**IMPROVING THE TRANSPORT SYSTEM AS THE BASIS FOR ECONOMIC GROWTH IN THE REGIONS: AGENT BASED MODELS APPLICATION**

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**ABSTRACT**

The development of transport infrastructure is an important factor in the economic growth of the territory. The ability to predict the transport demand and traffic on the road network is vital for development of regional and urban transport system. Agent based modelling has emerged as a practice tool of traffic and transport planning in region and urban area. The purpose of the research is to assess the possibility of using agent based models for transport planning in Russian regions and cities.

In order to reach the set, it was studied the theoretical basis of the scientific method. The main trends in the development of the transport system in the cities and regions of Russia were assessed. It was made an assessment of the impact of the road transport infrastructure development on the economic growth of Russian regions. It is shown that when analyzing Russian regions, it is necessary to take into account the level of development of not only the automotive infrastructure, but also other types of transport. The role of transport infrastructure for economic growth was shown. The characteristics of different types of agent based models used to solve problems of the regional and urban transport system were given and it was done the corresponding conclusions.

The results of our research will allow revealing the basic tendencies of development of transport system as a basis of economic growth in regions, to determine the possibility of using agent based models in solving such problems. In conclusion, we offer some practical recommendations for improving regional transport system and provide economic policies to ensure economic growth.

**Keywords:** Regional economics, economic growth, transport system, agent based models, regions of Russia.

**INTRODUCTION**

To a research of regional transport systems, we consider, it is possible to apply models of processes (process models) and spatial models. Models of processes express the theories predicting the exchange nature of energy and weight in systems taking into account changes in time [1]. Here it is possible to include ideas exchange, culture, knowledge, projects implementation successful experience. The spatial ideas, on the contrary, express the theories predicting structure of areas (domains) from line items of the economic entities and their signs organized in interdependent complexes [2].

The geographical information systems (GIS) are difficult spatial models that are used for presenting and storaging information about the phenomena and their layout and/or their sizes [5]. Unlike GIS models of processes take time category into account and consider behavioral aspects as set of the spatial relations in the region.

**1. THEORETICAL BACKGROUND AND BIBLIOGRAPHY**

Lets define what the agent based models represent. On an equal basis with individually oriented they belong to the category of models of object-oriented process. They define temporal behavior as an object sign, but not the environment and, thereby, create an opportunity for idea of the temporal period in which objects change asynchronously [6], unlike simultaneous up-dating (or the synchronous).

Note that individually the oriented models (individual-based models - IBM) are often used in ecology [7], while the agent based models are used more often in social sciences [8]. They create an opportunity for movement simulation and gained the development irrespective of GIS.

We will consider agent based of model in more detail. They, as a rule, include the following three components.

1. Approach from below up. Properties of macrodynamics can be well understood only as result of microdynamics with an involvement of the main agents [9]. It contrasts with the descending character of traditional neoclassical models in which agents of the bottom level are provided by individuals and are connected to equilibrium and hyper-rationality. Models of the joint-stock company, on the contrary, describe strongly heterogeneous agents functioning in difficult systems which develop in time [10]. Therefore the aggregated properties are interpreted as arising from the repeating interactions between agents, but not from the requirements of rationality and equilibrium imposed by models [11].

2. Limited rational agents. In a type of the fact that the environment in which economic agents, rather difficult interact, it becomes simpler different assumptions [11]. So, agents can attribute partially some local principles of rationality (both temporal, and spatio-temporal). It is defined that social and economic systems by the nature are non-standard because of constant novelty, it is endogenous entered by agents. Therefore, agents face uncertainty [12] and can create the waitings only partially.

Agents are stimulated to study permanently in the conditions of turbulence, is endogenous the changing conditions. Proceeding from it, researchers of the agent based models claim that assumptions of hyper-rationality in combination with rational waitings are improper starting points for simulation. It is necessary to suppose rather that agents shall carry as restrictedly rational economic entities with the adaptive waitings.

