Integration of transport system management tasks

Vladimir Mavzovin[1], *Nikolay* Klevanskiy[2*], *Irina* Teterina[3], *Ramil* Zagidullin[4], and *Vladimir* Zyryanov[4]

[1]National Research Moscow State University of Civil Engineering, Moscow, 129337, Russia
[2]Saratov State University of Genetics, Biotechnology and Engineering named after N.I. Vavilov, Saratov, 410012, Russia
[3]Siberian State Automobile and Highway University (SibADI), Omsk, Russia
[4]Kazan Federal University, Kazan, 420008, Russia

Abstract. The article is devoted to the consideration of the actual problem of integration of transport system management tasks. The distribution of tasks on three levels of management – strategic, tactical and operational is considered. The purpose of the study is to present the results of structural modeling of transport system management tasks at different levels of management and to identify integrating elements. Structural modeling is carried out and five diagrams are presented, including two contextual ones. The schedule of regular passenger transport has been identified as an integrating element of the tactical level of transport system management. The developed structural diagrams show the feedback between the tactical and operational levels of transport system management. The conclusions and discussion of the results of the study are presented.

1 Introduction

The transport system is a combination of transport infrastructure, transport enterprises, vehicles and management. According to Federal Law No. 16-FL of February 9, 2007 "On Transport Security", infrastructure includes used transport networks or communication routes in the form of roads, railways, air corridors, channels, pipelines, bridges, tunnels, waterways, etc. Transport infrastructure also includes transport hubs or terminals where cargo is reloaded or transfer passengers from one type of transport to another. Examples of transport hubs or terminals can be airports, railway stations, bus stops and ports. Vehicles include conveyors, pipelines, ships, elevators, cranes, rockets, cars, bicycles, trams, trolleybuses, trains, airplanes. Transport infrastructure objects together with vehicles form a transport complex. Transport system management is a set of measures aimed at the effective functioning of this system through coordination, organization, ordering of the elements of this system, both among themselves and with the external environment. This study will consider systems with general purpose vehicles, that is, transport systems for the transportation of passengers and

[*] Corresponding author: nklevansky@yandex.ru

cargo. Such types of vehicles include railway, automobile, water and aviation modes of transport [1-6].

Depending on different characteristics, there are three levels of management of transport systems – strategic, tactical and operational (Table 1).

Table 1. Characteristics of transport system management levels.

Management level	Decision-making personnel	Work with system resources	The interval of validity of solutions
Strategic	Management (administration) of the system	creation (modification) of system resources	is 5-10 years or more
Tactical	Middle managers	allocation of system resources	Depending on the operating conditions –the duration of the season
Operational	Line managers	management of system resources, organization and control	Several days

The long-term tasks of the strategic management level include the problems of infrastructure and route planning.

The first task – infrastructure planning makes sense only for countries with underdeveloped transport networks and therefore is practically not reflected in foreign publications. In addition, the decision to expand transport networks is purely political in nature. Therefore, management solutions for transport systems, first of all, begin with route planning (routing) and continue with the formation of schedules, planning the operation of transport devices and service personnel, the distribution of passenger boarding/disembarkation places, loading/unloading of cargo shipments, etc.

The aim of the work is to present the results of structural modeling of transport system management tasks at different levels of management and to identify integrating elements.

2 Analysis of transport system management tasks

The initial data for the task of routing the transport system [7,8] are applications in the form of a list of pairs "point of departure – destination" in the form of a matrix (Origin/Destination Matrix – OD matrix). The routing source data also includes the overall infrastructure of the system's transport network. Using these initial data, the most appropriate route is selected from pre-determined potential routes combining departure and destination points. In addition, the predicted traffic frequencies and route capacities are determined. The routing task is solved every few years, since the network infrastructure and the OD matrix change infrequently.

Most of the management problems of transport systems are solved at the tactical level [9]. These problems include:

1. formation of the schedule of regular passenger transport;
2. routing of charter passenger and cargo transportation;
3. formation of the schedule of charter passenger and cargo transportation;
4. formation of the schedule of work of service teams;
5. formation of the schedule of vehicles.

