Railway traffic management system with the intellectual control

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***Abstract*—The article substantiates the necessity of applying methods of intellectual control in the railway traffic management system. The list of operational tasks that can be solved by intellectual methods is offered. The structure of an intelligent management system for the transportation process is proposed. The stages of the system creation are determined. The experience of implementing intelligent management on the Belarusian Railroad is described.**

***Keywords*—railway transport, transportation process, intelligent management, system structure, operational task**

I. Introduction

Railway traffic management system is complicated but holistic. Intellectualization of any element (goal, subsystem and so on) should be explored in connection with all subsystems and tiers of entire system. System properties are consequence of it complexity:

- the large number of interrelated and interdependent elements, with a change in the performance characteristics of any of the elements reflected in the functioning of the other elements and the whole system;
- the system and the elements included in it are mostly multifunctional;
- the system elements interaction occurs both through the realization of the physical process, and through information exchange, i.e. using transport channels and information channels;
- there is a common goal of the system, despite the diversity of local goals of the functioning of its elements;
- the elements interaction within including system and with adjacent systems (for example, with neighboring roads) is of an indeterminate extent stochastic;
- the human factor, both in making a decision and in implementing it, increases the uncertainty of the system states [1].

II. Theoretical prerequisites of intellectual control

Decision making in the railway traffic management system (RTMS) involves a high level of uncertainty of information about the environment and the object of operation, as well as the need to minimize the risks from making inefficient decisions. For these conditions, the development of control decision (CD) is proposed to be viewed from the position of situational management theory [2], based on the management of complex technical and organizational systems and logical-linguistic models for current situations. The process of situational management assumes the presence of the following elements (Fig 1):

- **analyzer** generates information on a specific operational situation and throws a message about the need for intervention in the management process;
- **classifier** arranges the information about the current situation to one or several classes to which the implemented control must correspond;
- **correlator** receives all information from the classifier and produces a control solution if a single solution comes from the extrapolator, and transfers information to the random selection block if the extrapolator forms several rules;
- **extrapolator** contains all the logical and transformational rules (LTR), determines what LTR should be used;
- **selection block** determine a rule from the LTR proposed by correlator.

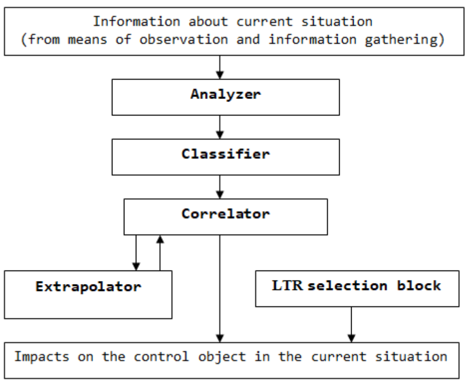

Figure 1. Generalized scheme for the implementation of situational management in RTMS.

Management of the transportation process using methods and models inherent in intelligent systems involves the solution of the following operational tasks:

- organization of railroad car traffic, design and real-time adjustment of the train picking plan;
- train schedule development
- locomotive work management
- real-time planning for work with trains and loading

- empty railroad car traffic adjustment
- real-time management for trains on districts and lines.
- real-time management of station complexes
- real-time management of the local cargo delivery in the local work areas.

The list of tasks to be solved will expand while the intellectual control application area in the railway traffic management system is growing. Within the scope of these tasks, individual subtasks may appear. For example, in the framework of the task "train picking plan design", subtasks can be singled out: design of a plan for sender routing; one-group trains, multi-group trains, local work, etc. This approach does not contradict the methodology of intellectual management, but only confirms the need for designing RTMS as a scalable, self-learning and dynamically developing system.

Regardless of the tier (network, road, linear) and the detail degree of the operational task, for all of them there are unified approaches to describing the problem environment and the search for rational SD. Such approaches are:

- consideration of the operational task solution functional environment as a multi-agent system in which each of the management objects may have local target criteria and, as a consequence, conflicts of interest;
- obligatoriness to consider the problem as multi-criteria. At the same time, both the set of criteria and the level of their significance can change at different times;
- solving operational tasks in conditions of incomplete and uncertain initial data;
- necessity to improve the methods of solving operational tasks through the organization of "learning". The learning of the system involves both the use of more effective methods of searching for rational CD, and the change in the optimality criteria and their significance, the definition (clarification) of the missing initial ones proceeding from the values of the parameters of the objects of the functioning environment;
- the task solution involves not only a quantitative assessment of the parameters characterizing an effective control decision, but also the possible difficulties forecasting associated with the CD implementation. Those the search for rational CD provides for a risk analysis of its implementation and possible consequences.

