# INNOVATIVE APPROACH TO MARSHALLING YARD CONTROL AUTOMATION

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## ABSTRACT

A block diagram of an automated control system of a marshalling yard operation with elements of artificial intelligence is offered. The intelligent units, which are «Neural network forecasting» and «Formation of control decisions», are considered. Their connection with processing of traffic volumes in an operationally controlled technological process is studied.

*Keywords: railway, automated control system, transportation process, marshalling yard, neural network technology, intelligent transport systems.*

**Background.** *Intelligent control at a linear level should be implemented in the first place in marshalling yards, which are the most important parts of a continuous process of cargo transportation by rail. By increasing its size it is required also to increase production capacity of railway stations [10, 15]. But even in times of recession of transportation volume work to improve the efficiency of the sorting process continues. New technologies are introduced and station operations are automated.*

**Objective.** *The objective of the author is to consider innovative approaches used for automation of marshalling yard work.*

**Methods.** *The author uses general scientific and engineering methods, mathematical apparatus, graph construction, modeling.*

**Results.** *The efficiency of the marshalling yard is largely dependent on the quality of operational control decisions made. In the conditions of intensive and uneven movement of freight trains on sections of the railway network, functioning of a plurality of rolling stock operators-owners, as well as limited station, shunting, traction and time resources it is a relevant task to develop innovative methods and technologies for organization of operational work in marshalling yards in the automated mode. Integration of all basic, information elements of the station marshalling complex should be performed in a model of an automated system of marshalling yard control with elements of artificial intelligence (ASIC MY).*

*Pic. 1 is a formalized scheme of interaction in the system of operational control of the marshalling yard work. External in relation to the individual objects of technological lines of processing of train- and car flows are control decisions $\overline{R}_{DSCS,DSC}$, $\overline{R}_{TNC}$, $\overline{R}_{DNC}$ (respectively of station, shunting, train and locomotive dispatchers). Internal, which relate to fleet, shunting areas and the locomotive depot of the station, are control decisions $\overline{A}_{DSPP}$, $\overline{A}_{DSPG}$, $\overline{A}_{DSPF}$, $\overline{A}_{DSP}$, $\overline{A}_{TCH}$. All decisions are implemented as planned parameters of work of various divisions of the station $x_{01}$, $x_{02}$,…*

*Control decisions of dispatcher level $\overline{R}$ are defined by functionality*

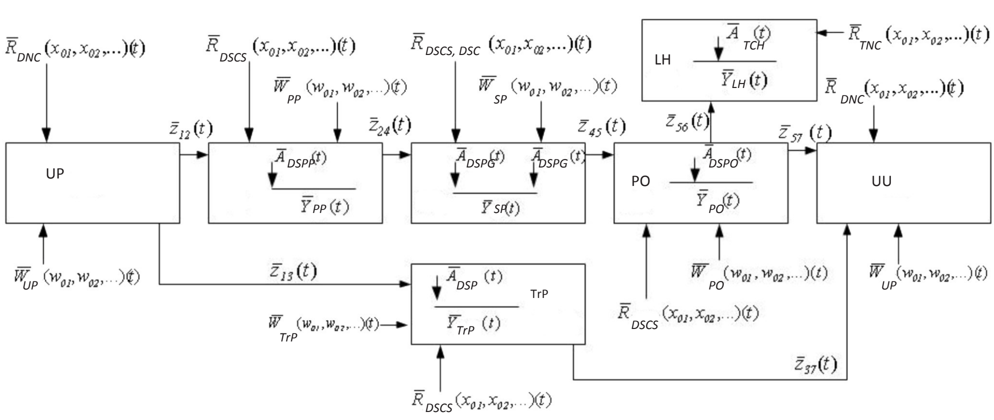
$$\overline{R}(x_{01},x_{02},...)(t)=F(x_{F1}\vee x_{TP1},x_{F2}\vee x_{TP2},...,$$
$$a_{r1},a_{r2},...,w_{r1},w_{r2},...,Y^{n}_{st}(y_{r1},y_{r2},...)(t). \qquad (1)$$