Since most of these problems are hierarchically interrelated, an integrated approach to solving tactical-level problems is needed.

Using the example of railway transport, it is necessary to note the difference in approaches associated with the incomparable length of Western European railway networks compared to

Russian networks. The task of forming the Train Timetable Problem (TTP) in European publications is considered in two types: cyclic [9] and non–cyclic [10]. The difference between them is that cyclical schedules are associated with the need for strict periodicity within a day or part of a day, while non-cyclical schedules, which are also periodic, have a period equal to a day or several days. The difference is also related to the input data: time intervals, which make it possible to choose an acceptable solution for non-cyclical schedules; frequency and fixed arrival times for cyclical schedules.

The solution of the TTP problem is not able to solve the specific problems of stations, which require a more detailed approach to the station topology. In [11], a solution to one of the problems is proposed – the distribution of passenger platforms (Train Platforming Problem – TPP). The solution of the TPP problem assumes the current train schedules as the source data and forms the routes through the stations. The problem relates to the operational level of management of transport systems and is solved using an integer model. The next problem of the stations is the Rolling Stock Planning Problem (RSPP), which is the concern of transport companies. That is, the formation of a train is the placement of cars of various classes to meet the needs of passengers and the public schedule without exceeding the existing fleet of the company [12]. The problem also relates to the operational level of transport system management.

The last one is the task of planning the work of maintenance crews (Crew Planning Problem), which distributes crews on planned trains in accordance with the requirements of trade unions and other qualification restrictions. The goal is to minimize the maintenance personnel needed to meet the daily requirement. The problem relates to the tactical level, and the organization and control of the work of maintenance teams (Crew Rostering) are solved at the operational level with the involvement of the appropriate managers of the transport system.

It should be noted that the presented management tasks significantly depend on the type of vehicles. Detailing these differences is not included in the objectives of this study and only those tasks that are similar will be involved in modelling, regardless of the differences in the methods of solution. And one more remark. Any control system becomes viable if there are feedbacks in it.

Structural modelling, called Structured Analysis and Design Technique (SADT) by the developer, was used to model transport system management tasks at different levels [13]. The Integrated Computer Aided Manufacturing (ICAM) program of the US Department of Defense recognized the usefulness of SADT. This led to the publication of part of the SADT in 1981 under the name IDEF0 (Icam DEFinition), as a federal standard for software development. The latest version of the IDEF0 standard was released in December 1993. Modeling using the IDEF0 methodology is recommended for use by the State Standard of the Russian Federation. Later, the SADT methodology became a tool for structural analysis of systems of medium complexity [14].

3 Materials and methods

The basis of the IDEF0 methodology is a graphical process description language. The model in IDEF0 notation is a collection of hierarchically ordered and interconnected diagrams.

Each model should have two context diagrams. The context diagram A-0, being the top of the tree structure of diagrams, shows the purpose of the system and its interaction with the external environment. After detailing the main function of diagram A-0, the functions of the context diagram A0 are determined. Further, the functions of diagram A0 are divided into subfunctions until the required level of detail of the simulated system is reached. Diagrams that describe each fragment of the system are called decomposition diagrams. After decomposition, domain experts analyze the correspondence of real processes to the created diagrams. After eliminating the inconsistencies found, further detailing of the processes is carried out.

The IDEF0 methodology uses a simple graphical modeling notation. The main components of the model are diagrams that display the functions of the system in the form of rectangles (functional blocks), as well as connections between functions and the external environment by means of arrows. The use of two graphical primitives allows you to quickly connect and activate the customer's activities to describe business processes using a visual graphical language.

The choice of AllFusion Process Modeler 7 (BPwin) as a design tool was due to the fact that it is based on generally accepted modeling technologies such as IDEF0 and SADT. With AllFusion Process Modeler 7 (BPwin), you can produce detailed documentation of all aspects of business processes. That is, the necessary actions, ways of their implementation and control over the required resources, as well as to visualize the information received.

