameters relative to the given constraints, for example, in terms of delivery time and cost. At the same time, each parameter has its own limits of change or possible permissible values. In particular, the value of the “desired product” parameter (G) affects the method of packaging, packaging and transportation, transshipment and storage of goods, that is, its transport characteristics, as well as the type and type of transport by which this product is transported. The parameter "the right place" (A) imposes significant restrictions not only on the choice of modes of transport, but also on their interaction and sequence of work due to the absence of certain access roads and communication routes in a given territory. Similarly, it is necessary to set restrictions on each of the parameters of this function, Taking these provisions into account requires and promotes the introduction of modern innovative approaches to the development of railway transport infrastructure and transportation technology [1-3].

The principles of systems analysis and logistics methodology make it possible to develop some theoretical provisions that are responsible for increasing the efficiency of the transportation process, to highlight the logistics functions of marshalling yards for the formation of technological schemes for the supply chain of goods in the area of gravity;

consider the structure of the simulation model of the supply chain of goods in the area of gravity of the marshalling yard (node) and the city.

Sorting stations. The marshalling yards are technically, technologically and organizationally best prepared for the implementation of a system of transport and logistics services using the technical and technological base of marshalling and adjoining freight stations and terminals in the railway junction.

According to their purpose, marshalling yards are intended for mass disbandment and formation of trains, process local and transit carriage flows. Here, the limiting link of the marshalling yard is the marshalling hump and the departure park.

To implement the set task for the marshalling yard, the following tasks have been proposed:

- improvement of the hump profile (H) [1];

- increasing the possibility of increasing the number of formed local trains (transfer, export and modular), based on resource-saving technologies [2];

- formation and departure of local trains according to fixed traffic schedules, coordinated with freight stations and terminals.

When organizing the movement of transfer trains at the junction, the following costs associated with:

- with the accumulation of wagons at the marshalling yard;

- with the movement of wagons from the marshalling yard to freight points;

- with the production of cargo operations;

- with downtime of reloading mechanisms;

- with various inter-operational downtime arising from the movement of cars.

This entire complex process can be broken down into five less complex processes (Figure I.).

These processes incur the following costs:

I. In the process of performing technological operations with wagons at the marshalling yard - MY

a) for the accumulation of transfer trains - A;

b) for the formation and placement of trains in the departure park - FP;

c) for the processing of compositions - C;

d) for waiting and departure - W;

II. The process of moving transfer trains along connecting lines - CL:

a) to pay for locomotive crews - L;

b) for fuel consumption (or overcoming resistance forces) - F;

c) for acceleration and deceleration of trains - R;

d) for the movement of trains - S;

