About Creation of the Intelligent Transportation Control System in Railway Transport

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***Abstract*—The relevance of the development of an intelligent system for managing the transportation process is determined. The structure of the system construction theory is given. The experience of developing automated systems on the Belarusian railway is described and the effectiveness of their implementation is evaluated. It has been established that the main condition for the interaction of automated systems with each other is the use of a single ontology of the transportation process. It is indicated that the OSTIS technology is an effective tool for describing the process-object ontology of the transportation process. The advantages and limitations of using OSTIS technology in ITCS are established.**

***Keywords*—Intelligent Transportation Control System, Ontology, process-object approach, transportation process, OSTIS technology**

Automation of individual tasks of managing the transportation process (TP) was one of the first areas of informatization of the railway transport activity. However, in modern conditions, the efficiency of previously developed automated systems (AS) has decreased due to significant fluctuations in the power and structure of traffic flows and changes in the technologies of the transportation process.Further development of existing AS has significant limitations: the exact mathematical model of the object may be too complex or unconstructible; changes in the external object environment lead to the action on the object of a number of perturbations, which are an additional source of uncertainty about the state of the object; performance requirements can be loosely formalized and inconsistent. It is proposed to overcome these shortcomings by moving from information-reference and settlement systems to intellectual ones.

BelSUT has developed a theory for building an Intelligent Transportation Control System (ITCS), the use of which in the development, implementation and operation will increase the adaptability of transportation process technologies to a changing operational environment, solve new operational problems, ensure coordination and continuity of control decisions, improve system manageability, which Together, it will ensure the efficient functioning of the railway in the face of changes in the volume and structure of traffic flows and optimize the operating costs for the organization of transportation activities [1], [2].

A graphical interpretation of the methodology for creating an ITCS is shown in “Fig. 1”.

The creation of the ITCS is aimed at:

- implementation of a coordinated integrated transportation process management system (TPMS) using by all participants in this activity a single digital model of the transportation process (DMTP), which describes the transport processes, covering the activities of all involved departments and all levels of management;
- improving the quality of information in the TPMS;
- formation of services for operational information and technological interaction of participants in the transportation process within the framework of a single long-term, medium-term, shift-daily and current planning, execution and control of agreed and approved plans;
- implementation of adaptive automatic control of technological processes for operational work and control over the execution of control decisions (CD);
- operational step-by-step and process assessment of CD.

The functioning of the ITCS is aimed at improving the efficiency of the TP by:

- increasing the speed of traffic flows;
- reducing the turnaround time of the wagon, including by reducing the time spent by the wagon in an empty state;
- reducing operating costs, including by increasing the productivity of locomotives in freight traffic, increasing the efficiency of using the car fleet;
- implementation of rational options for passing train flows in a changing operational environment;
- reducing the number of overtimes at technical stations during the turnover of a freight car and increasing the transit capacity of car traffic.

Currently, the following functional modules of the ITCS have been implemented or are being implemented at the Belarusian Railways. The AS ”Graphist” software package (“Fig. 2”) allows you to develop train schedules (DTS) [3], [4]. Currently, it is in commercial operation at the Transportation Control Center of the Belarusian Railways.

