Application of geospatial technologies for analysis and development of transport infrastructure and cadastral activities in urban areas

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Abstract. The current state, development and transformation of transport infrastructure in urban areas are due to factors such as increased safety, environmental requirements, as well as the provision of new opportunities through the connection of vehicles to the Internet. Connected, Autonomous and electric vehicles have become key areas of development in the automotive industry. By the end of 2020, there will be more than 14 million connected vehicles on the roads of Russia, 3.5 million of which are trucks and more than 10 million personal cars. In this paper, the object of the study is the transport interchange of regional importance as a structural component of a single urban space of the city district of Tyumen, Tyumen region. The authors present the results of theoretical research and practical work on the implementation of geospatial systems and technologies in the design of roads. The features of the design of this object using GIS technologies are considered. The analysis of the database of cadastral information about the object of research in the Unified state register of real estate (usrn) with the use of the Internet portal of the Federal service of state registration of cadastre and cartography - Rosreestr.

1. Introduction
The urban area is represented by a variety of objects, which together establish a system of relationships and form the space. Therefore, such a space forms social relations and thus determines the main criteria for the development of society. As noted by Perelygina A.: "Development in relation to the urban environment is not identical to the construction of grandiose buildings of glass and concrete. The city is a complex organism, which is influenced by the political and socio-economic situation. Looking at the architecture of a settlement, you can understand what processes took place within its economic and social life, what events were the most significant. The solution of issues of creating an environment optimal for living, recreation, leisure in our country is hampered by several related factors” [1].

The road industry is the main branch of any developed country. Therefore, roads are called "blood-system" of any state. The development of road infrastructure has a significant impact on urbanisation. They represent a significant social and financial significance in the existence of the current community.
Today, the development of urban areas depends on the rational use of land to ensure effective social policy. Roads are known to be the urban artery responsible for meeting the needs of the population.

Construction and operation of roads is very expensive, but at the same time and very important facilities. In addition, the presence of a full-fledged road network determines the development of social relations of society. Therefore, transport infrastructure, in general, and extensive road networks in its structure are the main factor in the development of urban systems.

2. Novelty
As part of the implementation of measures to digitalize the Russian economy, work is being carried out on the digital transformation of the transport complex to create a new ecosystem that will improve the quality and availability of transport services [2]. Therefore, geographic information and IT-technologies are used in many areas. In this connection, their functionality and the ability to use for a wide range of users has expanded. Geoinformation and IT technologies help to perform spatial analysis of territories, including urbanized ones, as well as to solve a wide range of practical tasks such as:

- city and land cadastre;
- control of large-scale construction;
- control and management of the movement of various machines, mechanisms, goods and people;
- time and frequency services;
- agriculture, industry, mining;
- ensuring the safety of activities;
- geographic information systems (GIS).

The purpose of the study is to consider geographic information technologies for the creation of transport infrastructure as an element of a single urban space on the example of the city of Tyumen.

The novelty of the study is that the reliability of determining the location of the object of research in a single urban space is provided by modern navigation technologies, design, presentation and visualization of it – using geographic information systems and IT-technologies, which will contribute to the possibility of combining information and digital resources for the implementation of digital transformation of the transport complex of the Russian Federation.

3. Objects and Methods
The object of study – the district road, located in the city of Tyumen, Tyumen region.

The infrastructure of geospatial data of roads should be defined as a system of spatial and temporal data obtained for various objects of roads, as a result of research, design, construction, operation and management of real estate, designed for the collection, processing, storage, modeling and dissemination of information.

The main stage in the system is the production of engineering surveys, they are the basis for the following production stages.

The main objective of the survey is information about the entire area with all its characteristics. Formed trigonometric confirmation in the course of research must be the basis for the further removal of the plan in nature (in the territory).