III. The process of moving wagons at a cargo station - CS:

a) for the processing of trains upon arrival - P

b) for the disbandment and formation of trains by destination - D

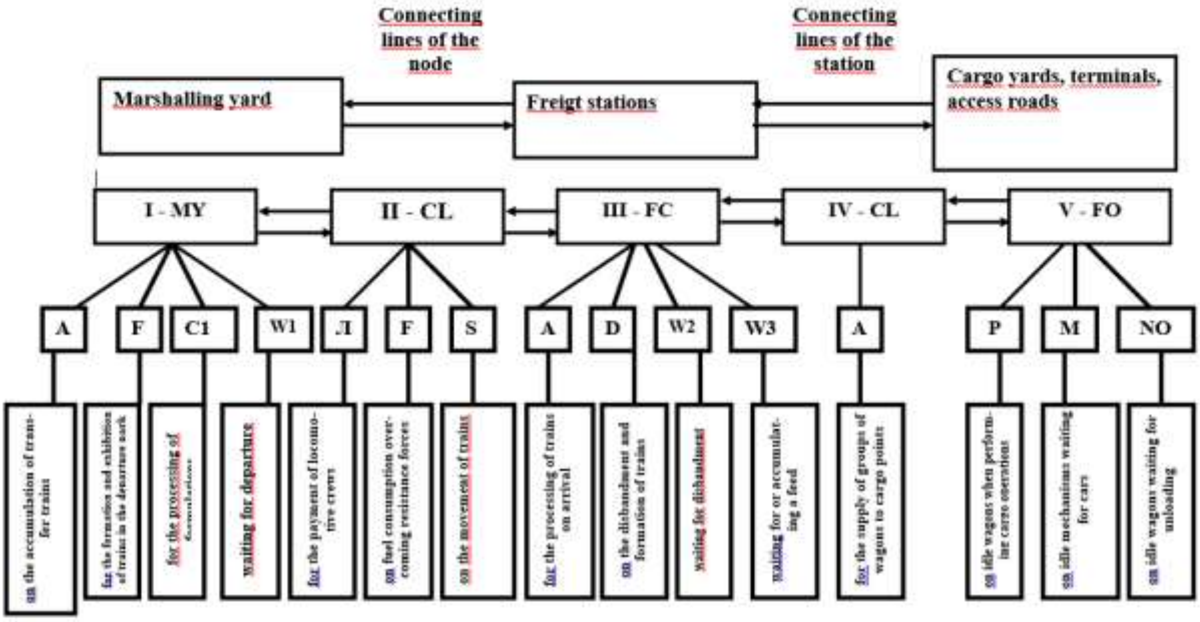


Fig.1 The process of movement of local wagons from the marshalling yard to the freight terminals in the transfer trains

c) waiting for disbandment – W2;

d) waiting or accumulating feed – W3;

IV. The process of moving wagons between the freight station and

cargo points – CP;

a) for the supply of groups of wagons by cargo points - L;

V. Process of carrying out freigt operations – FO;

a) for idle time of wagons when performing freight operations – P;

b) on idle mechanisms waiting for cars - M_{mech};

c) for the idle time of wagons awaiting unloading due to the non-operation of some cargo points at night - NO.

The basis of technical and economic calculations for determining the optimal size of transfer trains is the differentiated cost of a train-kilometer, depending on the weight and composition of the transfer. The calculation procedure consists of two stages.

When calculating the first stage, it is assumed that the size of the trains of transfer trains depends on the value of the main cost parameter 1 train-km and main idle time of transfer locomotives at stations of turnover to; at the second stage of calculations. the preliminary dimensions of the transfer movement are brought in line with the most advantageous in terms of the operating conditions of freight stations and terminals in the node [6].

The positive side of this technique is that the author proposes to coordinate (bring in line) the dimensions of the movement with the technology of the work of freight stations. In addition, the need to check the possibility of forming group transfer trains is noted.

Freight station and terminal tasks adjacent to the marshalling yard. Freight stations located in the railway junction are a connecting link in the logistics chain for the supply of goods between the marshalling yard and terminals, access roads of enterprises, and the CUC. Freight stations are intended for receiving and dispatching, forming and disbanding local trains and transmissions, supplying and cleaning wagons for freight objects, loading and unloading goods.

Analysis of indicators of the used indicators participating in The process of movement of local cars in transfer trains showed that they can be grouped into 3 interconnected modules (from fig. 1):

module-1 - organization of shunting work on the formation of local trains at the marshalling yard;

module 2 - planning the work of local trains (Fig. 2) between the marshalling yard and the freight station, freight terminals [4];

module 3 - planning the supply, placement and removal of wagons from cargo objects [4].