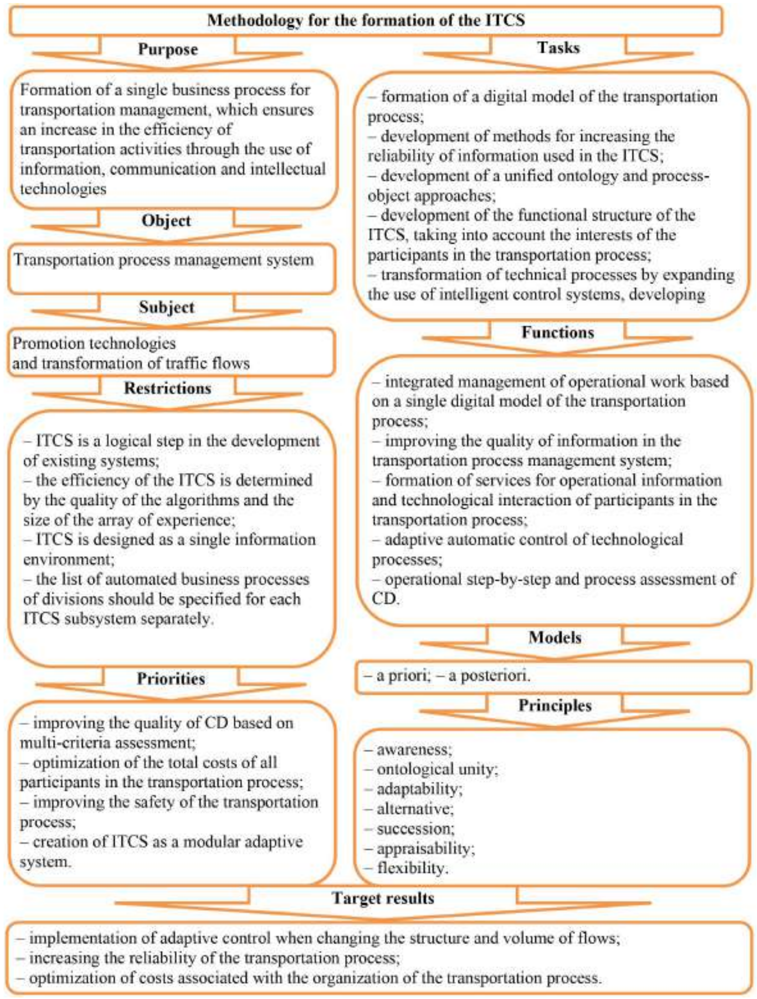

Figure 1. Graphical interpretation of the methodology for the formation of ITCS.

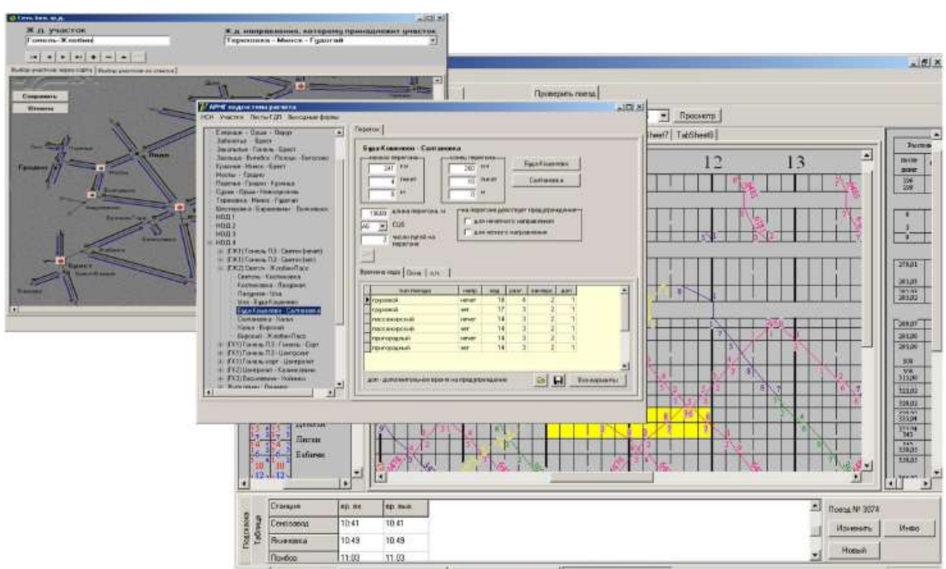

Figure 2. Modules for automatic construction of the DTS and its adjustment in AS "Graphist".

The intelligent algorithm for the development of the DTS is designed in such a way that, depending on the relative position of trains in the DTS and their categories, determine which of the station intervals should be used in each specific case. The calculation is made taking into account the mutual influence of the stations of the section. The solution of the problem is envisaged at the range of any length and configuration. Intellectualization of the functions of the development of the DTS allowed to reduce the workload of engineering personnel by 20-30%. The introduction of AS "Graphist" made it possible to increase the sectional speed by 7-11.5% in some sections and reduce the specific energy costs for train traction by 3-6%.

An automated system for shift-daily scheduling of cargo work (AS SDS) has been developed and put into commercial operation, which for the first time in the world provides end-to-end scheduling of railway freight work for the entire polygon of the road, all levels of management (road, departmental, linear) and all planning periods [5].

The AS SDS ("Fig. 3") implements the functions of intelligently linking wagons to requests (taking into account their condition, location, expiration category, owner and other features), as well as other elements of intelligent technologies: forecasting the time of arrival of wagons at the station, adjusting planned indicators for the second shift depending on their implementation for the first; formation of plans taking into account the directive establishment of an increased task for loading, etc.