The data obtained in engineering surveys, in practice, almost always processed in an automated mode. The use of modern software provides the establishment of information capacity of the data. It should be noted that the information about the road should be able to be presented in geographic information systems, in order to implement the use of such data. Therefore, the basic principles of road design, as set out in the work [3], are established in the scientific works.]

a) the presence of the optimum approval of the highway and its objects with respect to relief;

b) obtaining acceptable operating conditions of the road;

c) creation of optimal characteristics of objects;
d) determination of the size and price of construction.

Data on the spatial position of the road have such characteristics as accuracy, reliability, completeness, normativity.

The road construction project includes a road plan. It contains all the necessary design data, according to which the length of the individual parts and the entire trunk is determined.

The following calculations and the preparation of relevant documentation is carried out with respect to the picketing and horizontal distances specified on the plan and profile. However, the actual position of the road under construction is spatial, and its actual length is not specified and is not taken into account in the project documentation, which leads to an underestimation of the actual length of the road and, as a consequence, to a decrease in the volume of earthworks and pavement.

In the future, there is a wrong removal of the area of the project position of the axes of buildings. For the same reason, Executive and control surveys revealed deviations of design and actual data, which is particularly evident in the hilly, foothill and mountainous terrain. A special influence on the discrepancy between the design and the actual length of the track has no project accounting for the lengths of the vertical curves, as in the picketing plan and longitudinal profile, they are considered as straight horizontal sections, and in the statement of "straight and curves", where the length of the route is determined, no.

For the rational approval of the highway, the decision of which is made in 3D space, today there is no approved technology.

In the Russian Federation (Russia) a large number of scientific and production organizations are engaged in the automated design of roads [3]. The most widespread software products firms Gredo-Dialoquie (Minsk), IndorCAD (Tomsk, MADI), road research Institute (Moscow).

The process of computer-aided design of the plan and longitudinal profile of the highway route is offered in one of the modules of the software complex "GREDO" GREDO – Road "program [3]. The projected 3D polylines of the main axis of the project trace are typically composed of two 2D polylines, each of which is a plan or longitudinal profile model. Each of these models is defined in its rectangular coordinate system: XY – for the axis plan; PC and H – for the axis profile.

The spatial length of 2D polylines of the profiles of these objects is calculated in the same way as the length of 2D polylines of their plan, namely, as the sum of the lengths of the elements that make up the geometric models of these polylines. 2D planar polylines and 2D polylines of their profiles are also described by line segments, circular arcs and parabolas of 2nd and higher degrees (bicubic splines, arcs of various transition curves, etc.). At the same time, researchers karpik A. P., Nikitin A.V. note "the length of the profile polyline will almost always be greater than the length of the plan polyline" [3,4]. Therefore, there is a need to develop a methodology for determining the spatial length of the route that meets the regulatory documents.

At the present stage in the Russian Federation are changing the rules and regulations for the design of roads in connection with the adoption of the European agreement on international highways and the intergovernmental agreement on the Asian highway network.

The development of road transport infrastructure is considered to be one of the most pressing challenges in the world. The main problems of the Russian transport infrastructure are noted in the work of Shcherbin S. V.: "capacity, territorial coverage, connectivity, construction, modernization and maintenance, environmental impact, sources and amounts of financing and more" [5].

The creation of a successful, powerful and cost-effective road transport concept that meets the needs of the community will require the use of appropriate tools-the geographic information concept. According to Shcherbin S. V. in work [5] transport GIS is obliged to guarantee performance of all "basic functions of construction, formation and the help of work of transport infrastructure, these as modeling and design, construction management, mental management of movement, the forecast of a condition of a network and a traffic, analytical functions (for example, an assessment of a throughput and connectivity of networks), inventory and certification of objects of motor transport, with one-time providing".
The role of GIS today is high in order to manage various kinds of information [6-8]. One of the tasks that transport GIS solves is to provide a developed transport system with effective financial performance. For example, GIS has tools for forecasting and planning the progress of repair and reconstruction of the roadway, also in the management of the road situation.