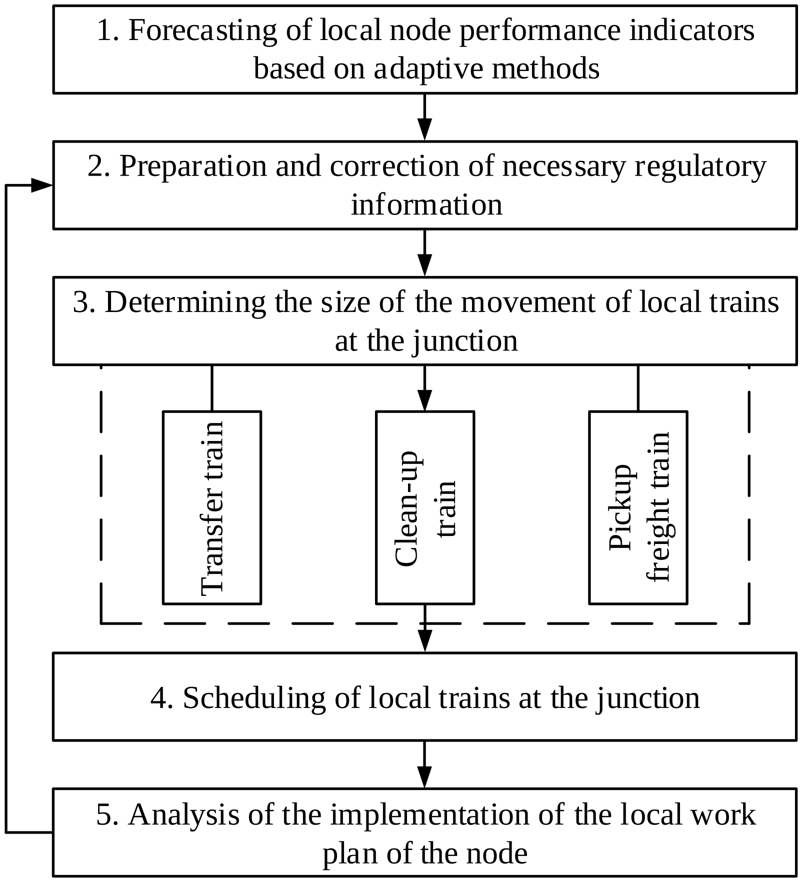


Fig. 2 Block diagram of the development of a local work plan for a railway junction.

Shunting work. Currently, the improvement of the operational management of the marshalling yard, in particular the planning of shunting operations in the areas of local work [4,5,6], is impossible without the introduction of modern computer technologies to automate the planning process [4].

An integral element of these systems should be a dynamic system for modeling the transport process, capable of providing the dispatcher with the necessary information, as well as simulating the movement of local trains on the site of the marshalling yard and the access roads of the enterprises served.

All shunting work at stations is organized according to the plan and technological process, which should ensure the timely disbandment and formation of trains, coupling, uncoupling, supply and cleaning of cars, departure and reception of trains [7, 8, 9].

There are two ways of standardizing shunting work - the method of traction calculations and the method of empirical coefficients with subsequent mathematical processing of the obtained statistical materials.

The nature of these movements is different and is determined by the configuration of the station facilities and the type of shunting work.

For a long period of time, the main criterion characterizing the quality of shunting work was the minimum time required. Almost any measures were considered effective in cases of even the smallest reduction in the downtime of wagons. However, in recent years, there has been a sharp increase in prices for diesel fuel purchased by rail, and the economy of expensive fuel comes to the fore during maneuvers. Consequently, it is necessary to more actively develop and introduce technical and technological means of reducing the specific fuel consumption in shunting work.

One of the tools contributing to the best use of shunting diesel locomotives is the regulation of shunting work. It is clear that the presence of correctly established standards allows you to take into account and analyze fuel consumption by comparing

the actual consumption per unit of volume of work performed (or per unit of time) with the established rate, to identify its cost overruns or savings. Progressive norms mobilize the initiative of locomotive crews for the rational and economical use of energy resources by diesel locomotives [8].

In accordance with the actual work performed, the main types of shunting work are:

- disbandment with the simultaneous formation from the hill (hood) of trains and transmissions;

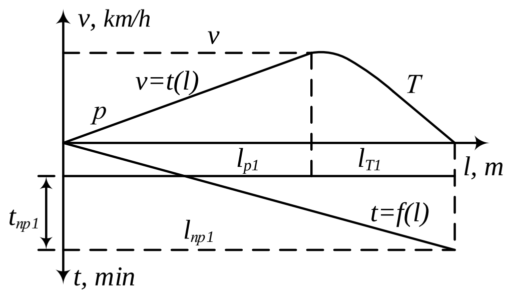
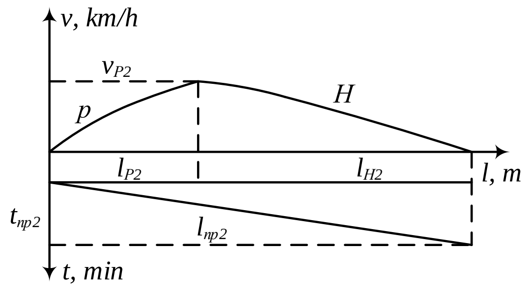
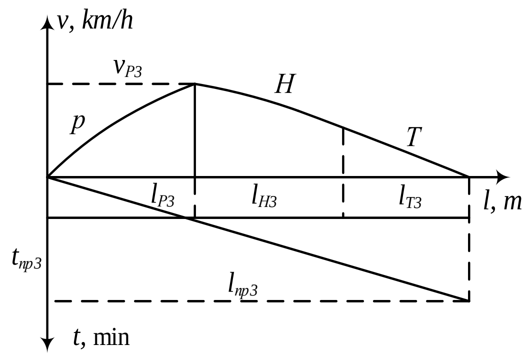
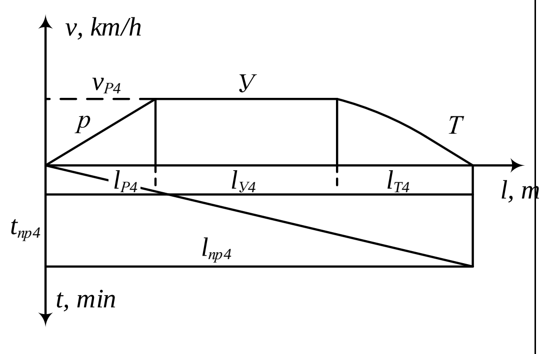
- completion of the formation of trains and transmissions from the side of the hill and exhaust lines;

