ABSTRACT

The Thesis presented for the degree of Doctor of Philosophy PhD on the specialty 6D070300 - Information systems by Akhmediyarova A.T. "Mathematical modeling of the transport systems of the metropolis with S-hypernetwork theory"

Relevance of the research topic. One of the main conditions for the existence and functioning of a large city is the efficient operation of the transport system, which is designed to ensure the timely delivery of goods and people flows anywhere in the city. For modern cities are characterized by irreversible trends like population growth and increased its motorization. The dynamics of the total length of highways growth lags far behind the dynamics of the growth of the fleet.

One of the important tasks of the State Program of the Republic of Kazakhstan in infrastructural development “NurlyZhol” is creation of modern transportation infrastructure of Kazakhstan and possibility to facilitate its integration with international transport system. “The transport infrastructure is circulatory system of our industrial economy and society” – as it was mentioned and defined by the Head of State NursultanNazarbayev.

Kazakhstan is the absolute leader of Central Asia in the level of motorization. At the beginning of the 21st century, there were a million cars in our country, and now this number has quadrupled. But the number of cars, from the point of view of economists, is directly related to the level of people's well-being. As of January 1, 2018, the number of registered cars in the Republic of Kazakhstan was 3,851,600 units (stat.gov.kz). The growth rate of the number of cars outstrips the growth rates of the population. Now in Kazakhstan for 100 people there are 21.4 cars (for comparison: for 100 citizens of Uzbekistan - only 6.7 cars). According to this indicator, Kazakhstan is located between Brazil and Oman. And the world leaders are Monaco and the United States, where every citizen has a car.

According to the Texas Transportation Institute congestion highways approaching the pre-crisis peak level. Researchers estimate that in 2017, US residents spend in traffic jams 5.5 billion hours, while the time required and payment of excess fuel will cost them 121 billion (0.85% of GDP). Every American driver due to traffic jams on average spends 38 hours of personal time, and 86 liters of gasoline per year, which cost him 818 dollars. This amount does not include the cost of excessive depreciation of vehicles as well as for damage to health (physical and mental) and environmental damage that is very difficult to express in monetary terms.

In the city of Almaty 467 thousand units of transport are registered, in addition, 300 thousand registered cars in the Almaty region are moving around the city. Every day in Almaty, about 700 thousand vehicles move with an average speed at the peak hour of 19 km per hour. For example, in cities that are comparable to Almaty by population and other parameters of Budapest and Warsaw at rush hour, cars move around the city 1.5 times faster. According to expert estimates, daily losses of the Almaty economy from traffic jams are more than 600 million tenge.

Officially in Almaty, there are 1,801,713 people (as of January 1, 2018). Two thirds of them make daily trips to work, study and back - on buses, on their cars, by taxi. Together we are losing 90 billion tenge. Or more than half a billion dollars.

According to the Almaty akimat, the quality of atmospheric air in Almaty remains unacceptably low. The index of air pollution for many years stably exceeds 10 units, which corresponds to the criterion for a tense situation. Smog covers most of the city, and 90% of this smog is made by transport.

Every year Almaty fleet increased by an average of 40-60 thousand cars. In 3-4 years the drivers have to spend in traffic jams is not 1, and 2-3 hours a day.

Study and modeling of the modern metropolis is a very topical issue. Several academic journals devoted exclusively to the dynamics of traffic - it's Transportation Research, Transportation Science, Mathematical Computer Simulation, Operation Research, Automatica, Physical Review E, Physical Reports and others.

The development and research on the effectiveness of various methods of traffic control (TC) are devoted to D. Drew, T. Hamada, Silyanova V., F. Haight, V.A.Cherepanova, MS Fishelsona, V.V.Zyryanova GI Klin¬kovshteyna, I.N.Pugachev, V.T.Kapitanova, M.P.Pecherskogo, M.V.Yashinoy, L.S.Abramova and others.

Numerous studies (Silyanov VV, Drew D. Lobanov EM, Fishelson MS, Cherepanov VA, VT Captains, Hilazhev EB, Tribunskaya VM, AP Buslaev, VM Prikhodko, Tatashev AG, Novikov AV, Yashin MV et al.) have shown that the purchase of research in the field of system crucial for solving optimal control problems of transport infrastructure ties.

Transport infrastructure multifactorial, as the object of the system analysis, is a defining characteristic of its complexity. Solving the problem of functional, institutional and information integration of heterogeneous subsystems of intelligent transport systems is hampered by the shortage of methods and tools for the construction of adequate models and solutions on their basis of transport infrastructure management tasks.

Mathematical model of connectedness, models and methods of structuring complex systems, some aspects of the theory of S-hypernetwork and modeling of urban transport systems hypernetwork considered in V.K.Popkova.

One of the information processing tools can serve as methodological and instrumental equipment of object-Orient Rowan analysis and design (PLO) transport systems based on patterns. OOP provides the variability of information processing and organic evolution of automated support technologies research on models with the correction and completion of knowledge about the object of research with new data obtained during the experiment. New possibilities are opening up thanks to modern technology of information processing, using the theory of S-hypernetwork.

Thus, the mathematical modeling of the city transport systems with S-hypernetwork theory is claimed and actual scientific task.