Based on the results of the operation of the AS SDS, it was found that by improving the accuracy of planning, the share of unscheduled loading decreased by 20-30%. For the first time, a system of number-wise planning of cargo work with high planning accuracy (91-94%) has been implemented. The use of intelligent technologies in the planning system made it possible to increase the ratio of double operations by 8-12%; reduce the downtime of a local car at individual freight stations of the station by 6-9%.

An automated system for linking train formation with a train schedule (LTFDTS) has been developed and put into commercial operation ("Fig. 4") [6].

The main output decisions are: the schedule for the departure of freight trains from train stations for the forecast period; a plan for processing trains at train stations during the forecast period; dislocation of trains and wagons at train stations at the end of the forecast period. An intelligent solution of LTFDTS is also an abbreviated predictive DTS, in which, by means of multifactorial selection, all trains participating in train formation are linked to the threads of the predictive DTS.

Intellectualization of the train formation planning process at the Belarusian Railway range using LTFDTS made it possible to increase the efficiency of dispatching control by increasing the reliability and automating the development of a predictive train schedule with further use in the automated train traffic control system (autodispatcher). This made it possible to enlarge the ranges of train traffic control by 1.3-1.5 times and optimize costs; reduce the time spent by trains and locomotives at technical stations by reducing the waiting time of technological operations from 15 to 20 percent; to ensure the coordination of the predictive DTS with the train and locomotive model of the road, reducing non-production losses of locomotive crews up to 20 percent.

Various development companies participated in the creation of these and a number of other systems. One key condition for their creation was to ensure the exchange of CD between different systems of the ITCS. For these purposes, a unified ontology of the transportation process was formalized.

The ontology of the transportation process presupposes the existence of unified ways of describing the system and the processes occurring in it. This task is inextricably linked with the formation of a digital model of the transportation process (DMTP). Actual mechanisms for the formation of the CMPP should allow for the real-time simulation of the state of the TP. This requires the unification of requirements for the content and form of presentation of information about the parameters of the functioning of objects [7].

DMTP may include:

1) models of objects (including resources) of the TPMS;
2) process models – a description of the processes occurring both in the TPMS and in the external object environment;
3) models of the external object environment, describing the external impact on the objects of the transportation process;
4) situation forecasting models – the study of options for the development of the transport situation in case of emergency changes in the state of the elements of the transport system, the external environment, with changes in the characteristics of information flows;
5) CD formation models that provide an analysis of the operational environment and the formation of effective CD;
6) assessment models that provide an assessment of the effectiveness of the implemented CD, the state of objects and the parameters of the software.

CMPP is focused on the implementation of dual control, i.e. adaptive control, in which not only the goals are achieved, but also the model is refined.

All DMTP objects are divided into the following subgroups:

- static objects (infrastructure objects);
- dynamic objects (tracking objects) ("Tab. I").

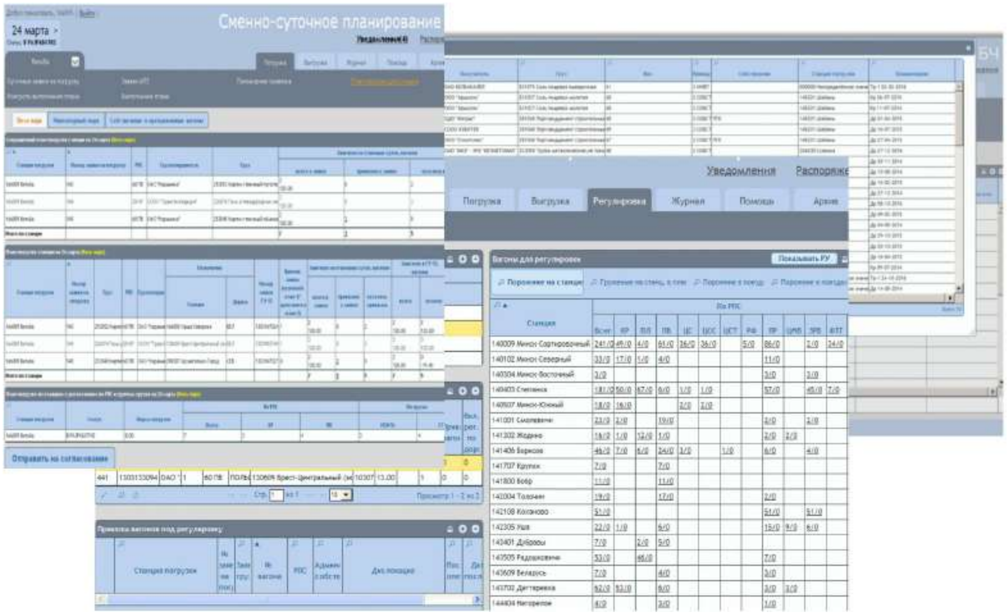

Figure 3. Modules for intelligent planning, linking applications to wagons and monitoring the implementation of plans in AS SDS.

