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On the Way to an Information System of Russian Transport Networks

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Abstract: Currently Russia faces great challenges in mapping its large transport system to characterize transport as an important sector of the national economy, as well as the country's place in the system of Eurasian corridors and the economic space of Eurasia as a whole. The Department of Cartography and Geoinformatics of the Faculty of Geography of Moscow State University has been working on the creation of a spatial database and geo-information support to assess the state and functioning of the transport system of Russia.

The concept of using a system approach and special geographic research is proposed. This concept includes the workflow from designing the GIS project architecture and database creation to thematic mapping and visualization of results in the form of a Geo-resource. The final goal of the project is creating the Internet geoinformation resource. The practical realization of the Geo-Resource is based on the development of a special mapping application integrated into the structure of the resource and connection of this application to Geo-Database as a main depository of spatial information.

Keywords: thematic maps, geo-database, transport network, geo-information resource

1. Introduction

Thematic maps of the transport system are an important part of the analysis of economic state and the necessary characteristics to assess trends and prospects of economic development. Transport system is one of the most vital sectors of the national economy, as well as the country's place in the system of Eurasian corridors and the economic space of Eurasia as a whole. Any transport system is a very complex object, including different types of transport and nodes, joined in one body. That is why the development of transport system mapping methodology is the most difficult task related to the visualization problem of different map scale levels based on the principles of consistency and integrated approaches. The relevance of the topic is due to the need for new research in this direction also because it is associated with an ever-changing demographic and economic situation.

Since 2017, the Department of Cartography and Geoinformatics of the Faculty of Geography of Moscow State University has been working on the creation of geo-database and geo-information support to assess the state and functioning of the transportation system of Russia. This work is complex both in theoretical and methodological terms, and it is based on a set of technological approaches in accordance with the research stage and the structure of transport system and its different levels organization. This includes the determination of scale levels, collection of source data, detailing of information for mapping transport networks of the Russian Federation (federal, regional, local) and designing a geo-database, as well as issues related to the thematic and geometric matching of the source data. The concept of using a system approach and special geographic research is proposed. This concept includes workflow from designing the GIS project architecture and database creation to thematic mapping and visualization of results in the form of a Geo-resource.

One of the main tasks of the project is to study the thematic subjects of the transport system, to determinate the necessary characteristics for their GIS- representation, to create object-oriented thematic geo-database.

2. Research methods

2.1 Background

In the process of selection and system-structural analysis of the collected material, the cartographic and statistical sources, including historical and literary, as well as Internet resources, scientific works and manuals on the topic of transport were studied (Bugromenko, 1987; Schreckenberg et al., 2001; Tarkhov, 2005). The main task, which was to be performed simultaneously, was to combine heterogeneous data from different sources,

convert them into digital form, organize and store them in a strictly formalized form in the database for further use in various tasks.

In order to improve the relevance of the collected material the program documents of complex nature were studied (Transport Strategy of the Russian Federation up to 2030, approved by Government Directive of 11.06. 2014, it sets forth long-term state transport policy priorities, including transport system development goal) and also for transport industries (Development strategy of Russian railways holding for the period until 2030 approved by Government Directive of 17.06.2008). These data are part of the state information resources and give us a complete picture of the current situation and prospects of the transport industry. The main source of quantitative information is the official statistics obtained on the websites of the Federal state statistics service (www.gks.ru.ru); the Federal Service for State Registration, Cadastre and Cartography (Rosreestr: https://rosreestr.ru/site); JSC «Russian Railways» (www.rzd.ru), Federal Agency of Sea and River Transport (http://www.morflot.ru) and RosTransNadzor (http://rostransnadzor.ru). Other specialized and departmental materials were also used.

The following cartographic materials were also used for the development of thematic content and its further presentation on the basis of network technologies: "Transport network of the USSR", 1:4 000 000, created in 1989 in MSU as a wall map for High school; the map "Transport of Russia and neighboring countries", 1:3 700 000, edition "Atlas PRINT"; the map "Transport infrastructure. 2010-2030", presented on the website of Good Logistics (http://goodlogistics.ru). The maps of various atlases were used in addition: "Modern railway network" and "Modern road network", 1:15 000 000 (National Atlas of Russia, volume 3, 2008) and "Transport network of Russia", 1:17 000 000 (Atlas of socio-economic development of Russia, 2009).