*In the expression (1) $x_f \vee x_{TP}$ is a comparison of figures of technical plan for the station with their actual values at the beginning of planning period in the control cycle; $a_r$ is technical-technological figures of the control object of dispatch level. Disturbances, which are in the process of planning and control of operational work of a marshalling yard and adjacent sections, are expressed in terms of a parameter $\overline{W}_r(w_{r1},w_{r2},...)$.*

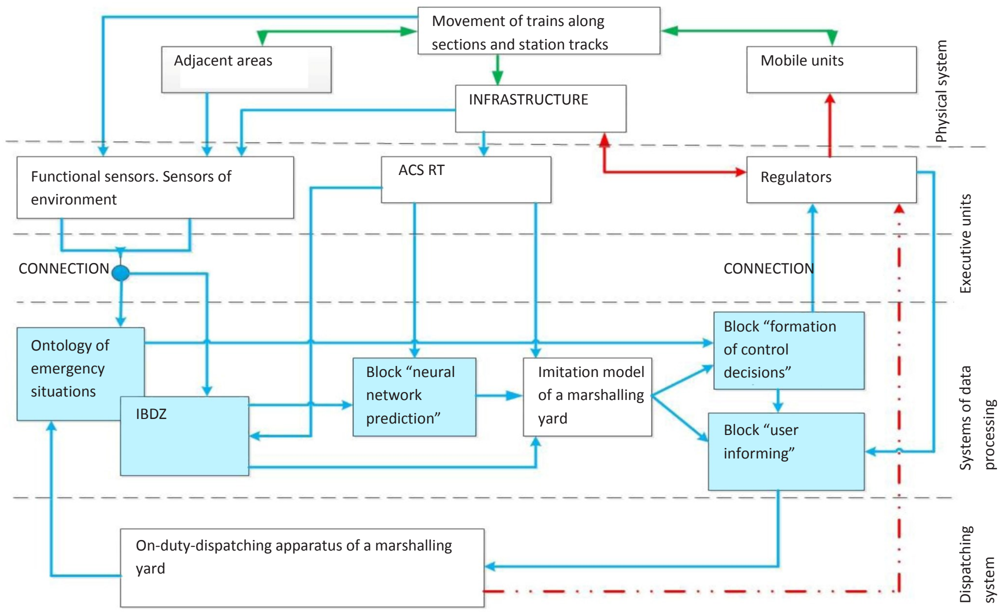
*Disturbances within the operating system of marshalling yards occur due to failures of technical means and violations of established technology. The external disturbances should include the impact of technology disruption on systems, operationally interacting with rail transport, expressed in the non-uniformity of incoming train- and car flows.*

*Multivariate state of operational control system $Y^{n}_{st}$ is determined by the parameters of placement of mobile control objects directly at the marshalling yard.*

*In formal interaction scheme (Pic. 1) tasks of displacement of train- and car flows for control units*




***Pic. 1. Formal scheme of interaction in the control system of operational work at the marshalling yard.***




***Pic. 2. Block diagram of the automated control system of marshalling yard work with the elements of artificial intelligence.***

*in park of acceptance and transit (PP, TrP), marshalling park and departure park (SP, PO) and in locomotive sector and adjacent areas of departure of trains (LH, UU) are expressed in the form of parameters $\overline{z}_{12}$, $\overline{z}_{21}$, etc.*

*The most sustainable mode of reception and departure of trains for the marshalling yard is determined by performing the following expression based on consistently increasing values of the parameters of the processing capacity of production lines, as well as unconditional fulfillment of the task $\overline{z}_{56}$:*

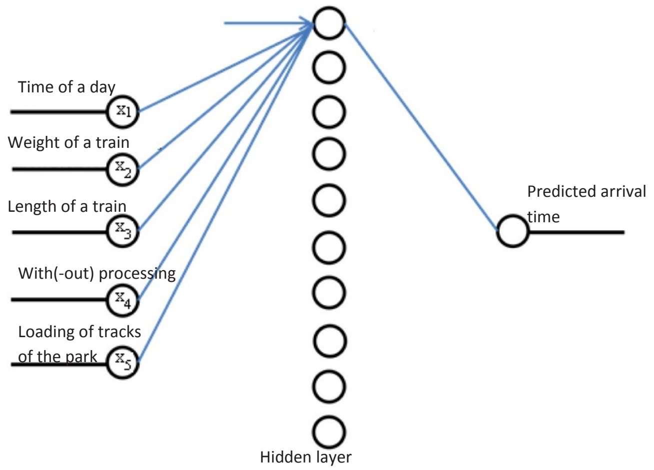
$$\overline{z}_{12}+\overline{z}_{13}\approx\overline{z}_{37}+\overline{z}_{57}. \quad (2)$$