- maintenance of local points located at the station and outside the station (access roads), including at intermediate stations;

- hitching, uncoupling and rearrangement of individual cars, groups or sets of trains in one fleet from track to track or from park to park;

- delivery (cleaning) of wagons to the points of repair, elimination of commercial faults, etc. [8,10].

The time for the execution of the main components of flights and semi-flights in general is normalized depending on the length of the shunting movement, the size of the shunting train, the speed of movement, the slopes of the track and other factors [6].

No.	Indicator name	Time to complete basic operations	Description
1.	OL - TR		1. According to this type of semi-flight, the driver performs movements with or without wagons, accelerating to a speed vp1, and then immediately starts braking to a complete stop; in this case, the length of the half-run is lpr1, and the time is tpr1.
2.	OL - RI		The difference from 1 is that after reaching a certain acceleration speed vp2, it turns off the traction and then the movement proceeds by inertia until it stops completely; can be used to save fuel.
3	PR-RIT		The driver, after coasting, applies braking to stop at the desired point on the way.
4	PR-RUT		It is used if the half-run length is long enough; first there is acceleration to speed vp1, then movement with a steady speed, braking to stop at the required point of the way

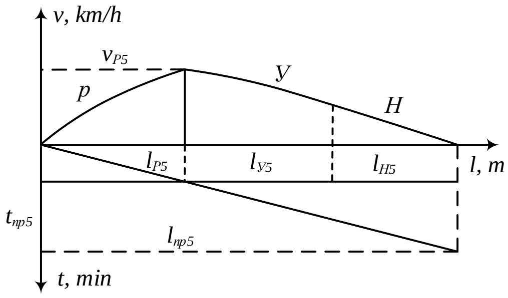
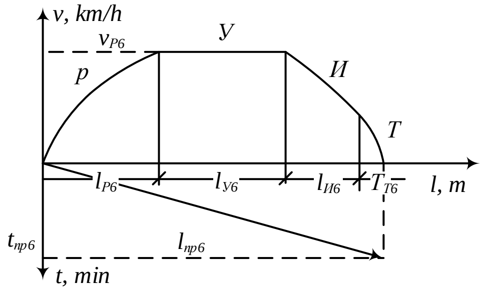
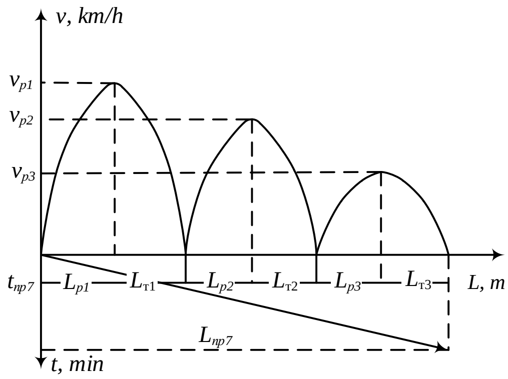
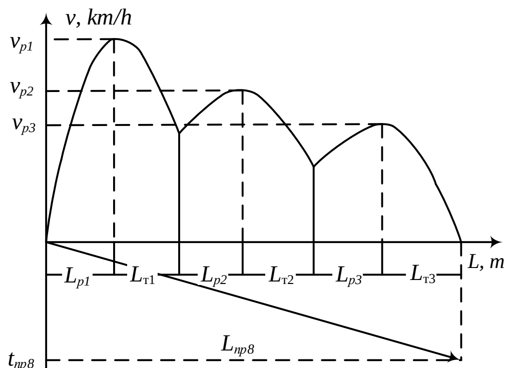
5	PR-RUI		It differs from 4 in that at the end of the movement, instead of braking, the train moves by inertia until it comes to a complete stop.
6	PR-RUIT		Same as 5, but braking is applied to stop at the set point after coasting.
7	PR -RI RI-RI		A more complex type of movement: without changing the direction of movement, several accelerations and several decelerations are applied until a complete stop; as a rule, the speed of each subsequent acceleration is lower than the speed of the previous one, i.e. vp3 <vp2 <vp1.
8	PR-CHI-CHRI		In some cases, maneuvers without changing the direction of movement are performed several accelerations and several decelerations, however, braking within a half-run is performed not until a full stop.