2.2 Conceptual design of Transport Information System

The basic structure of the transport system of any region is a set of transport networks including rail and road systems, sea and river transport, airlines, pipelines as well as the network of transport nodes and other systems providing functionality and economic development of the region as a whole.

The final product of the project is a geo-information resource based on the Internet, combining spatial data sets and related heterogeneous thematic information, responsible for the practical implementation of the main goal of the project – a general analysis of the transport system of Russia.

The choice of Internet geographic information resource as the final result of the project is determined by the following factors:

- Comparison of maps based on the use of network technologies is one of the priorities of the modern geoinformation mapping
- Wide audience of potential users
- High flexibility of GIS resource for updating, adding and editing the information
- The possibility to include additional spatial data via the Internet using a network standards for spatial information transmission

The structure and content of the geo-database is determined in accordance with the task, as well as a number of specific issues related to the geometric and thematic matching of data obtained from different heterogeneous scale sources. This particularity is determined primarily by the departmental affiliation of the initial data. Most of the disciplinary information is related to intradepartmental zones, which do not coincide with the administrative division by subjects of the federation (for example, the boundaries of 16 branches of Russian Railways do not coincide with the boundaries of subjects of Russian Federation).

The developed database includes general geographic (basic) and thematic blocks. The general geographic block contains spatial information on settlements, hydrography, administrative boundaries, and transport communications over the territory of Russia for scales of 1: 8 000 000 - 1: 4 000 000. Additional multi-temporal statistical information is linked to settlements and administrative divisions. This information is necessary to estimate analytical and aggregated indicators.

The set of initial data of the thematic block is formed on the Geo-databases data and open access cartographic materials. This dataset includes all components of the transport system with associated qualitative and quantitative characteristics.

When developing geo-database the initial information was systematized and structured according to separate thematic blocks. A related task was the development of reference manuals for the geo-database classifiers, necessary to establish logical links between different objects within a layer and between layers of the spatial database (Lurie et al., 2015). As a result the geo-database makes it possible to find and evaluate sets of special thematic indicators corresponding to the administrative division of the Russian Federation.

The workflow included several stages:

- Initial stage
- Gathering and primary analysis of information
- Creating Geo-database
- Publishing Geo information resource

The initial stage of GIS resource creation includes the development of its conceptual model: the definition of the purpose and main tasks, principles of operation, analysis

of the target audience, organizational issues, inventory, collection, analysis and geographic formalization of the object, which depend on the methodological foundations and flowchart of creating the geoinformation resource and integrated functionality.

Gathering, primary analysis and systematization of all information related to the project task of project is a very important stage. All requirements have been already determined at the initial stage of the study. Since the transport system is a very complex system, consisting of several separate subsystems, compound each other, it was extremely important to find some specific features common to different modes of transport. These features give us a unique opportunity to analyze the logical relationship between different modes of transport, the level of transport accessibility of any region.

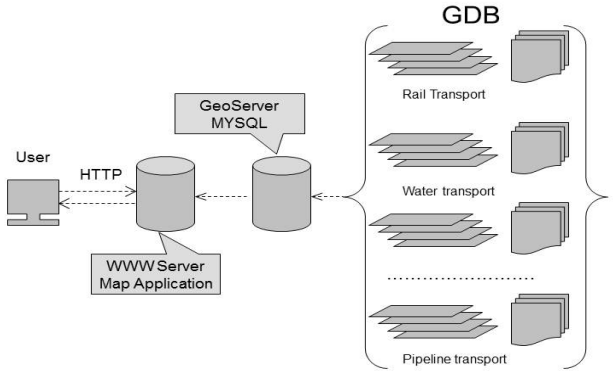

Figure 1. Principal Scheme of Integration GDB into the Structure of Geo Information Resource.

Geographic formalization of the source information is the main condition of the integration of information into the developed structure of geo-database. The database includes spatial data and other additional information related to the transport system. The structure of the database should provide logical relations between different datasets. The result of this stage is a dataset of spatial information represented by a set of GIS layers and a set of additional heterogeneous information linked to different layers objects.

Publishing of geoinformation resource is the final stage of the research. This resource will include spatial and multi-temporal datasets and additional multimedia information. The practical realization of the Geo-Resource is based on the development of a special mapping application integrated into the structure of the resource and connecting of this application to the geo-database as the main Depository of spatial information. Creating the intuitive user interface and the implementation of additional information functionality (spatial/temporal requests, attributive queries, etc.) are the main tasks due to development of the Geo-Resource. The use of special JavaScript libraries, formats for transmitting spatial and attributive information, systems database queries allows creating dynamic pages online, when the user determines what data he wants to see on the map.