*The level of compliance with the specified ratio between tasks affects largely the operational reliability of the marshalling yard and the implementation of its main qualitative and quantitative indicators.*

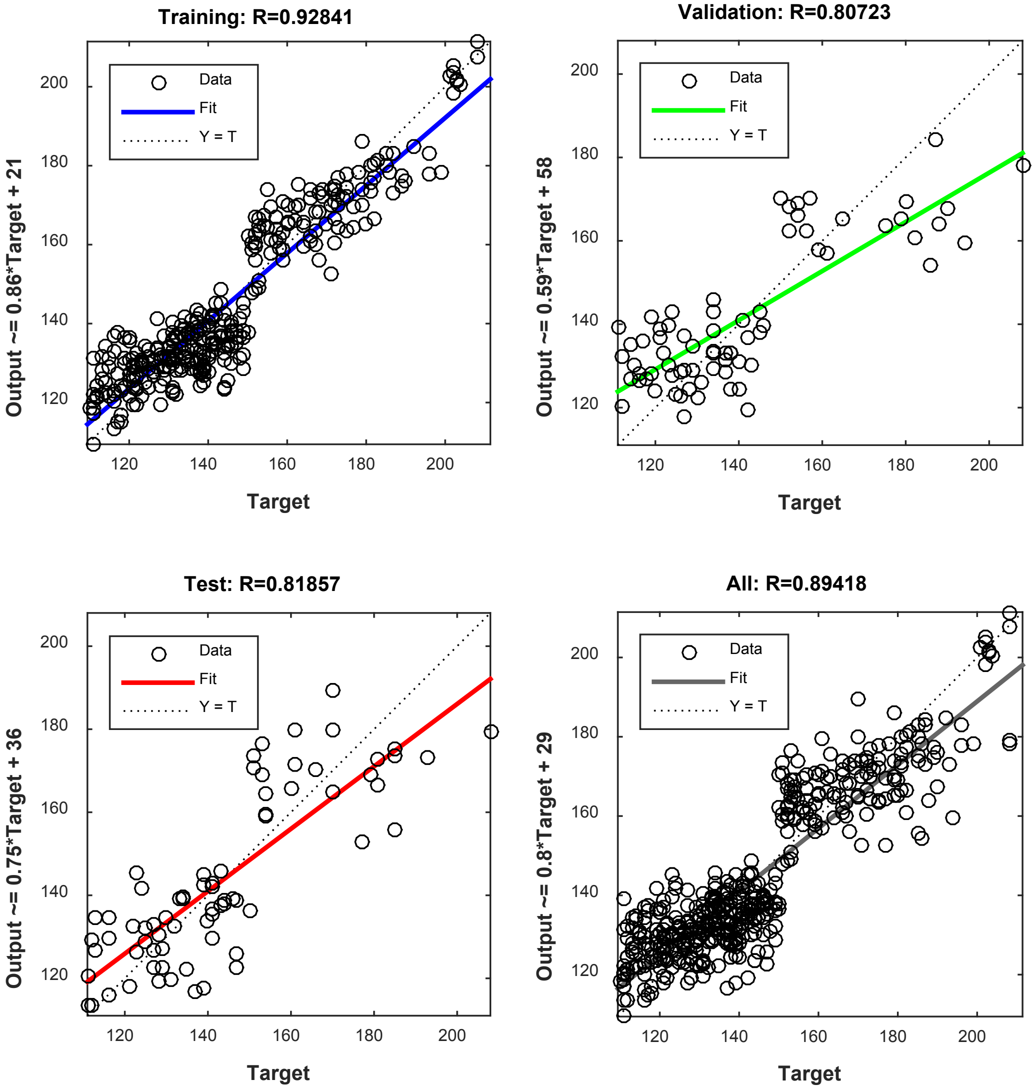
*Control solutions in the chain of technological lines of the system of processing of a car flow at the stage of planning t is also generated by a relevant manager on the basis of functional:*

$$\overline{A}_{st}(x_{01},x_{02},...)(t)=F((x_{01},x_{02},...),a_{st1},a_{st2},..., w_{st1},w_{st2},...,Y_{st}(y_{r1},y_{r2},...))(t), \quad (3)$$