One of the main features of the geospatial support of the transport system is its versatility, provided that it is effectively used for any type of transport. This requires the ability to manage financial flows in order to preserve, review and provide spatial data (visualization) to automate administrative movements and ensure that the best administrative conclusions are accepted. Therefore, we will formulate the basic principles of geospatial support of the transport system:

- availability and openness of the use of geographic information system for any users (including public authorities and other interested persons);
- normatively, that is, the geographic information system must meet the regulatory and legal support of all levels of documents, including international standards;
- multi-functionality, that is, the possibility of geo-information system of interaction with other types of information systems, including through exchange data formats.

The creation of an urbanized area implies the modeling of a single urban space. Also an integral part is the procedure for monitoring the territory. The process of creating and monitoring a single urban space model is shown in the diagram in figure 1.

Transport infrastructure, in General, and transport interchange of regional importance, in particular, are one of the elements of a multi-level digital model of the unified urban space of the city of Tyumen.

The object of the territory of the unified urban space is a linear object of transport infrastructure of regional importance: surrounding the highway of Tyumen on the site from the highway Tyumen-Khanty-Mansiysk through Tobolsk, Surgut, Nefteyugansk to the highway Tyumen – Borovsky – Bogandinsky. Eastern bypass [9].

The Eastern bypass of the city of Tyumen is one of the most necessary and important transport projects in the region. Its construction began in the 80s of the last century. Some sections of the road were built in the 2000s. The project completion date is 2019.

**Figure 1.** The process of creating and monitoring a model of a single urban space.

The relevance of the project consists in the following provisions:

- due to the Eastern bypass, the Central part of Tyumen will be significantly freed from cargo transit transport;
- urban residents will also be able to freely drive to work on the bypass road, bypassing the Central streets;
• with the commissioning of the bypass will be significantly improved the work of the entire transport scheme of Tyumen;
• the new road will connect the Federal highway, bypassing the Central streets, which will not only improve the environmental situation in Tyumen, but also reduce the wear resistance of the roadway.

On October 21, 2015, the bridge over the Tura river was put into operation in Tyumen. The construction of the bridge across the Tura river and the traffic junction on Dambovskaya street on the Eastern bypass were completed ahead of all deadlines, in less than a year. This interchange will improve the traffic of the North-Eastern part of Tyumen and, accordingly, will unload the bridge across the Tura in the alignment of Melnikaite street, reduce the flow of cars through the crossing, which will allow parents to bring children to kindergartens, will be adjusted bus traffic.

To date, 1,300 tons of superstructure have been collected. The total weight of the metal structures of the future bridge will be 9742 tons. The length of the bridge and interchange, including access roads-3.5 kilometers (including through the Tour itself – 718 meters).

The total length of the Eastern bypass-76 kilometers. 60 km of them have already been built, a segment of 7.5 km is in the active stage of construction. For the remaining kilometers develop technical documentation. The Eastern bypass is part of a large-scale project designed to improve traffic in the city centre. The bridge over Tura in the area of the forest Base, the junction on Dambovskaya street, a new road that connects the plant "Tisma" and treatment facilities near the village of Bykovo, all this is part of a large project "Eastern bypass of the city."

Figure 2 shows the launch complexes of the Eastern bypass of the city of Tyumen.

Figure 2. Start-up complexes of construction of the Eastern bypass of the city of Tyumen.

Under the third start-up complex is meant a motor road on the section from the transport interchange at the intersection with the road Tyumen — Bykovo to the highway Tyumen — Krivodanova. In total, the project of launch complexes five, one and five are ready and actively used by motorists. Figure 3 shows the location of the projected road construction project of the Eastern bypass of the city of Tyumen.

Administratively, the boundary of the territory of the linear object is located within the boundaries of the city district of Tyumen, on the territory of the Lenin administrative district and within the boundaries of the Emba Rural settlement of the Tyumen municipal district. The approximate area of the projected territory in accordance with the task of preparation of documentation on the territory planning (hereinafter – the Task), approved by the order of The main Department of construction of
the Tyumen region from 20.02.2016 № 114-OD "on the preparation of documentation on the territory planning", is 35.43 hectares. In accordance with paragraph 5 of the Task the boundary of the projected area is clarified and is 36.34 hectares.