2.3 Creating the the set of maps

The formed database makes it possible to solve the problem of creating a map "Transport system of Russia. Current state" and provide a wide range of users with the results of research in the form of geoinformation resource.

A conceptual approach is developed and a universal data model was created to represent the objects of linear localization and network structures, focused on mapping thematic indicators of transport systems. The structure and maintenance of a multiscale object-oriented spatial database for different modes of transport has been developed. The content of database, a set of layers and a set of indicators characterizing the availability of different modes of transport the natural and economic systems of Russia will be determined in accordance with the planned creation of multi-scale thematic cartographic works.

Creating the map “Transportation System of Russia” requires a set of measures to collect and analyze the initial information, which includes the compilation of heterogeneous sources, extracting the most reliable results and further data generalization. This required a considerable amount of time and efforts.

The initial stage of data collection was accompanied by a level of detail that may not be reflected in the mapping software being created. However, data collection at a scale of 1:1 000 000 and smaller is necessary to meet all the topological conditions that play an important role in the modeling of transport systems. Based on the concept proposed in this project, this level of detail should be called the “baseline data collection level”. The main task of mapping in this case was the most detailed display of objects.

The spatial data of each set reflect the geographical and economic specifics, depending on the purpose of a particular scale. It is displayed in the database being created. To ensure a large-scale transition, 3 levels of specification have been developed. The detail of the collected information corresponds to its presentation at 3 levels of the scale.

The first level is a generalized cartographic model of the entire transport network of the country (cartographic image of the whole territory of the Russian Federation). It is an overview level, and the scale of communication lines visualization is 1:8 000 000 - 1 10 000 000.

The second level is a larger representation at the level of large regions: the image of transport networks of economic regions and intra-regional transport links. At this level, a comprehensive analysis of the territory for railway and road accessibility is appropriate. Render scale at this level is 1:4 000 000 - 8 000 000.

The third level is the representation of transport networks for the regions. At the same time, it can be a way of communication not only within the region or other

administrative borders, but also the territorial-industrial complex, railway lines of a separate large industrial facility (plant). This level displays the actual current situation in the specific area. Range scale 1:1 000 000 -1 4 000 000.

The final selection of communication line elements for the presentation in the form of a geographic information resource is carried out according to different principles, depending on the visualization at a specific scale of mapping. On a large scale, special attention is paid to the principle of selecting the most important roads, preserving the main features of the transport network configuration, the ratio of Railways and roads. In the transition to small-scale mapping, one of the main tasks is the selection of cross-cutting directions of transport routes. Later on they will form the polymagistral routes – the most important transport axis of the country – "the unity of parallel lines of different types of general and special transport in the geographically close and unidirectional bundles" (Polyan, 1988).

When displaying the road and rail network, special attention should be paid to the characteristics of transport nodes. This is an important part of the work, as currently the methods of complex display of the nodes characteristics on the transport maps are practically not presented. The feature class “transport nodes” contains data that allow analyzing the area of the region according to the degree of interaction of roads and railways across the country, regions and cities, since the bulk of freight and passenger traffic is carried out with the participation of two or more modes of transport. In this feature class the following characteristics are presented: the significance of the node (the largest, large, medium and small) and the type of node on the set of types of main transport: (land, land-river, land-sea).

The number of indicators in the content of the database is determined in accordance with a number of multi-scale thematic cartographic visualizations, but to obtain a variety of detailed information about the management of the transport system of the Russian Federation, it is necessary to display a sufficient number of indicators for each level to obtain a variety of detailed information about the management of the transport system of the Russian Federation.

Spatial and multi-temporal analysis of geo-database makes it possible to identify and demonstrate the infrastructures of the different transport modes in Russia: rail, road, river and pipeline transport, to show the history and prospects of development. For example, there will be an opportunity to see the evolution of such roads as the Tsarskoye Selo Railway, the Chinese Eastern Railway, the Trans-Siberian Railway and others in the historical aspect.