Fig. 2. Symbols and timing of basic operations

The most possible acceleration speed of the shunting train V_s is determined from the ratio of the locomotive power N_l and the traction force F_k at a steady speed:

$$N_л = \frac{F_k \cdot V_p}{270 \cdot \eta}, \quad (2)$$

where η is the transmission efficiency of the locomotive (taken as 0.8);

V_p - estimated speed of acceleration of the shunting train, km / h;

$$F_k = (P + Q_{мс})(w \pm i_{пр}) \tag{3}$$

where P - mass of a shunting locomotive, t;

$Q_{мс}$ - mass of the shunting train, t;

w - total specific resistance to movement, kgf / t;

$i_{пр}$ - reduced slope of the path, ‰.

Acceleration time, min:

$$t_p = \frac{V_p}{2 \cdot (f_k - w)} \tag{4}$$

where f_k - specific tangential traction force of a shunting locomotive, kgf / t:

$$f_k = \frac{F_k}{P + Q_{мс}} \tag{5}$$

Distance that the shunting train travels during acceleration, m:

$$l_p = \frac{4.17 \cdot V_p^{\ 2}}{b_T - w}, \tag{6}$$

where b_T is the specific braking force.
Braking time, min:

$$t_T = \frac{V_p}{2 \cdot (b_T + w)} \tag{7}$$

Distance that the shunting train travels during braking, m:

$$l_T = \frac{4.17 \cdot V_p^{\ 2}}{b_T + w} \tag{8}$$

Time of movement of the shunting train by inertia, min:

$$t_И = \frac{V_p}{2 \cdot w} \tag{9}$$

Distance that the shunting train travels during inertia, m:

$$l_{И} = \frac{4.17 \cdot V_p^{\ 2}}{w} \quad (10)$$

The distance that the shunting train travels during the movement at a set speed, m:

$$l_{У} = \frac{t_{У} \cdot V_p}{0{,}06}. \quad (11)$$

When standardizing, only those costs of the duration of the preparatory and final operations that require interruptions in the work of locomotives are taken into account. Standards for the duration of the preparatory and final operations, in accordance with [5].

For the convenience of performing calculations for standardizing shunting work, the duration of technological breaks is recommended to be taken into account by adjusting the duration for half-runs of upsetting, pulling, etc. through a coefficient that takes into account possible breaks in the use of the locomotive due to hostility of movements. Hostility coefficient α_{hs} is determined by the ratio of the duration of operations that cause interruptions in the production of shunting work $\sum t_{br}$ lane, to the total duration of these train processing operations $\sum t_p$ about:

$$\alpha_{hs} = \sum t_{br} / \sum t_p \quad (12)$$

The choice of the most rational methods of shunting work and its correct rationing are based on dividing shunting operations into separate semi-flights and flights. The technological duration of the shunting half-run, min, is calculated by the formula (13) [6]:

$$t_{hr} = \frac{(\alpha_{sb} + \beta_{sb} w)v}{2} + \frac{0{,}06 l_{hr}}{v}, \quad (13)$$

where α_{sb} is a coefficient that takes into account the time required to change the speed of the locomotive by 1 km / h during acceleration, and the time required to change the speed of the locomotive by 1 km / h during braking, α_{sb} = 0.0407 min / (km / h);

β_{sb} - coefficient taking into account additional speed changes

movement per one car in a shunting train per 1 km / h during acceleration, and an additional change in the speed of movement per one car in a shunting train, per 1 km / h when braking, β_{sb} = 0.0017 min / (km / h);

m is the number of cars in the shunting train;

v - permissible speed during maneuvers, km / h;

l_{hr} - half-run length, m.

