

Construction of a conceptual model of transport system for a coal mining region

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Abstract. The methodological approaches to creation of a conceptual model of complex transport system for coal-mining region are substantiated. In the structure of the system base model the ensemble of local interconnected subsystems is distinguished. The local structure of the traffic management system of cargo transportation company is developed, the factors and indicators affecting the efficiency of cargo management are highlighted.

1. Introduction

The need for dynamic development of cargo transportation companies (CTC) in Kemerovo region is confirmed by the fact that the processes taking place in the complex transport system, are described by a large number of parameters, interaction of which is not possible to describe by the corresponding equations and relationships, that can be solved analytically.

The transport system in Kemerovo region corresponds to all the attributes of a complex system, that is proved by the following features [1]:

- unique character in terms of ensurance of coal flows – more than 200 million tons per year, while similar transport systems in other regions of Russia are characterized by a smaller scale of transportations and diversity of traffic flows of goods;
- weak structuring of theoretical and factual knowledge about the future of the transport system in connection with the reduction of coal production and capacity of coal market under the influence of growth of competitive energy sources, the requirements to the reduction of environmental pollution, expansion of pipeline transportation of oil and gas;
- composite character of the system, as it includes local interconnected subsystems in the form of cargo transport companies, distributed in the space of geological-economic regions and hierarchically subordinated to different firms, holding companies and industrial associations.
- heterogeneity of subsystems according to coal sources (mines, open-pit mines, processing plants), types of carbon storages, schemes of transportation flows on the private tracks;
- contingency and uncertainty of factors in the transport system, including the dynamics of coal market, seasonality of coal consumption, accidents at coal mines which are coal suppliers, climate conditions, failure of technical facilities, human factors, etc.;
- multicriteriality of the effectiveness evaluations of organizational and technological processes that result from the individual evaluation criteria of each subsystem performance; a



multiplicity of indicators characterizing the performance of the whole transport system; the presence of non-formalized qualitative indicators taken into account by the decision-maker;

- great dimension of the transport system, which requires the construction of an ensemble of local models for each sub-system or a group of sub-systems. In the study of the mutual influence of the set of subsystems the assessment of various aspects of the functioning of the entire system is carried out.

Despite individual characteristics of the transport system the common indicators can be defined, that identify it as part of the theory of complex organizational systems [2]: the diversity in accordance with the physical and mathematical features; high adaptability of subsystems models and the entire system to real specific conditions; the acceptable risk of realization of control actions; multicriteriality of performance evaluation of each system element; large dimension and a multiple connections of subsystem elements, etc.

According to [3-4] when considering the transport system as an object of research a set of interrelated economic, social, natural and technogenic factors in the structure of the coal-mining region should be considered. The main actors of the transport system of the mining region are mining and raw materials processing companies: coal open-pit mines, ore and sand pits, mines, enrichment and sintering plants (Figure 1). The transport private tracks (technological roads in the structure of the enterprise) are intended for acceptance of mining enterprises products, storage, sorting, loading and shipment of products to consumers. On the public tracks of JSC “Russian Railways” (JSC “RZD”) the formation of routes and goods shipment to customers takes place. The common structural subject of the transport system is the market of ready products. The transport system operates in a particular environment, which is formed with regard to the influence of nature and reactions of society in the form of operating personnel.

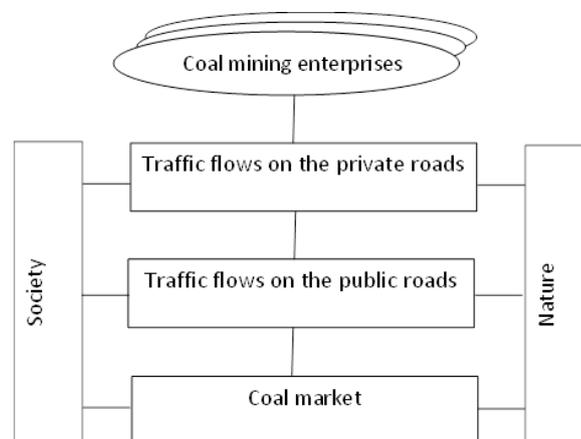


Figure 1. Subjects of the transport system in the mining region.

The mechanism of transport system functioning in the coal-mining region comprises a set of procedures and rules to be observed by the subjects when making management decisions. A special case is a control mechanism that includes only a set of managerial decision-making procedures. Mechanisms of functioning and management – strategy of behavior and decision-making by the parties.

The governing body (center) selects a decision-making procedure. The function of the governing body consists in prediction of the transport system development through modelling, selection and implementation of rational variants of the functioning of the control object with the subsequent monitoring and evaluation of management efficiency.

