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Methodology of Substantiation of the City Transport System Structure and Integration of Intelligent Elements into it

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Abstract

The city transport system is regarded as a complex formation with numerous developments due to the non-linear nature of main transport processes. Designing a method for selection and substantiation of different alternatives in transport system developments as a mathematical model provided a definition and justification for the following: 1) a digital model of a city street and road network as well as public transport routing system 2) a specific system of non-linear dynamic models of the transport and economic system of a region 3) tools for prediction and processing of calculation experiments. This method allows carrying out a multivariate simulation for the development of a transport system.

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Keywords: Intelligent transportation system, street and road network, route network, non-linear modeling, simulation

1. Introduction

Intelligent transportation systems (ITS) are designed and developed as a response to existing challenges related to management of road traffic, pedestrian and passenger flows in large cities. The costs related to the traffic management systems quite often surpass the benefits which can be gained once the ITS is implemented. This reflects a complicated nature of the flows mentioned above. Possible risks lead to that cautious attitude with which both classical traffic

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management systems and more advanced intelligent transportation systems are treated today in Russia at the implementation stage.

The complexity of a specific transport system shall be studied and described during the FEED and pilot projects to be respected during the design stage and implementation of the ITS. Any transport system can be assumed to have a combination of stochastic and deterministic processes which give rise to a complicated and hard to predict behavior and a tendency to phase transitions and bifurcations from which the non-linear nature of the transport system originates.

The effects of the non-linear behavior of transport systems traffic congestions, shock waves, phase transitions in terms of Kerner theory [Kerner (2011)] etc. produce mostly negative consequences for road traffic. This causes a lot of problems which require immediate actions in response. Primarily, these actions are not related to the application of the ITS but are more commonplace in nature because many Russian cities have major defects in their road and street networks and traffic management. Another activity is the development of transport sections of plot plans, transport development strategies, integrated transport maps, traffic management plans which shall address current issues of the transport system based on thorough understanding of the complex nature of functioning of the transport system and theoretical knowledge [Gasnikov (2013)].

It has to be noted here, that designers of plot plans, transport development strategies, integrated transport maps, traffic management plans and ITS have no reliable methods to substantiate their choice for a particular development of the street and road network of a large city which could make the delay time as short as possible and increase the capacity with minimum investments in transport infrastructure. Accordingly, automatic traffic management systems and traffic management systems have to follow the architecture of the street and road network which was originally provided in plot plans and/or traffic management plans.

A city transport system shall be regarded as a complex formation with numerous developments due to the non-linear nature of main transport processes [Popkov (1999)].This paper targets at developing a method required to select and substantiate the development alternatives of the transport system. A *transport system* is a system of city individual and public transport together with the street and road network, route maps and necessary infrastructure. So the scope of our research is a city transport system and the subject is a method of validation of a transport system structure to implement ITS elements.

2. Theoretical foundations

As it was said above, a transport system has both stochastic and deterministic processes. So the first building block which underpins the method is the theory of *macrosystems* where the stochastic behavior of its components is transformed into deterministic behavior of a system as a whole [Popkov (1999)]. Let us consider a general functional schematic of a macrosystem (Fig.1).

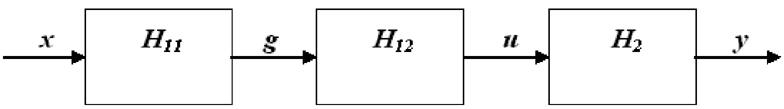

Fig.1. Transformations in a macrosystem.

As is the convention with the theory of macrosystems, x and y in Fig.1 stand for inputs and outputs respectively which can be deemed in terms of (control) inputs and outputs resulting from the functioning of the system. Internal processes $g(t, z)$ characterize its stochastic states while $u(t, z)$ represent its deterministic states. Here z is a set of system localizations. Representation H_{11} describes the stochastic behavior of elements of a macrosystem or its micro level, while representation H_{12} describes the transformation of stochastic state $g(t, z)$ into deterministic state $u(t, z)$ (averaging operation). The connection between the state $u(t, z)$ and output $y(t, z)$ is characterized by deterministic representation H_2. The composition of H_{12} and H_2 describes the macro level of the system.