Technological time when performing an empty half-run, when m = 0, will be calculated by the formula:

$$t_{hr} = \alpha_{sb}\left(\frac{v}{2}\right) + 0{,}06 l_{hr}/v \qquad \text{(fourteen)}$$

The settling of cars on the tracks of the sorting yard is carried out as follows: a process engineer builds a station diagram according to a drawing, the resulting diagram is converted into a weighted undirected graph, where the dispatcher indicates the initial position of the train, its characteristics, the final destination, and then, based on the created graph, the program calculates the route [9.11].

For effective management of local work, taking into account not only technical, but also economic criteria, it is necessary to develop a new software and hardware complex closely intertwined with modules 1, 2, 3, (module 1 - organization of shunting work on the formation of local trains at the marshalling yard; module 2 - planning the work of local trains (Fig. 1, 2) between the marshalling and freight station, freight terminals; module 3 - planning the supply, placement and removal of wagons from cargo objects).

When developing a model of operational management, one has to deal with a huge number of instructions, guidelines and techniques, expressed both in the form of clear formulations, formulas and rules, and in the form of hard-to-formalized logical expressions. In view of the enormous dimension of the system and the conditions of constant uncertainty, the attempt to build a rigorous mathematical model comes to a standstill. The experience of constructing neural network models of systems based on artificial neural networks [13-15] comes to the rescue. The experience of operating systems using the theory of artificial intelligence has not badly proven itself in countries such as Japan, Germany, Russia, etc. [16-18]

Artificial neural networks are one of the most dynamically developing and actually used in practice branches of the theory of artificial intelligence.

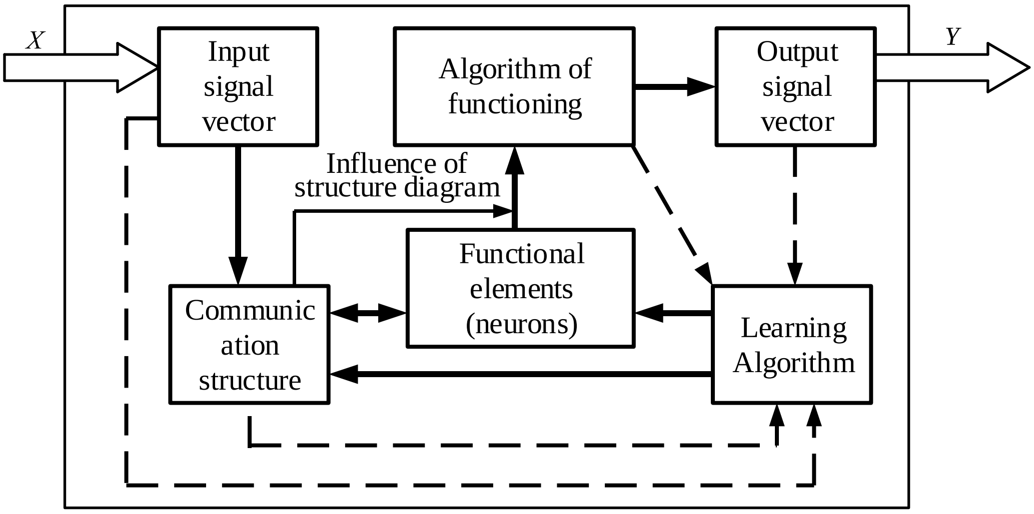
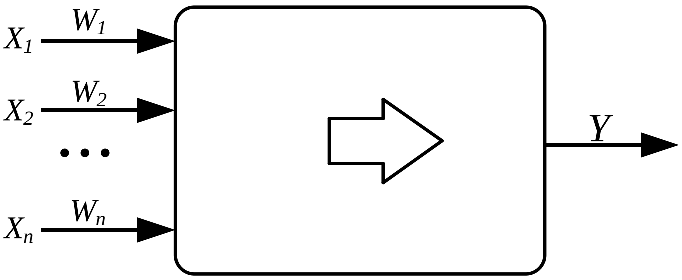


Fig. 3 The structure of a generalized model of the functioning of an artificial neural network.

The implementation of the principles of neural networks is carried out using the model shown in Fig. 4.