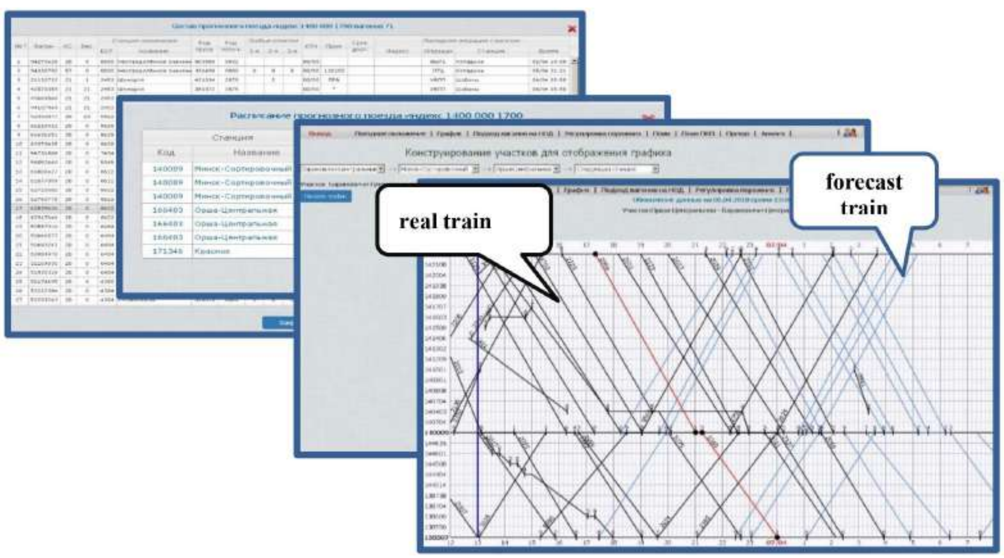

Figure 4. Modules of intelligent planning of composition formation and predictive DTS in LTFDTS.

Table I
DMTP FACILITIES

static objects (infrastructure objects)	dynamic objects (tracking objects)
Railway; – department; – railroad station; – interstate crossing point; – control area; – control room; – railway direction; – railway section; – haul; – block section; – depo.	– train; – railway carriage; – container; – sending; – locomotive; – brigade; – document.

Based on the digital transformation of the logical entities of infrastructure objects, an ontology of static objects is formed. Each logical entity consists of several connected objects, which in the database are divided into the following sub-schemes (groups of tables): railway, departments, railway stations, railway sections, depots and auxiliary tables. This subgroup of modeling objects also includes such logical entities of the TP as a train schedule, a train formation plan, a local cargo delivery scheme, etc.

The given subschemes consist of a number of separate interconnected tables with a description of elementary (topographic) objects. For example, the digital model of the "railway station" object includes the following elementary objects:

- paths;
- turnouts;
- traffic lights;
- passenger platforms;
- building;
- artificial constructions;
- subgrade, etc.

Based on the digital transformation of logical entities such as "train", "car", "container", "dispatch", "locomotive", "document", an ontology of dynamic TP objects is formed. Each logical entity consists of several logically connected objects. In accordance with this, the set of dynamic objects is logically divided into the following subschemes: trains, wagons, containers, shipments, locomotives, crews. When formalizing an ontology in the form of a database, the set of dynamic objects is supplemented by documents and auxiliary tables that describe the properties of each object.

Tables of descriptions of control objects are logically interconnected. Information about each tracking object is entered into the corresponding logical subcircuit, which consists of several levels. Each database table of the next level is a child of the table of the previous level.

Modeling of infrastructure objects and vehicles for solving operational problems of the ITCS is based on semantic and ontological links between these TP objects.

In the ontological scheme of TP, objects are interconnected within their group. The "station" object is an element (attribute) of higher-level objects – "department" and "railway section". In turn, the "railway section" is an element of the "department" object, and its attributes are determined based on the parameters of the station object. The topmost level in the group of static objects is the "railway".