3. Direct network interactions. Interactions between economic agents in the agent based models are in straight lines and, by determination, non-linear [13]. Agents interact directly as the current decisions directly depend on the adaptive waitings and on the last choices made by other agents of "population" (through distribution of the available externalities). Agents integrate in structures and create local area networks. These structures are endogenous to change in time. In combination with heterogeneity and limited rationality it is quite probable that processes of aggregation are uncommon (nonzero) and sometimes generate appearance of structurally new objects [14].

**2. STUDY METHODOLOGY**

Let's consider the possibility of using agent based models for improving the transport system as the basis for the region's economic growth, using the example of the city of Moscow. The research toolkit is AnyLogic software (v. 7.1.2 PLE). The agent based model consists of 8 blocks (6 main and 2 additional), and is represented by 2 types of agents (people - city residents and enterprises). The main blocks of the model: Main, Zones, Roads, Enterprises, People, Public Transport; Additional - Joins, Simulation: main.

The main unit (Main) is integrating, and provides communication of all components of the model. Here common indicators are calculated actions and events are synchronized, visualization tools, model animations are located, etc.

People and Enterprises are both the main blocks of the model, and the types of agents. During the implementation of the model, People interact with Enterprises in such a way that they either already work and receive a monthly income, or are on the labor exchange in search of a new job. People arguments are age, current monetary balance, monthly income and transport costs, area of ​​actual residence and place of work, presence or absence of personal vehicles [15].

Most of the above parameters are set from external statistical databases in the form of a probability distribution of quantities. The individual behavior of People is described using the State Chart tool, which is necessary to distinguish several states from agents that consistently replace each other in response to environmental changes and influence decision making. People can be in one of four states: Satisfied, Acceptable, Bad, Waiting [3]. In the Satisfied state People buy cars, in Bad - they can change jobs or move to a more favorable area for them (fig.1).

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Fig.1. State Chart for People

The parameters characterizing agents of type Enterprises are the area of actual placement, the company's monetary balance, the staff of employees, the wage fund, the number of vacant positions in the enterprise, and the maximum number of jobs. The behavior of this type of agents, as well as people, is described using the State Chart tool and depends on the state of the enterprise in which it is located. Enterprises can be in one of 3 states: Grow, Stable, Unstable (fig.2).

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Fig.2. State Chart for Enterprises

Interacting with the environment in the model, People live in city areas - specific Zones. At the same time, they pay monthly housing services, pay rent. People can change the area of ​​residence based on their preferences or changes in their financial situation. Enterprises located in Zones interact with the Zones medium by monthly rent payment, the amount of which is established as a result of market relations, i.e. Under the influence of the mechanisms of supply and demand for commercial real estate in a certain Zones.

The external environment also includes public roads (Roads) and public transport lines (Public Transport), which People use when traveling between home and work. From the choice of the type of transport (personal or public) depends on the amount of monthly transportation costs and the time that agents spend on the road [4].

**3. RESEARCH DATA**

As initial data for the model, statistical databases for the city of Moscow were used at the time of modeling (01.01.2012).

For each of the administrative districts (Zones) were given the initial values ​​of the number of population and enterprises, the cost of utility services, the average market value of 1 square. Meter of the total area of ​​housing, the value of rental rates for commercial real estate.

Characteristics of agents of the type People - age and wages - are probabilistic distributions of values, based on the number of permanent population by age, and the distribution of the population of Moscow by the level of average per capita monetary income, respectively. Also, the initial number of cars per capita is set, which allows individuals with personal vehicles to be identified at the time the simulation begins.

The main variable of agents of type Enterprises is the maximum number of jobs, which is determined by the distribution of the number of enterprises in groups: the share of microenterprises (with the number of employees up to 15 people), small (up to 100 people), medium (from 101 to 250 people) and large enterprises 250 people).

For public transport (Public Transport), the maximum load (number of passengers) of the transport network per hour is defined initially, which is determined by

* for the Underground - as the maximum number of passengers carried by the subway per day, depending on the distribution of passenger traffic by the hour of the day on a business day;
* for Mosgortrans - as the total passenger capacity of an inventory of rolling stock by types of land transport (buses, trolleybuses, trams), adjusted for the utilization rate of the fleet in operation.