Rice . 4 Basic neuron signals (x- input signals; y- output signals; w- weighting factors)

The presence of weight coefficients in the structure of the neuron allows for adaptive learning of the system.

The architecture of artificial neural networks (ANN) is formed in such a way, the structure was convenient for perception and learning, from the standpoint of practical implementation of cheap [18]. The choice of ANN topology is dictated by the problem to be solved, as well as by the developer's experience.

One of the key points for solving the problem using neural network algorithms is the choice of the network topology. The convergence of the calculation of the neural network, its stability and the adequacy of the solutions found, and therefore the entire work as a whole, depend on this choice. To select a topology, it is necessary to determine the neuron model, activation function and calculation methods [17].

In addition to the choice of the topology, the developer must assign the total number of neurons in the network and the number of neurons by layers, the type of neuron activation function, the method for setting the synaptic connection coefficients, and the method for testing the health of the new network.

Regardless of the presented considerations about the possibility of teaching efficient operation of a network, the structure of which is not necessarily optimized for the problem being solved, the network must have at least some kind of structure. It is easy to show that the initial choice of a reasonable structure, well adapted to the specifics of the problem being solved, can significantly reduce the duration of training andimprove its bottom line.

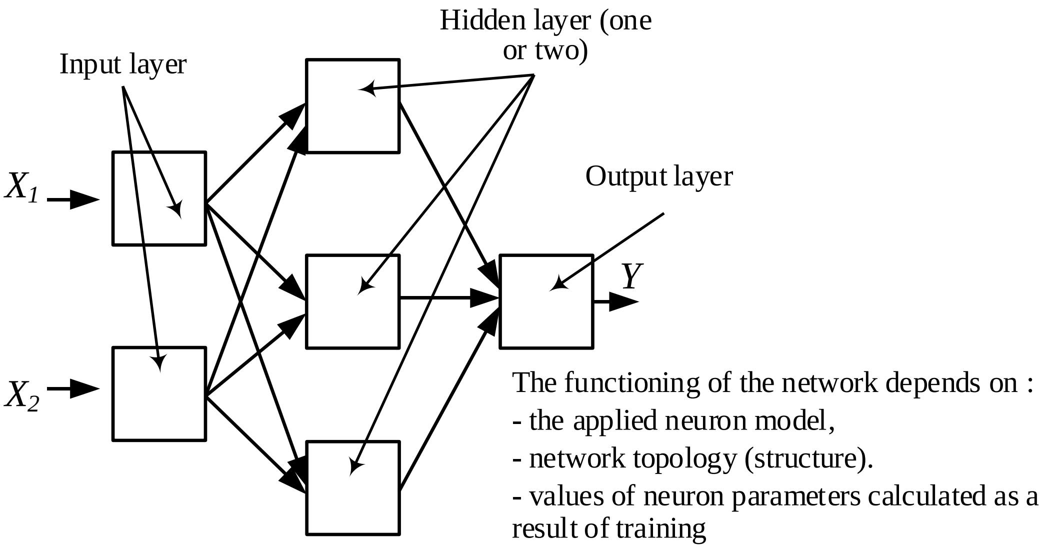


Fig. 5 Neural network structure

The choice of the method of connections is the prerogative of the network designer, most often the "each with each" scheme is used, in the expectation that the learning process will lead to the "self-crystallization" of the required set of connections at the inputs, which will turn out to be unnecessary in terms of solving the problem, in the learning process will appear zero weights, which practically breaks those unnecessary connections.

The very first layer among the layers, the neural network, needs to consider the input layer. This layer receives data from the outside networks (in this way we describe the problem to be solved). When designing the input layer of the network, it is easier to make a decision when the number of elements of this layer is precisely predetermined by the amount of input data that must be taken into account when solving the problem. There is one circumstance associated with the input of data into the neural network, which needs to be paid attention to. Neurons have the ability to generate a solution in the form of numerical values (in the form of table 1.)