The positioning parameters of dynamic objects (objects of tracking) are connected with each other and with elementary infrastructure objects. Depending on the stage of the SP, the parameters of the tracking objects are combined into one top-level tracking object, or vice versa, the top-level object is divided into lower-level objects. After the loading process, the "dispatch" object is included in the temporary group of the "wagon" object. The technological lifetime of this group ends after the unloading operation is completed. A similar procedure is performed when transforming the objects "car" and "locomotive" into the top-level object "train".

Traditionally, AS are focused on collecting, aggregating and presenting information to a person. A distinctive feature of the ISMS should be its focus on solving operational problems (problem orientation).

The object-oriented approach is based on the representation of each object of the software domain in the form of a classifier and its description by a set of properties – characteristics. To describe the relationship between objects, a special unit of data is used – a relation. Combinations of these elements form models of objects and situations. The classifier is a set of initial units of information (concepts of the selected subject area) systematized according to classification criteria and their groupings, representing generalized concepts. Creation of a model of objects of the required subject area of TP allows you to adapt the basic knowledge of the ITCS to solve the necessary ET.

The process-oriented approach is based on the formation of a model for the execution of technological operations of the software, aimed at achieving the ultimate goal of solving the operational and (or) completing the solution of the problem within the time limits established by the technology. A process is generally understood as "a set of interrelated and interacting activities that transforms inputs into outputs."

To describe the TPMS, a process-object ontology of TP is proposed as a symbiosis of ontological description, object-oriented and process-oriented approaches [1].

An effective tool for describing the process-object ontology of TP, in our opinion, is the OSTIS technology. This choice is due to the following important properties of the technology [8]–[10].

1) OSTIS technology is a technology of component (modular) and platform-independent design of semantically compatible intelligent systems that have knowledge bases of any complexity and implement parallel models of knowledge processing. This allows you to effectively integrate systems of various developers with each other and feel complex CD.
2) The knowledge base of an ostis-system, i.e., a system built using the OSTIS Technology, is a semantic network that generally has a complex hierarchical structure, in which there are elements denoting not only external entities and relationships between them, but also various classes elements of the semantic network, various fragments of this network, various connections between the indicated classes, between the indicated fragments. All this provides unlimited opportunities for the transition from knowledge to metaknowledge. This approach makes it possible to ensure the solution of new ET, including those based on the formation of CD under conditions of uncertainty in the initial data.
3) The basis of parallel models of knowledge processing in systems built using OSTIS Technology is the model of asynchronous knowledge management. The essence of this model is that all (!) knowledge processing processes performed by a certain set of agents are initiated by the corresponding situations or events that occur in the semantic memory during the processing of the knowledge base. At the same

time, any computer system, incl. and the one that does not solve intellectual problems can be built on the basis of the OSTIS Technology, i.e., in the form of an ostis-system. This property makes it possible to develop IS through the phased implementation of intelligent functions in automated systems.

However, the use of OSTIS Technology has significant limitations:

- a relatively small number of developers own this technology, and those companies that know this technology do not have the competence in building management systems in transport;
- the study of the OSTIS Technology is quite problematic, since a single description standard has not been approved.

The Republic of Belarus has the conditions to take the lead positions in the world in the development of intelligent control systems for railway transport:

- there is a team of scientists-experts who have been dealing with the issues of informatization of transport processes for decades. Most experts work at BelSUT or are its graduates;
- scientific schools in the field of artificial intelligence (BSUIR, BSU, etc.) are effectively functioning in a number of universities;
- there are many software development companies with a staff of highly qualified programmers, most of which are concentrated in the Hi-Tech Park.

In this regard, an important task is the formation of scientific and practical consortiums that have the necessary knowledge and competencies to build an ITCS using OSTIS technology.

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О создании интеллектуальной системы управления перевозками на железнодорожном транспорте

Ерофеев А. А.

Показана актуальность разработки интеллектуальной системы управления перевозочным процессом. Представлена структура теории построения систем. Описан опыт разработки автоматизированных систем на Белорусской железной дороге и оценена эффективность их внедрения. Установлено, что основным условием взаимодействия автоматизированных систем между собой является использование единой онтологии перевозочного процесса. Показано, что Технология OSTIS является эффективным инструментом описания процессно-объектной онтологии транспортного процесса. Установлены преимущества и ограничения использования Технологии OSTIS в ИТКС.

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