*where $\overline{A}_{st}(x_{01},x_{02},...)(t)$ are control decisions for implementation of planned parameters of the technological process of processing of a car flow,*




***Pic. 3. Scheme of connection of the input and the hidden layer of ANN.***




***Pic. 4. Correlation analysis of modeling of forecast of train arrival time at the marshalling yard.***

*realized in different technological lines of the marshalling yard;*

$x_{01}$, $x_{02}$... *are planned tasks, that should be implemented at the level of individual technological lines of the station;*

$a_{st1}$, $a_{st2}$,... *are parameters, characterizing technical and technological state of facilities of the marshalling yard;*

$w_{st1}$, $w_{st2}$,... *are disturbing influences exerted on the process of operational management of the operational work of the marshalling yard;*

$Y_{st}(y_{r1}, y_{r2},...)$ *is a multi-dimensional state of the operating system of the transportation process at the marshalling yard.*

*Development of control decisions in the conditions of incomplete and inaccurate information, as well as an imitation of human creativity through processing and use of knowledge of on-duty dispatcher apparatus of the marshalling yard is impossible without gradual introduction of elements of intelligent technologies [8, 12, 13] in ACS, functioning on the railway transport. An important task is to transfer human operator experience into machine intelligence. This transition is suggested to be carried out in accordance with the developed structural scheme of an automated control system of the work of the marshalling yard with the elements of artificial intelligence, shown in Pic.2.*

*Here the intelligent modules are block «Neural network forecasting» and the block «Formation of control decisions», which is responsible for correct execution of a sequence of train and shunting operations within the boundaries of areas of the marshalling yard.*

*Currently, the most promising quantitative method of forecasting is to use the technology of artificial neural networks [9, 11]. In general, predictive neural network is a machine that simulates the way how the human brain processes a particular task. Using even the simplest neural network architecture and database (about actually performed transportation with the values of the basic parameters) makes it possible to get a working system of forecasting, and system's accounting of affecting factors is determined by the inclusion or exclusion of the corresponding*

$$\left\langle \begin{array}{l} X_1^1 - characteristics\ of\ the\ track\ №1\ of\ the\ park\ №\ 1; \\ X_2^1\ - characteristics\ of\ the\ track\ №2\ of\ the\ park\ №\ 1; \\ \qquad\qquad\qquad\qquad\qquad ...; \\ X_{p-1}^{I(J)} - characteristics\ of\ the\ track\ №\ n-1\ of\ the\ park\ I(J)\ ; \\ \\ X_n^{train} - characteristics\ of\ the\ train \end{array} \right\rangle \to \left\langle \begin{array}{l} Y_1 - park\ of\ reception\ № \\ Y_2 - track\ № \end{array} \right\rangle \qquad (5)$$

*receptor of the input layer in ANN [5, 6]. During training examples are presented to the network from the database and it adjusts itself inferences mechanisms with their account and entering new information is used for correction of parameters of interneuronal connections which constitute a dynamic knowledge base [1, 2, 4].*

*For approximation of a function of several variables, the most versatile approach is the use of an artificial neural network with a direct connection, static neurons and sigmoid activation function (Pic. 3). ANN with static neurons hereinafter refers to a network in which at the output signal appears at the same moment when the signals are delivered to its input.*

*The results of work of a neural network is the forecast of arrival of a train of a certain category and composition to the marshalling yard with regard for current positions of trains at the station and adjacent areas.*

*Simulation results of predictive neural network represented by correlation analysis of the learning process (Pic. 4) on the example of real railway sections of Moscow Railway, showed the fundamental possibility of applying ANN apparatus for solving the problem of forecasting the arrival of trains at the marshalling yard. The accuracy of data obtained in the process of modeling should be regarded as sufficient in order to develop the methods of neural network forecasting in developing ASIC MY. The direction of further improvement of this predictive model is the development of factorologic database.*