Tab. 1

Symbols and timing of basic operations

	Indicator name	**Time of execution of basic operations (normative)**	**Training sample (from 100 to 200 values)**		**Predicted values of indicators after training x1 ... xn**
3.	Securing railway rolling stock	5	….	… ..	NS1
4.	Locomotive uncoupling	1	….	… …. ..	… ..
5.	Locomotive hitch	5	….	… …. ..	… ..
6.	Testing auto brakes	5	….	… …. ..	… ..
7.	Unpinning		….	… …. ..	… ..
8.	Relocation of railway rolling stock from POP to hood 20	twenty	….	… …. ..	… ..
9.	Dissolution 20	twenty	….	… …. ..	… ..
10.	Delivery of local wagons from the cargo area and non-public railway tracks		….	… …. ..	… ..
11.	Cleaning of local wagons from the cargo area and		….	… …. ..	… ..

	non-public railway tracks				
12.	Arrangement of local wagons along the fronts for unloading for loading and cleaning of wagons from the fronts 20	20	….	… … ..	… ..
13.	Completion of the formation of railway rolling stock of a single-group train 15	15	….	… … ..	… ..
14.	Completion of the formation of railway rolling stock of a prefabricated single-group train 15	15	….	… … ..	… ..
15.	Boarding of wagons on the railway tracks of the marshalling yard of the train	65	….	… … ..	… ..
16.	… ..	……	….	… … ..	… ..
N			….	… … ..	… ..

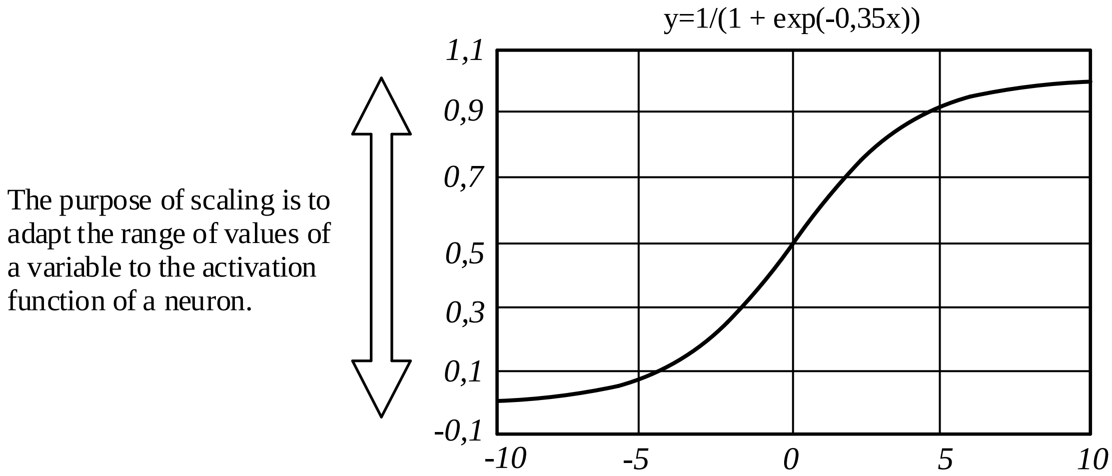


Fig. 6. Scaling range of the variable in accordance with the range of values allowed for the neuron

According to the chosen method, the corresponding algorithmspredictive modeling is based on inductive learning, which is a formalized identification of analogues of the studied situation.

In this case, the situation characterized by the vector of values of the parameters of the state of the system, at each cycle of the analysis, can be referred to a certain area in the parameter space using the adaptive learning algorithm [15].

Before starting to build a neural network model, it is necessary to determine the number of factors, the value of which will be perceived by the neural network as input (criterion) parameters. With a significant increase in their number, the obviousness of the decisions made disappears, and their interpretation becomes more difficult. In accordance with generally accepted approaches, their number should be reduced by removing from the model functionally related factors [16] in view of redundancy (one of them).

A significant number of adaptations of the neural network method are presented on the software market. During the research, the STATISTICA Neural Networks package was used. Its advantages include the implementation of a powerful analytical method - a genetic algorithm for selecting input data, which allows you to form an optimal set of input variables and makes it possible to select the most significant ones for subsequent analysis using traditional models [10-13].

Conclusions: The developed methodology presented in the article to optimize shunting work on the tracks of a marshalling, cargo station and terminals sets the task to reduce the cost of transporting goods along this chain by reducing costs and, if necessary, the time of shunting work and the possibility of its more rational planning.

The key tasks of this article are the formation of initial data for the use and training of neural network models for organizing the movement of local cars in the gravity area of the marshalling yard, the use of neural networks to solve the problem.

Further research will be aimed at developing the remaining elements of the system and combining them into a single whole.

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