4 Results and discussion

Figures 1 and 2 show contextual diagrams A-0 and A0 of the structural model of transport system management tasks.

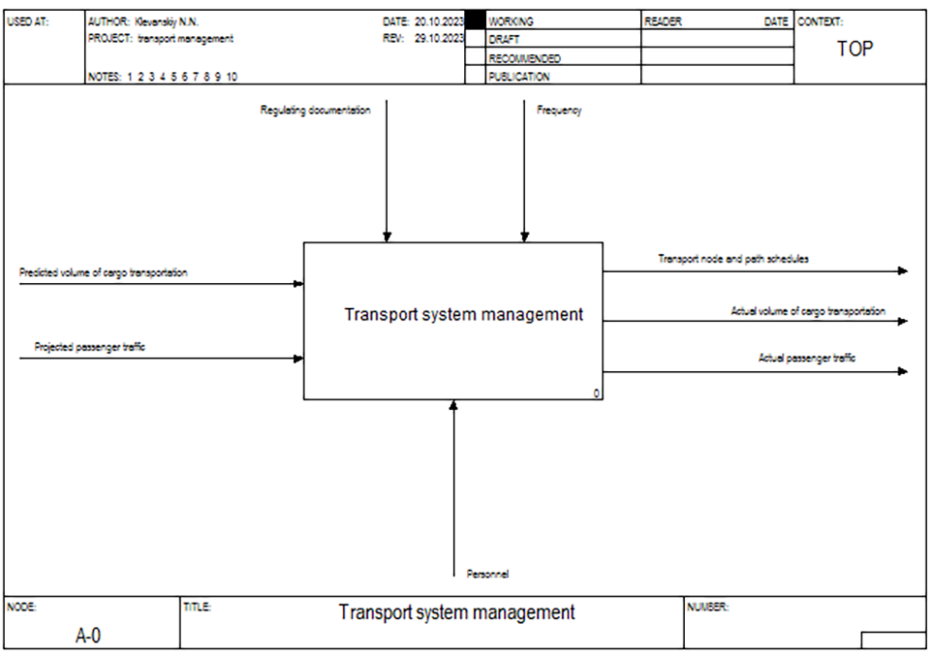

Fig. 1. Context diagram A-0.

Diagram A0 represents groups of business processes at each of the three levels of system management. A thickened line in the diagram shows the feedback between the operational and tactical levels of control. This information link, as part of the schedules of transport hubs and communication routes, transmits changes made at the operational level in the work schedules of maintenance teams and vehicles. The reasons for the changes may be related to changes in the list of maintenance crews or temporary unavailability for technical reasons of some vehicles.

The decomposition of block 1 of Diagram A0 is shown in Figure 3. Figure 4 shows diagram A2 showing the decomposition of block 2 of Diagram A0.

In diagram A2, the SCHEDULE is highlighted in red, which is the schedule of regular passenger transport. The information flows included in other functional blocks are also shown in red. That is, it is the SCHEDULE that is the desired integrating element for the tactical level of management. The thickened lines in Diagram A2 represent feedback information flows. These flows are directed to the corresponding functional blocks of the diagram, transmitting to them the information changed at the operational level about the work schedules of maintenance teams and vehicles.

