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PROSPECTS OF GRAPH THEORY USAGE IN THE ECONOMICAL AND GEOGRAPHICAL ASPECTS OF TERRITORY PLANNING

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In article problems of using graph theory to solve some tasks of economical and geographical planning are considered. The abilities of geographical information systems (GIS) are also discussed. More attention is given to the potential of graph theory application in the planning of territorial industrial complexes and clusters.

Graph theory is the section of discrete mathematics that studies graphs, groups of non-empty sets of nodes and edges (each edge connects only two nodes). In spite of large number of unsolved problems and unproven hypotheses fields of usage are wide enough. Among them are: social networks and communications, information technologies and geographic information systems (GIS), etc.

Speaking of GIS, the geographical objects (any objects located on the earth, under or above its surface): existing or designed buildings, installations, blocks, even settlements can be treated as nodes of graph; and roads, engineering networks, power lines as edges of the graph. Applying different calculations on the graph allows finding the shortest detour, planning the best route, defining a «service area» of shops, malls, ambulance stations, fire stations.

Modern GIS have a big arsenal to solve any tasks of spatial planning. The solution of some of them, such as optimization of transport costs by distributing stops and determining the shortest path between these stops, considering limiting factors (time, capacity machines and maximum travel time) becomes more illustrative using graph theory. A number of modern GIS software has extensions dealing with the principles of graph theory. ArcGIS has «Network Analyst», Quantum GIS contains «Road Graph». Such modules have been successfully used by enterprises and organizations, governments, allowing them to carry out their activities more efficiently and to make grounded strategic decisions. The graph theory is useful and efficient when choosing the place for industrial complex, service center, and transport and logistics center from several options, when analyzing the geography of supplies.

On the other hand, «Network Analyst» (as well as extensions on the bases of some other GIS software) has a significant feature: it is well designed to solve traffic problems, especially for public transport and is less convenient for logistics. So the analysis, for example, of nearby shops, it performs easily using such parameters as distance, elapsed time, and not so easily when considering the cost of goods, range, etc. But latter are taken into account by the consumer as well, when choosing a store, in which he will go shopping. Therefore such modules are not so convenient for solving the whole spectrum of economic and geographic problems including logistics in full.

For these purposes, where the modules of GIS software are not so efficient, it is better to address to special software, for example software «Grafoanalizator» (current version 1.6) for Windows or «Rocs» (current version 1.12) for UNIX-like operation systems. One can build directed graph with weights of edges and nodes. However, the choice of criteria for weights of nodes and edges determination.

The choice of criteria for determining the weight of edges and nodes depends on the tasks and objectives of planning. Conditionally we divide the tasks of spatial planning at the macro (regional) and micro (enterprise) level. At the macro level, we will evaluate the potential of the regions, settlements. The weight of the node will include:

– the population of the village, the region;
– the quantity and quality (skills, qualifications) of workforce;
– number of enterprises by economic sector,
– availability of scientific institutions, higher and secondary special education, enterprises and organizations of scientific and technical sphere;
– other criteria if applicable.

The weight of edge will consist of:
– distance between cities in kilometers;
– the value of migration streams between nodes in a thousand people per year;
– the volume of mutual trade between enterprises «nodes» in currency per year;
– the frequency of interactions / business contacts between enterprises and organizations of «nodes»;
– other criteria if applicable.

Optionally instead of graphs one can use the gravity model, by analogy with Newton's law of universal gravitation [1], which states that two points attract each other with a force that is directly proportional to the product of the two masses and inversely proportional to the square of the distance between them.

In this case, the mass will represent a set of values of the evaluation criteria. Taking pairs and calculating the value of their «mutual attraction» one can compare settlements and get an idea of the weight of settlement in regional economical system and its relations with other localities/regions.

Let's call micro-level, planning at the level of companies and organizations, such as planning a cluster or an industrial complex. The key features of the cluster are: the geographical proximity of participants and the presence of companies in the same or related industries (cluster members). The correct choice depends on the effectiveness of the cluster as an economic agent; strengthening the competitive advantages of firms and the region. To date, the problem of selection of participants, cluster formation is relevant and one should consider it. For cluster formation the following factors are important:

– the presence of enterprises of small, medium and large enterprises, specializing in working in particular sector;

– the presence of companies operating in related sectors;

– the presence of businesses and organizations serving the cluster members, but do not participate directly in the production (banks, insurance sector, consulting companies and others.);

– satisfactory financial and economic condition of enterprises;

– availability of educational and scientific institutions that provide training (retraining) of specialists and have the research base on the profile of the cluster;

– the geographical proximity of the participants;

– the possibility of the existing or the ability to quickly create a new transport and logistics network;

– the presence of centripetal tendencies among potential cluster members.

One should clarify: technological proximity, contiguity production, geographical proximity are criteria, which distinguish cluster and the holding.

The assessment of potential clusters is made by two steps. The first step is evaluation of enterprises and organizations. It is sufficient to assess the innovative activity or innovation potential, the coefficient of absolute liquidity, financial independence ratio, asset turnover ratio and other parameters, if necessary. Innovation activity includes: interaction with science, design bureaus; investment activity; active renewal of productive assets; the presence and number of innovations successfully completed during the last 3 – 5 years. Evaluation of enterprises and organizations is expressed by weight of a node.

The second step is assessment relations between enterprises and organizations. Weight of the edge will reflect the frequency and amount of interaction between enterprises and organizations, the degree of contiguity of production, and other factors.

However, the cluster activity is affected by such factors as the macroeconomic, fiscal, monetary policy of the state at a given time, the investment climate, even personal relationships between management of companies, force majeure. An effort of cluster members is not enough to run the project and these conditions are difficult to express in some quantitative terms. All the same, the results can be used in selecting potential participants of cluster, in planning of new members, in coordinating the cluster, industrial and innovation policy in the regions. Potential investors can assess the attractiveness of the enterprise and the region for investments. And most importantly, we should remember that an important feature of mathematical methods is that they use to explore the mediated reality. They are used exclusively in the form of models – in some formal abstractions. Soviet economist, Nobel laureate L.V. Kantorovich said that mathematical models can reflect the structure, relationships and the dynamics of the observed phenomena, and it's important to observe constantly their corresponding properties of the simulated reality [2].

So, we came to a conclusion that the standard tools of geographic information systems are not so suitable for solving the problems of economic and geographical planning. Graph theory has application prospects for solving this type of problems, but the list of criteria and their quantitative expression affecting the weight of edges and graphs currently requires further study in order to clarify and verify the above statements and provide opportunities for the practical use of these hypotheses.

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