Also systematic and structured information gathered in the geo-database allow people to create new analytical maps of transport and additional graphic and illustrative material on different thematic topics. The main result of geo-database usage is a cartographic representation of the transport system of the Russian Federation. All other maps in this case will act as a significant part of the data set, which is defined as geographic information resources. A series of thematic maps was created as the basis of the information-analytical system thanks to the created database:

- General transport map "Transport of Russia. Current state»
- Maps showing the structure of the network (by mode of transport)
- Transport infrastructure maps (network, nodes, enterprises)
- Maps of road network density (by mode of transport)
- Transport accessibility (combined transport support indicators)
- Transport Zones and Transport Nodes
- Polymagistral routes in Russia
- Transport activities (transport-movement of goods and passengers)
- Maps on History of transport routes development in Russia

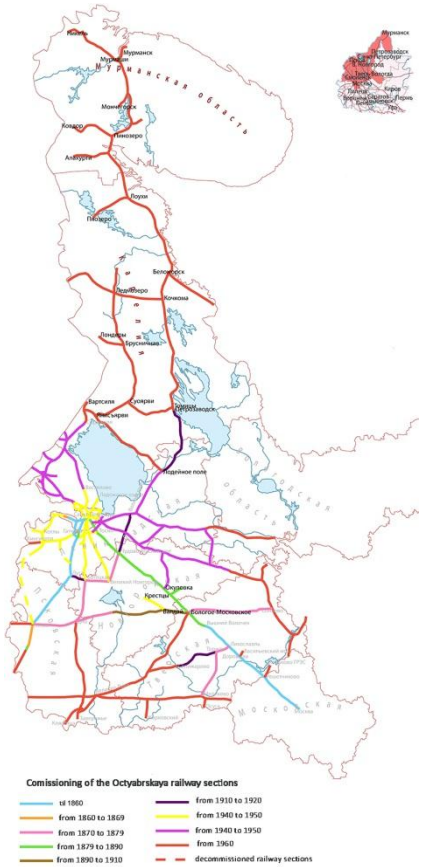

Figure 1 demonstrates the map of the commissioning of the Octyabrskaya railway transport system as an example of a historical map created by information from the geo-database.

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In the course of the work on the creation of cartographic support for geoinformation resource "Transport system of Russia», the criterion for Railways indicators selection was the specifics of transport in the Russian Federation, as well as the geographical and geopolitical position of the country. For example the density of public Railways should be shown as a characteristic of the railway infrastructure development, and transportation of goods and passengers data as an indicator of the transport work performed. The database should include all roads under construction, taking into account the fact that promising areas for the construction of new Railways are those zones that are characterized by limited land development and environment conditions (Eastern Siberia, the Far East).

It is mandatory to show the narrow-gauge railways and feeder roads sidings linking the stations, located on trunk roads, industrial or agricultural enterprises (logging road, peat roads, etc.). Filling the content of the database with such indicators is necessary to represent the current state and prospects of development of natural and economic systems of Russia by various modes of transport.

In addition it is necessary to highlight the integration of multimedia content into the structure of Geo-Resource, which allows the user to get information about various aspects of the Russian transport system development in an interesting way.

3. Conclusion

Complexity of the mapping object calls for the specifics of the developed spatial database, where each mode of transport is presented as a separate dataset. In includes both spatial data and other types of information that characterize a particular mode of transport.

However, there are a number of common features that are a one-size-fits-all approach to all modes of transport (belonging to administrative boundaries, the amount of infrastructure financing, the number of employees in the industry and some other indicators).

The project in the form of geo-information resource is based on the developed spatial data base. Among the positive aspects of this implementation scheme should be noted a large audience of users, the possibility of using third-party data, flexible functionality, and an interactive component that allows you to saturate the content of the resource with multimedia content.

3.1 Acknowledgements

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4. References

Bugromenko V. N. (1987). Transport in territorial systems. Science, Moscow, Russian Federation.

Lurie I. K., Alyautdinov A. R., Semin V. N. (2015). Development and use of network information resources of spatial data for solving scientific and applied problems //Infrastructure of scientific information resources and systems. Collection of selected scientific articles in the proceedings of the Fifth all-Russian Symposium., St.-Petersburg, Russian Federation.

Polyan P. M. (1988). Method of selection and analysis of the supporting frame of settlement: Part 1, resp.edited by G.M.Lappo. M.: Institute of geography of RAS, Moscow, Russian Federation.

Tarkhov S. A. (2005). Evolutionary morphology of transport networks, Universum, Smolensk, Russian Federation.

Schreckenberg M., Lienemann C., and Wahle J. (2001). Intelligente Verkehrsinformation durch Wake up. In: W. Deiters and C. Lienemann (eds.), Informationslogistik, Symposium, Dusseldorf, Germany.