In addition, statistics are used for such characteristics of public transport as the length of metro lines and the number of stations, the number of stops for land transport, the average capacity of vehicles.

The metro is limited by the minimum interval of movement (30 seconds). Roads (Roads) are characterized by capacity and speed limits on the roads (40 km / h).

**4. RESEARCH RESULTS**

The characteristics of the agents of the model are given from external statistical databases in the form of a probability distribution of quantities. Therefore, to assess the quality of the model, it will be optimal not only to use classical statistical methods, but also to check the effect of the stochastic component of the model on the results of the simulation.

We built agent based models of the transport system in Moscow. An example of such a model is shown in Figure 3.

To compare the results of the model with the actual data using statistical methods, the following basic socio-economic indicators (control variables) were chosen:

* Population size (at the end of the year, thousand people);
* total area of ​​residential premises, an average of one inhabitant (at the end of the year, m2);
* per capita monetary income of the population (per month, rubles);
* gross regional product (total, million rubles);
* gross regional product (per capita, rubles);
* number of enterprises and organizations (at the end of the year, thousand);
* average annual number of employees of organizations, (thousand people).

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| C:\Users\SOLNISHKO\Desktop\Безымянный.png | - Monthly wage fund and number of employees in the enterprise  The total distance traveled by car: -1.556% (-839 km)  Status of public transport roads:  Normal  High load  Congestion  Fig. 3. An example of an agent based model for Moscow, executed in a software product AnyLogic (v. 7.1.2 PLE) |

For each of the listed indicators, the values ​​of the main statistical characteristics are within the limits of admissible values ​​(Table 1).

Table 1. Quality characteristics of the model

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| Indicators | Mean relative error | Mean-square deviation | Correlation coefficient | Teil's Inequality Ratio |
| Population  (at the end of the year, thousand people). | 3,12% | 382 | 0,998 | 0,010 |
| The total area of living quarters on average per capita (at the end of the year, m2) | 0,57% | 0,10 | 0,978 | 0,002 |
| Average per capita monetary income of the population (per month, rub.) | 5,61% | 2317 | 0,980 | 0,013 |
| Gross regional product (total, million rubles) | 5,09% | 651374 | 0,957 | 0,024 |
| Gross regional product  (per capita, rubles) | 4,77% | 49986 | 0,961 | 0,018 |
| Number of enterprises and organizations (at the end of the year, thousand) | 1,33% | 81 | 0,813 | 0,015 |
| Average annual number of employees of organizations, (thousand people) | 1,74% | 138 | 0,902 | 0,002 |

To assess the effect of the stochastic component on the results of the work, a multiple experiment was performed using identical initial parameters of the model and a set of trajectories was constructed for the above indicators.

As a result, the standard deviation of the calculation variants (spread of trajectories) for a 5-year period by all indicators did not exceed 1.5% (accordingly, the probability of dependence of the results on the stochastic component is negligible and can be neglected). Thus, we can speak of a rather high descriptive and predictive ability of the constructed agent based model.

In addition, the values ​​of the above indicators will be further used as control variables in regression models (as a vector of socio-economic characteristics of the population).

**CONCLUSION**

The development of transport infrastructure is an important factor in the economic growth of the territory. The ability to predict the transport demand and traffic on the road network is vital for development of regional and urban transport system. Agent based modelling has emerged as a practice tool of traffic and transport planning in region and urban area. The agent based model consists of 8 blocks (6 main and 2 additional), and is represented by 2 types of agents (people - city residents and enterprises). The main blocks of the model: Main, Zones, Roads, Enterprises, People, Public Transport; Additional - Joins, Simulation: main. People can be in one of four states: Satisfied, Acceptable, Bad, Waiting. Enterprises can be in one of 3 states: Grow, Stable, Unstable. The external environment also includes public roads (Roads) and public transport lines (Public Transport), which People use when traveling between home and work.

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