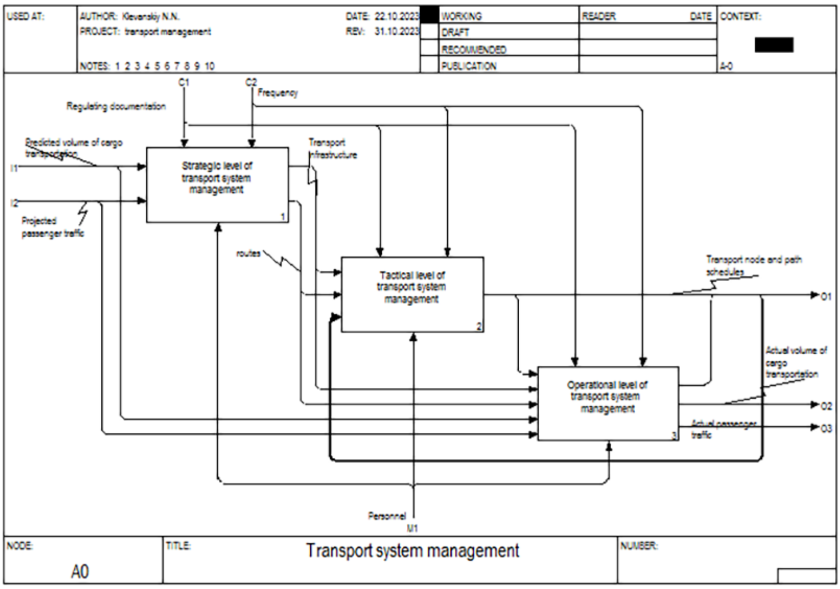

Fig. 2. Context diagram A0 – the main groups of business processes of transport system management.

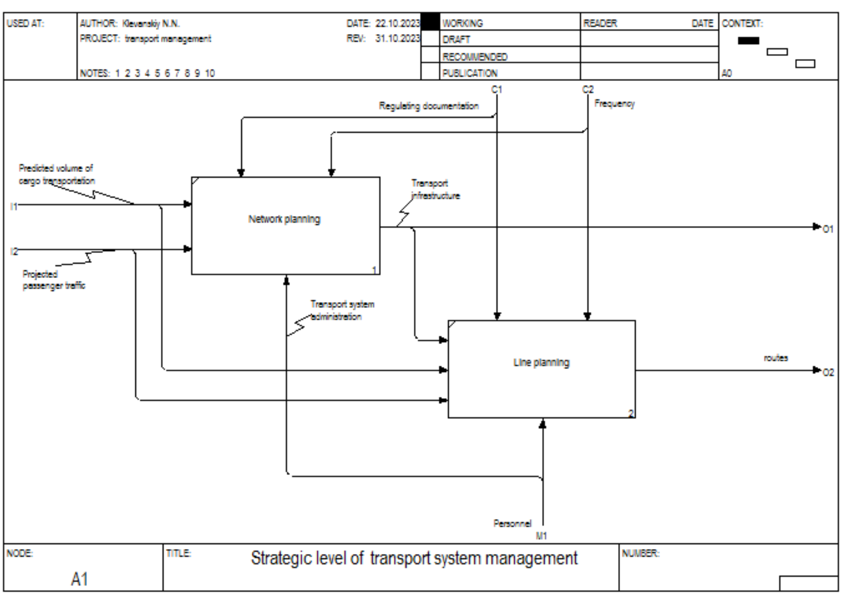

Fig. 3. Business processes at the strategic level of transport system management.

The variety of resources of transport systems leads to various problems of the tactical level of management of transport systems. The peculiarity of these problems is that the solution of most of them is associated with the need for an initial solution to the problem of forming a timetable for regular passenger transport, that is, obtaining a TIMETABLE and then solving other tasks at the tactical level (Figure 4). The task of routing cargo and charter passenger traffic requires special attention. There are two ways to solve this problem. The first way is to develop methods for embedding the desired schedule into the SCHEDULE [15]. The second most common method uses specially organized windows in the SCHEDULE. The desired schedules are embedded in these windows.