The use of unified approaches to the description of the problematic environment will provide the following advantages in comparison with the "traditional" methods of solution:

- initial data uncertainty Decrease due to use of the harmonized initial data;
- decrease in entropy in solving operational tasks by using the results of solving some problems as initial data for solving others;
- the ability to search for global extremes in assessing the efficiency of the transportation process, rather than local for each individual task;
- ensuring an objective assessment of the influence of results from solving one operational problem to the decision about control solutions in another task.

III. Experience in the design and implementation of a railway traffic management system on the Belarusian Railways

The Belarusian State University of Transport has developed technical documentation for the development of the Integrated Train Management System at the Belarusian Railways (ITMS-BRW) (Fig. 2).

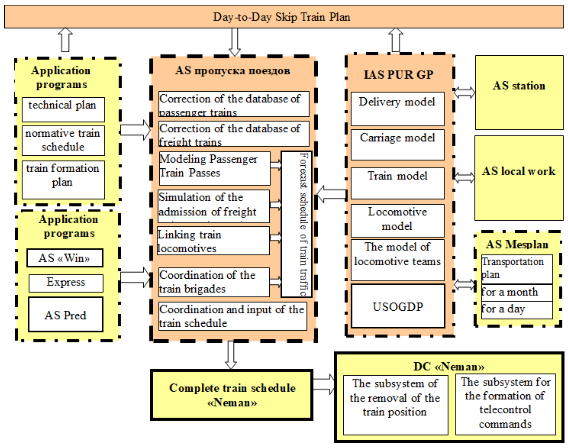

Figure 2. Functional structure of the Integrated Train Management System at the Belarusian Railway.

Creation of the ITMSBRW involves the following stages:

1) Creation of transportation process information and mathematical models on the basis of a unified road network for data transmission, information and reference systems development and implementation, a phased transition to modern microprocessor-based dispatching centralization systems in the sections of the Belarusian Railways.
2) Intellectualized information and planning systems development and implementation, which oriented to the TMC (Transportation Management Center) real-time dispatch center, restructuring of the transportation management system at the Belarusian Railways departments.
3) Transition to intelligent forecasting, planning, management and decision support systems, implementation of measures for additional centralization and concentration of road management, restructuring of the linear transportation management system, development of promising measures, development of necessary technical, technological and regulatory documentation.

At the moment, the tasks of the first stage have been largely solved at the Belarusian Railway: monitoring, displaying and control the signaling devices state, monitoring the train situation, automating the trains' routes, maintaining the executed traffic schedule and applications to it, analyzing the schedule executing, railway cars and locomotive models handling. The release of this tasks set allowed to significantly reduce the load of train dispatchers. As a result, the required number of dispatching circles was reduced from 33 to 21.

The tasks of the second stage are: construction of the forecast train traffic schedule, planning of train building at the stations, locomotives and locomotive crews provision planning for the completed trains (ready for departure) on the basis of the train handling simulation. Currently, most of these systems are in industrial and pilot maintenance in the TMC. Specialists of the Belarusian Railways took part in their development with the direct participation of the BelGUT staff. The automated system for the collection of requests and planning to provide technological gaps (AS "Okna") and the system of accounting and alerting “warnings” for trains (AS PRED) railways have been put into commercial use. The system of real-time train building planning (USOGDP) and the system of the forecast trains schedule automatic construction (AS PGDP) are in trial operation. An end-to-end system of shift-daily loading / unloading planning, which includes all tiers of management, operates on all objects of the Belarusian Railways.

In parallel, BelGUT carried out work on automating the development of normative and variant train traffic schedules, and individual tasks of train formation plan automated calculation were solved. The release of the second stage tasks made it possible to ensure the rhythm of the train traffic process, to reduce the idle time at the station while waiting for departure, and to reduce the required fleet of train locomotives.

Thus, the prerequisites for the third stage intelligent transport systems introduction are created. Such systems include automatic preparation of train routes, offering recommendations on the trains including into the traffic schedule, optimal trains crossing and outrunning, adjusting measures to prevent or eliminate difficulties in the trains handling.

IV. The problem environment of intellectual management in railway transport

Intellectual railway traffic management system (IRTMS) should have qualitatively new "intellectual" properties [3]:

1) the ability to conduct purposefully in any operational environment;
2) the ability to adapt to changes in environmental conditions;
3) the ability to learn and build knowledge bases on the interaction of the environment and the IRTMS;
4) the ability to apply the knowledge acquired to make a decision and organize its execution in changing environmental conditions.

To implement these properties, it is proposed to consider IRTMS as a multi-agent system. A multi-agent system has the following properties [3]:

1) Autonomy and reactivity. The agent is independent and self-governing. The agent receives data from the external environment, responds to its changes and does not require the user to take any additional steps to start the work.
2) Decentralization. There is no agent managing other agents in the system. In this case, one agent may exist in the system, which will generate other agents and set goals for them, but the internal behavior of agents is determined only by their own rules, goals and intentions.
3) Communicative. The agent must communicate with other agents using some agreed language of communication. In the process of communication agents can exchange knowledge or set other agents new targets for implementation.
4) Purposefulness. Each agent must have a specific goal that the agent is trying to accomplish. The behavior of this agent, its interaction with other agents and the external environment must be subordinated to the fulfillment of this goal.