2. Construction of a conceptual model for a complex transport system

The most complete information about the complex transport system can be obtained by the experiment. However, the duration of the experiment with the developing system can be compared with the existence period of the researched object. In the conditions of current production the possibility for a pure experiment is also limited by the presence of internal and external influences on the object. In these cases it is necessary to construct and examine a model of a complex system.

The essence of modeling as a research method consists in the construction and analysis of models adequate to the transport system in the mining region. Using the model it is possible to analyze the response of the control system, to select and implement in practice specific control action, which leads to the fulfillment of the goal set by the control governing body (center).

Taking into account the possibility for forming a plurality of transport system models in the coal-mining region, it is advisable to take some basic model as a base, to which alternative models can be created.

The following variant, given in Figure 2, is offered as a base model.

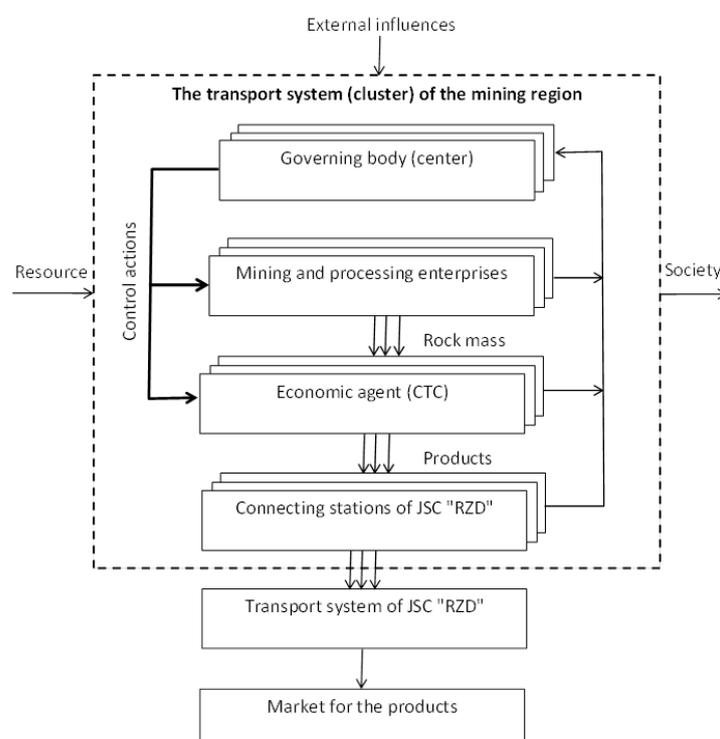


Figure 2. Structure a base model of the transport system in the mining region.

Holdings and large firms are included into the base model as governing bodies (centers), the production base of which is represented by mines, quarries, open-pit mines, processing plants engaged in the extraction and processing of mineral raw materials. The products of these companies are formed in the warehouses in the form of mined coal, ore, concentrate.

The presence of multiple elements of a complex transport system, such as mining and processing enterprises, roads, means of transport, coal storages, crushing and screening facilities, loading points, rail transport, tracks of non-public use, parks, stations, etc., predetermine the conditions of uncertainty. These conditions of the complex systems functioning do not allow the efficiency of the whole system to be evaluated by a separate isolated element or subsystem. Only an analysis of all subsystems with regard to their interaction can lead to a comprehensive evaluation of the entire system. However, in real conditions it is impossible to carry out the experiment due to the following reasons:

- high production costs during due to change of operational mode of the researched object in the process of the experiment in case the results of innovations are not satisfactory;
- duration of the experiment, which may correspond to the duration of the operation period of the facility.

In this regard, the analysis of the complex system can only be done through the design and analysis of a real object model. The solution of problems of a complex research object, as a rule, is carried out by construction and analysis of several interrelated local models that reflect different features of the complex system behavior as well various levels and stages of its examination.

To construct a working version of the base model of the transport system in the coal mining region it is necessary to establish the following local models in the structure of the basic model (Figure 2):

- transportation of the mined rock from mining and processing enterprises to the CTC storages;
- unloading, formation of storages, separation of rock mass, fire-safety measures;
- loading of the rock mass into the railway wagons;
- transportation of the rock mass in the wagons to the connecting station of JSC “RZD”;
- shipping goods by freight rail to the consumer.

All local models should be divided into two ensembles: the external models and the internal models. The internal model are related with the simulation of activities of a particular cargo transportation company on the private tracks with the implementation of management mechanisms of enterprise state dynamics in the conditions of uncertainty [5]. The external models include descriptions of irregular freight traffic loaded with the mined rock coming from coal mining and processing enterprises and models of sales in the market environment with regard to the workload of JSC “RZD” tracks.