Purpose of the study. The aim is the mathematical modeling of the city transport systems with the use of S-hypernetwork theory.

The main result of this study is to optimally control traffic flows of the city, based on the development of integrated solutions using cyber-physical systems of monitoring, modeling, forecasting and optimization with the use of S-hypernetwork theory.

Objectives of the study:

To achieve the goal in the work the following tasks are set:

1. Analysis of the structural features of the megapolis transport network in order to improve models and algorithms for efficient management of traffic flow in the network.

2. Develop a methodology for planning the transport flow and routes adapted to existing transport interchange infrastructure and a crossroads based on the theory of S-hyper networks.

3. Develop a subject-oriented environment for analysis, modeling and decision support for effective traffic management.

4. Conduct a computational experiment and simulation based on the processing of heterogeneous information flows and develop a methodology for efficient management of traffic flow through the metropolitan transport network.

Object of study. The object of study in the thesis are the transport infrastructure of the city management system, including road network, technical means of traffic management and traffic flows.

Subject and research methods. As the methodological basis of the work were used methods of system analysis, traffic management, graph theory, S-hypernetwork theory.

Scientific novelty:

1 A unified approach to modeling and control of transport traffic is developed on the basis of the modern theory of S-hyper networks and the improved method of Popkov VK, which provides a comprehensive solution to the problems of the structural and functional organization of the transport infrastructure, taking into account the heterogeneity of its components.

2 An algorithm and a program have been developed that minimize the number of locations for cameras in a given territory, provided that it is fully traced.

3 An approach using overclocking traffic lights is proposed, which increases the throughput of intersections, the effectiveness of which is proved by imitation modeling based on fuzzy logic.

Regulations for the defense

The proposed mathematical and information models and algorithms for controlling traffic through cross sections of a transport network based on S-hyper networks make it possible to increase transport flows and the efficiency of loading transport networks in large cities.

The scientific results within a theses requirements

In the introduction the urgency of the chosen theme of the dissertation, the study identified the objects and subjects is the objective of the dissertation; lists the tasks that are set and solved in order to achieve this goal, revealed the practical value of the work and its elements of novelty.

The first section of the analysis carried out infrastructure metropolis, its mathematical modeling in the form of S-hypernetwork for the main modes of transport. It is revealed and it is shown that the theory of S-hypernetwork applicable for analysis and synthesis of many systems of the network structure, including the tasks of analyzing firewall structural interactions of complex systems of different nature. A mathematical formulation of the routes and metrics in the S-hypernetwork for calculating the distance and the distance to known methods in a specially constructed graphs, digraphs, hypergraphs and ultragraphs.

The second section deals with modeling of crossroads and intersections unit using fuzzy logic to control traffic lights. Considered ways of managing traffic flows at traffic lights by using accelerating traffic. Based on the analysis identified positive features of application acceleration traffic lights. A mathematical model for each type of interchanges. An algorithm for constructing an optimal transport interchange, in which the passage of the truck assembly is significantly reduced, and costs are reduced.

In the third section, we developed the concept of a simulation model of traffic flow and management of transport systems. As part of the simulation model to simulate the flow in the area of road transport networks and identified, in general, positive impact the introduction of one-way traffic. Examples of the calculation of the capacity portion of the road transport network. An algorithm to eliminate traffic jams by changing the mode of traffic lights to eliminate extra plugs on the side, to this route, the roads. A routing algorithm and a routing table compiled and formulated the principle of optimality. Mathematical routing problem reduces to finding the shortest path in an undirected graph. A mathematical model is most fully reflecting the actual electric transport network and an algorithm for finding the shortest path between two stations at a given time.

In conclusion it reflects the main results of the thesis and the information on the practical application of research results.

Testing results of the study.

Substantive provisions and results of the study were presented at: Eighth International Asian school-seminar "Problems of optimization of complex systems" (Omsk, 2012); II International scientific-practical conference "Information and technology innovation, integration of science, education and business" dedicated to 20th anniversary of Independence of the Republic of Kazakhstan (Kazakh National Technical University, 2012); International scientific-practical conference "Actual problems of computational and applied mathematics" (Novosibirsk, 2014); V International scientific-practical conference "Innovative science and modern society" (Ufa, 2015), XXVII International Scientific and Practical Conference

"Natural and Mathematical Science in the modern world" (Novosibirsk, 2015), the II International scientific-practical conference "Information and telecommunication technologies: education, science and practice" (Almaty, kazniti name K.Satpaev, December 3-4, 2015 year), the International scientific-practical

conference "Kazakhstan's way - 2050: common goal, common interests, common future" (Almaty, the Caspian University, 17-18.03.2016 city).

Thesis performed in the laboratory of Mathematical Cybernetics and Computer Technology Institute of Information and computing technologies MES CN.

Publications. Theme dissertation published 30 papers, 8 of which were published in journals recommended by the Committee for Control of Education and Science of the MES, 1 articles published in the edition, which has a non-zero impact factor, is part of the Scopus database, 1 articles published in the edition, is part of the Thomson Reuters database, 15 articles published in collections of international scientific and practical conferences.

The structure and scope of the thesis. The thesis consists of an introduction, three chapters, conclusion, bibliography and applications, contains 114 pages of text. The bibliographic list contains 76 names of literature.