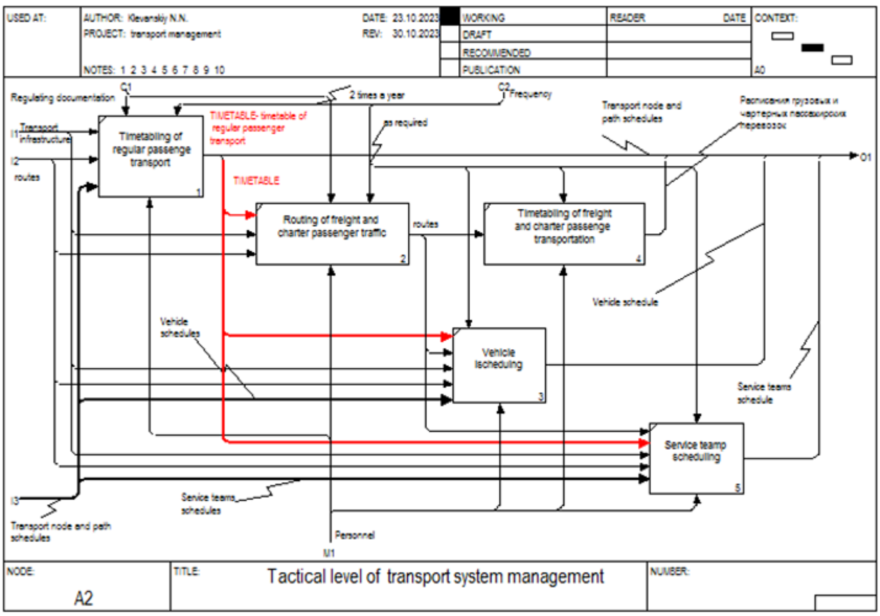

Fig. 4. Business processes of the tactical level of transport system management.

The result of the decomposition of block 3 of Diagram A0 is shown in Figure 5. Diagram A3 presented in Figure 5 includes three functional blocks related to business processes of the operational management level. With the help of the tasks of the first two functional blocks, it is possible, if necessary, to make changes to the corresponding schedules and transfer them through feedback to the tactical management level. The third functional block of the diagram solves the problem of fixing the values of real volumes of traffic flows.

5 Conclusion

Thus, the following results are obtained:

- structural modeling of transport system management tasks at the strategic, tactical and operational levels has been carried out;
- feedback is presented between the operational and tactical levels by transmitting the information flow of the system schedules;
- an integrating element has been identified for the tasks of the tactical level of transport system management. The schedule of regular passenger transport is accepted as this element.

In the order of discussion, the following questions/problems should be discussed:

- reasonableness of the distribution of management tasks by levels;

- the validity of the choice of the SCHEDULE as an integrating element of the tactical level of transport system management;
- assessment of the need to include the actual volume of traffic flows in the feedback between the operational and tactical levels.

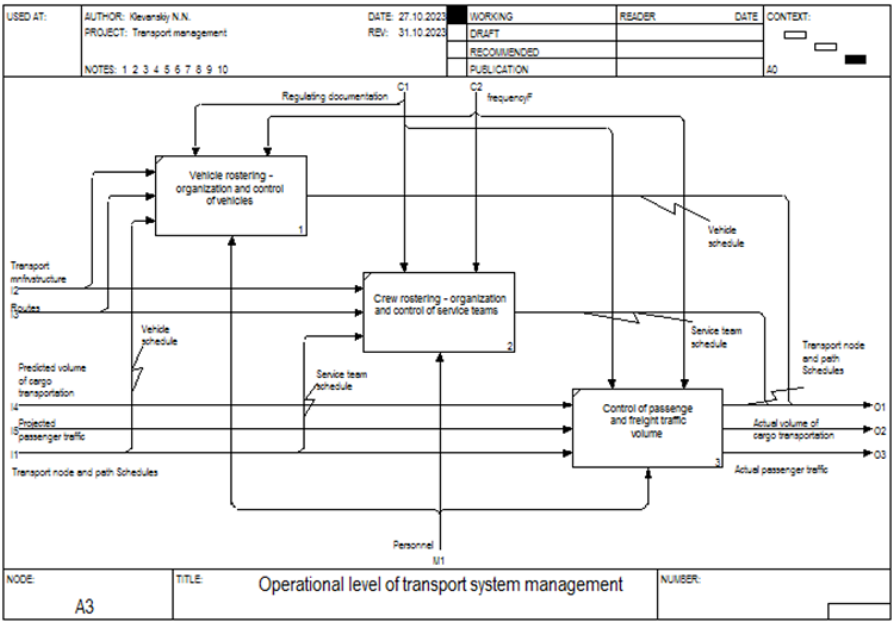

Fig. 5. Business processes of the operational level of transport system management.

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