It should be noted that although the CTC subsystems interact within a single system, they have their own goals that may be achieved applying different criteria. In this regard, the main task of modelling and transport system management is the search for managerial decisions, which would harmonize local objectives and criteria of subsystems or eliminate contradictions between them.

The use of the base and local models for the modelling of alternative trajectories of object development will allow the formalized strategies and scenarios to be justified, implementation of which is carried out with participation of experienced specialists.

The composite nature of a complex transport system M involves representation of its model as a tuple of three groups of components:

$$M = \langle A, S, T \rangle, \quad (1)$$

where A – set of system elements; S – set of possible links between elements; T – a plurality of time points.

In the process of modelling it is possible to change the composition and structure of the transport system according to the realized t_i in a point of time.

Heterogeneity of subsystems requires the use of different mathematical methods: for example, for the description of coal acceptance from producers and formation of coal storages the no-queue models can be used, for the description of traffic flows on the private tracks the apparatus of differential equations with restrictions is often used.

When considering an ensemble of interacting subsystems, the cataloged library of models should be used, taking into account the scope and functions of each model.

In accordance with the structure of the base model of the transport system in the mining region the local structure of traffic control system for one of the main economic agents – cargo transportation company (CTC) was developed (Figure 3).

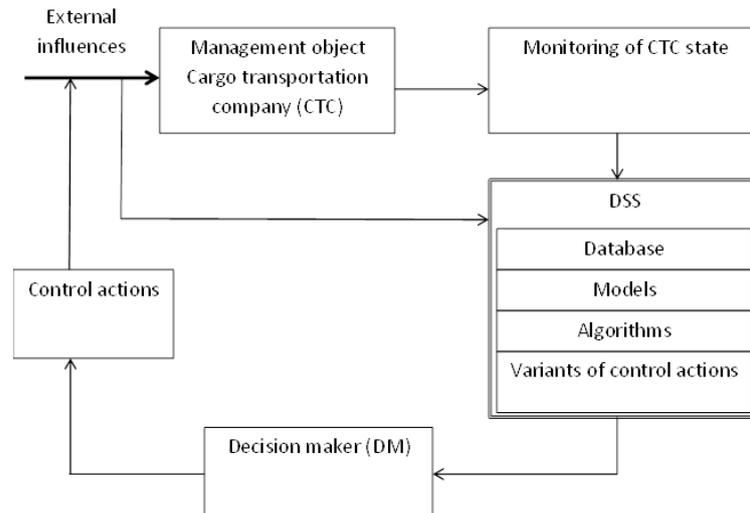


Figure 3. Control system of CTC cargo flows.

According to Figure 3 CTC as a control object functions in the structure of coal holding company or firm and carries out its activities taking into account external constraints in the form of scope of shipment to coal railway storages by coal producers, capacity of private and public tracks, coal market capacity, etc. Technological and organizational activities of CTC are effectively controlled, and the received the results of monitoring are formed in the form of a database. The efficiency of the results of the real technological and organizational processes is evaluated by the results of their modelling, and the variants of actions on the object are chosen in order to ensure the target indicators.

The final decision on the choice of the optimal variant of the action on the object is regulated by the decision-maker in the decision support system (DSS). While studying the problem situation the professional concepts and knowledge of the transport system researcher are used, which performs in the LLC “Consolidated Production Transport Directorate of Kuzbass” functions of a person making decisions.

To create a coal flow control model, which are formed in the coal warehouses for loading into wagons, transportation of the rock mass and the transfer of coal products to the consumer, it is suggested these processes to share the object of management, taking into account the functions performed, the following three subsystems (Figure 4):

I - processes of formation of a railroad coal depots dump unloading, processing and storage of the rock mass, loading, weighing and measuring cars; loading and unloading operations are carried out in-house and contracting means. Direct management of loading and unloading operations at the railroad warehouse workers responsible exercise - master loading complexes served by enterprises. In the production of handling operations involved in the processes of technological and organizational change in leadership personnel and daily regulations;

II – technological transportation of the rock mass by the private tracks, including shunting operations, selection of wagons with regard to shippers and consignees; wagons spotting to the places of loading and unloading; accumulation of wagons to be delivered to the connecting station;

III – acceptance operations by means of accumulation of railroad trains and their submission to the JSC “RZD” distribution network. The shipper routes of the specified weight and length are formed in accordance with the current plan of the West-Siberian Railway – branch of JSC “RZD” for formation of freight trains (in the direction of Avtovo, Vysotsk, Nakhodka, Tomusinskaya, Zherebtsovo, Novokuznetsk – North, Murmansk, Inskaya). The cargo and commercial work on the private railway track of JSC “SUEK-Kuzbass” PTU “Eastern Kuzbass” and the connecting station Terentevskaya is performed twenty-four-hour.