*Block «Formation of control actions» in its basis has a neural network model capable of recognizing different operational situations and finding appropriate quasi-optimal solution for the given initial data.*

*To solve the problem of the choice of routes for train receipt at the station a neural network model was developed that recognizes images of operational situations that arise in the process of development of control decisions for preparation of the train's reception route at the station. In the design of the subsystem methods of construction of recurrent networks were used [3], with the use of appropriate learning algorithms and the formation of the correct display of a pair of «correct input signal→correct output signal (X→Y)» on the type «input, known output»:*

$$X \to Y = \langle x_1, x_2, ..., x_n \rangle \to \langle Y_1, Y_2 \rangle = \\ = (\langle x_1, x_2, ..., x_n \rangle, \langle Y_1, Y_2 \rangle). \qquad (4)$$

*In accordance with the expression (4) an unambiguous value at the output layer of ANN for the system «park – track – arriving train» was received:*

*In the expression (5)* $X_p^{I(J)} = \{x_1; x_2; x_3; x_4\}$ *is a vector of state of the track P of the park I (J), which is characterized by the following parameters:*

*$x_1$ – track state (0 – free, 1 – occupied);*

*$x_2$ – presence of cars with oversized cargo in the train (0 – no, 1 – yes);*

*$x_3$ – presence of cars with dangerous cargo in the train (0 – no, 1 – yes);*

*$x_4$ – length of the track in conditional cars (0 – less than a conditional unit, 1 – more than a conditional unit).*

*In turn vector of the state of arriving train is determined by the parameters:*

$X_1^{train}$ *– presence of oversized cargo in the train (0 – no, 1 – yes);*

$X_2^{train}$ *– presence of cars with dangerous cargo in the train (0 – no, 1 – yes);*

$X_3^{train}$ *– factor, taking into account the length of the train within conditionally set for this park (0 – less, 1 – more);*

$X_4^{train}$ *– factor, taking into account distribution of cars in the disbanded train (car flow prevails for the even subsystem of the marshalling park – 1, for odd – 0);*

$X_5^{train}$ *– transit train with processing (0 – no, 1 – yes);*

$X_6^{train}$ *– transit train without processing (0 – no, 1 – yes).*

*Correlation analysis of learning outcomes of ANN indicates that the dispersion of the points around the dotted line and the degree of deviation of the regression line from it characterizes a mistake of ANN in choosing the number and the track of the park for receipt of a certain cargo train at the marshalling yard. For example, in the training sample R = 0,9993; in the test sample R = 0,9294 and in the control sample R = 0,8986. The experimental method has found that by reducing the number of neurons of the receptor layer by changing the input data coding system accuracy and correctness of training and work of ANN have not changed.*

*Thus, with this calculated example, was proved a principal possibility of using the apparatus of artificial neural networks to solve the problem of intelligent choice of the route – park and route of receipt of a cargo train arriving at the railway marshalling yard. In the modeling weighting coefficients in interneuronal connections and constants shifts have been found that can be used to create the appropriate software and integration with ASIC MY.*

*The conducted study of various neural network methods for solving the problem of the automated selection of sequence of shunting and train movements within the boundaries of the individual shunting areas of the marshalling yard [14] made it possible to formulate general principles and algorithm of constructing a model of a subsystem of the block*

*«Formation of control solutions» regarding intellectual choice of routes of mobile units along station tracks:*

*1) A marshalling yard is divided into separate shunting areas for which local neural network models are developed for selection of the sequence and the order of movement of train and shunting locomotives, compositions and trains. If necessary for the individual shunting operations optional dependences of the inter-district impact are found.*

*2) For each shunting area encoded routes and a list of basic train and shunting routes, of which they are composed, are defined.*

*3) Time moments are defined Tj, when it is required to select the order and sequence of implementation of routes under different states of the shunting area.*

*4) When justifying the prioritization of basic routes, semi-trips and trips for time moments Tj, in the calculations projected or calculated values of speed of movement when performing the routes (V) are used.*

***Conclusion.*** *The proposed method of situational neural network control of the work of the marshalling yard will improve the quality of operational planning and control on a dedicated production facility, reduce unproductive downtime on separate production lines, increase the rhythm of train and shunting operations, as well as implement more fully the concept of sparsely populated technologies in rail transport.*

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