The key aspect for the formation of an effective multi-agent system is the correct description of the problem environment and the subsequent ontological design [4]

When describing the problematic environment of the Intellectual railway traffic management system (IRTMS) for each agent, it is required to establish:

- performance indicators;
- the operating environment;
- executive mechanisms;
- sensors.

Description fragment of IRTMS problematic environment see in table 1.

In the control system of the transportation process, it is often necessary to solve multicriteria tasks, the performance indicators for various agents can vary. In this case, the same indicator in some cases can be considered as determining, in others - as a limitation in the solution of the problem, in the third - as a component of the integrated indicator.

Depending on the state of the problem environment of the system and the macro tasks assigned to the IRTMS, various purposes of functioning may be set. Depending on this, with the same initial data, various optimality criteria, methods and algorithms for solving problems can be used, and, as a result, different ”right” results can be obtained. Therefore, before solving the problem (agent actions), it is necessary to formulate a description of the problem situation.

While formulating the following criteria should be discovered:

- criteria for optimality of decisions;
- key indicators of the quality of decisions;
- features of the external environment of functioning.

In determining the problem situation it is necessary to solve the following issues:

- formulation of the problem and its classification in accordance with the characteristics established in the system;
- discover the newness of the problem
- discover the prerequisites, environmental conditions, macrosystem factors that led to the emergence of a new problem situation;
- description of the relationship of the problem situation to other tasks solved within the system (for example, the need for a planned repair of the track may require an operative correction of the train formation plan or not

Table I
DESCRIPTION FRAGMENT OF IRTMS PROBLEMATIC ENVIRONMENT

The problem environment parameter	**Description**
System of shift and daily planning of loading-unloading	
Benchmarks (Performance metrics)	Compliance with the delivery and the performance of cargo operations, the minimum need for loading resources, the minimum run of wagons in the empty state
Environment	Railway stations open for freight operations wagons, cargo, railway network
Executive method	Showing on the user workspace of plans and tasks for carrying out cargo operations
Sensors (input)	IAS SMD FT[a] messages about operations with wagons, transportation requests from the AS "Mesplan", showing data on the users workspace
Train formation planning system	
Benchmarks (Performance metrics)	Compliance with delivery deadlines, minimum time of wagons in stations
Environment	Technical stations, wagons at stations and in trains
Executive method	Showing train formation plan and train departure schedule on workstations
Sensors (input)	IAS SMD FT[a] messages about operations with wagons, executed train schedule, station tracks model
Train schedule development system	
Benchmarks (Performance metrics)	Provision of the specified throughput (maximum trains number), service speed
Environment	All trains in the main tracks on hauls and stations
Executive method	Showing developed train schedule on the workstations and in the executed schedule
Sensors (input)	Traffic controller workstation
Route preparation system	
Benchmarks (Performance metrics)	The minimum route preparation time, enforcement of the specified time intervals, the maximum level of reliability, provision of traffic safety conditions
Environment	All trains in the main tracks on hauls and stations
Executive method	Traffic light, actuators of switches
Sensors (input)	The hauls and station tracks block-sections controllers of occupancy, state controllers of the switches

[a]Information-Analytical System of Supports Management Decisions for Freight Transportation.

require, affect the unloading parameters of the station stations or will not affect, etc.);
- discover the completeness and degree of reliability of initial data on a problem situation;
- discover the methodology and methods for solving the problem, including on interrelated tasks.

It should be noted that a problematic situation is understood as any technological task being solved, and not only that which is connected with deviation from established modes of functioning.

Whale formulate a description of a problem situation, it is necessary to compose the **solving problem situations library**. I.e. a set of methods and techniques that were used to solve a similar problem in previous periods.

V. CONCLUSION

The involvement of intelligent management in the railway traffic management system in full will allow to increase the productivity of train locomotives by at least 5%, reduce the wagon turnover by 2.5%, increase the productivity of operative staff by 30%.

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ИНТЕЛЛЕКТУАЛЬНОЕ УПРАВЛЕНИЕ В СИСТЕМЕ ОРГАНИЗАЦИИ ПЕРЕВОЗОК НА ЖЕЛЕЗНОДОРОЖНОМ ТРАНСПОРТЕ

Ерофеев А.А.

В статье обоснована необходимость применения методов интеллектуального управления в системе организации перевозок на железнодорожном транспорте. Сформирован перечень эксплуатационных задач, которые могут решаться интеллектуальными методами. Предложена структура интеллектуальной системы управления перевозочным процессом. Определены этапы создания системы. Описан опыт реализации интеллектуального управления на Белорусской железной дороге.