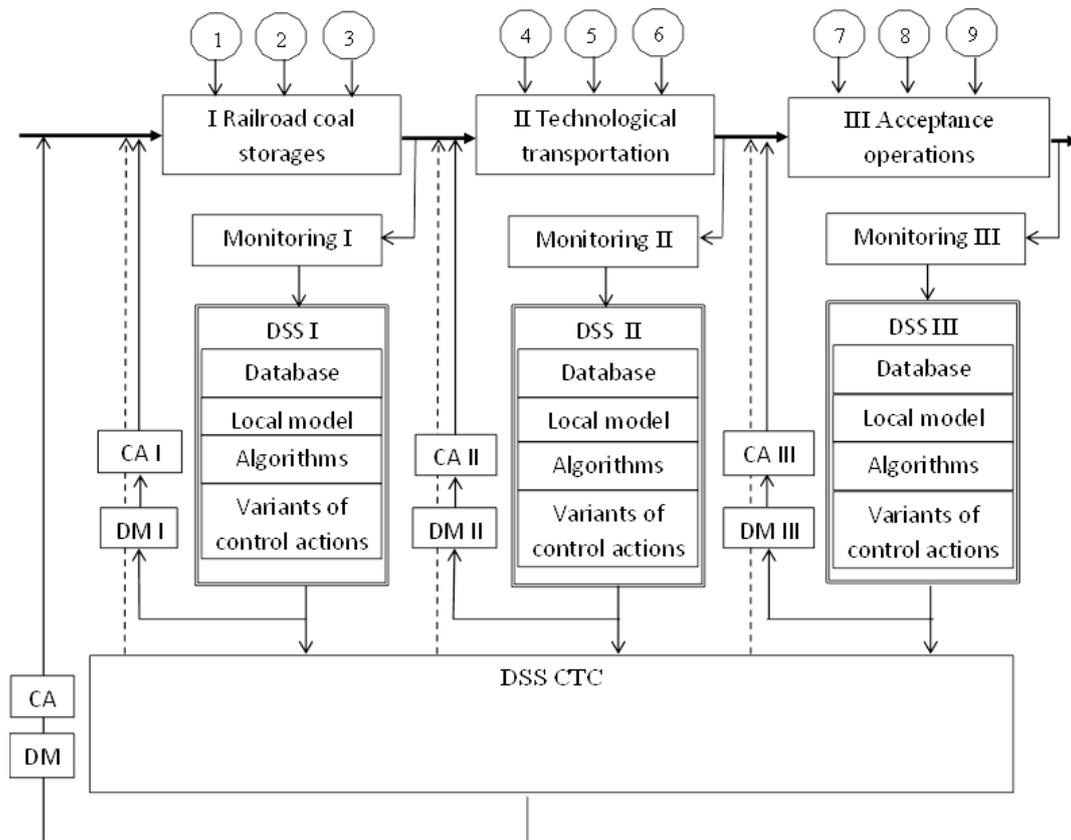


Figure 4. Structure of local elements and system models of freight traffic management at the CTC.

The following factors and indicators influencing the management efficiency of cargo flows at the CTC:

- scope and delivery rate of rock mass by coal mining and processing enterprises to the railroad storages;
- capacity of coal storage;
- processing capacity of loading points;
- state of the private railways;
- state and performance of locomotive transport and fleet;
- traffic management, communications, signalling arrangement;
- capacity of railways, stations to form trains;
- processing capacity of stations in JSC “RZD” network;
- capacity of the coal market.

Besides these main factors weather and seasonal conditions, human error, accidents and incidents, being the qualitative characteristics of uncertainty of the environment, influence on the efficiency of cargo flows control at CTC [6].

The identification of local subsystems in the structure of cargo flows control will improve the efficiency of decisions made by the relevant services and actors while controlling and adjusting the control actions (the dotted lines in Figure 4).

3. Conclusions

Thus, a conceptual model, that contains the list and the characteristics of the interacting elements, processes and factors affecting the management efficiency of cargo flows at a CTC, was developed.

An obligatory component of interaction of elements and the ensemble of local models is a unified information richness at the individual level of persons making decisions at all levels of the hierarchy.

References

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