Figure 3 shows a space image with the location of the projected object of road construction of the Eastern bypass of the city of Tyumen.

![Figure 3. A fragment of a satellite image with the location of the projected road construction object. Resource SAS planet.](image)

Methods and technologies used in the work: analytical, modeling, GNSS - technology, GIS - technology (MapInfo Professional, Gredo, SAS planet, Internet portal rosreestra).

Tyumen is the administrative center of the Tyumen region, one of the most developing cities in Russia, with significant socio-economic, scientific, technical and production potential. The area of the municipality city district city Tyumen-698.48 km² [10].

4. Results

The boundaries of the project of land surveying the territory of the linear object of transport infrastructure - the district road of Tyumen on the site from the highway Tyumen – Khanty-Mansiysk through Tobolsk, Surgut, Nefteyugansk to the highway Tyumen – Borovsky – Bogandinsky.

The purpose of the cadastral works on the object of study-the definition of the coordinates of the turning points of the boundaries of the formed land plots within the boundaries of the surveying project, which were determined using global navigation satellite systems-in the coordinate system of the MSC № 1 TO [11], adopted for maintaining the real estate register in the Tyumen region, as well as information from the real estate register about the fixed points. The resulting error in determining the coordinates of the characteristic points is within the permissible values according to Russian law.

Through geographic information technology data on the spatial position of the design object-land-were created in the program GIS MapInfo Professional (figure 4).

As a result of cadastral works, a boundary plan was formed, which is further issued in the form of an electronic document of XML format through the Internet portal of Rosreestr, provided in the order of the interdepartmental electronic interaction system - SMEV[12].

Entering of data on borders of the parcels of land in usrn is made within 30 days. On the basis of the approved documentation on the placement of the transport interchange, land plots with cadastral numbers were put on the state cadastral registration: KN 72:23:0222001:1735, 72:23:0222001:7977, 72:23:0222001:7971, 72:23:0222001:7971, 72:23:0222001:8639, 72:23:0222001:8190, 72:23:0222001:8632, 72:23:0222001:8311.
The result of the cadastral registration of the land plot with the cadastral number: KN 72:23:022001: 1735 is visualized on the fragment of the service of the public cadastral map of the portal of Rosreestr [13] (figure 5).

**Figure 4.** Formation of the object of cadastral works-land in GIS MapInfo Professional.

**Figure 5.** A fragment of the public cadastral map of Rosreestr with the object.
All land plots, and in General, the linear object of transport infrastructure, are transferred to permanent perpetual use of the SCU TO "UAD", for which, including the planned budget for maintenance and operation.

As a result of performed theoretical studies and practical actions with use of modern navigation technologies to perform cadastral works, design, presentation and visualization using geographic information systems and IT technologies formed part of the transport infrastructure model of a single urban space, which is a digital model of the land territory of linear transport infrastructure of regional significance: County road G. Tyumen on the section from the highway Tyumen-Khanty-Mansiysk through Tobolsk, Surgut, Nefteyugansk to the highway Tyumen-Borovsky-Bogandinsky.

The use of the capabilities of GNSS - technologies in cadastral works allows you to process observations in any weather and at any time of the day, gives the possibility of obtaining coordinates in real time, provides the possibility of automated measurements and processing of results, eliminates mandatory compliance with the conditions of mutual visibility between the geodetic points defined networking and allows you to increase the distance between the designated points up to tens of kilometers.

The development of transport infrastructure of urban areas gives a positive social effect, and the integration of modern navigation, geographic information systems and IT -technologies will contribute to the implementation of the concept of smart city (Smart Site) and the integration of information and digital resources for the implementation of the digital transformation of the transport complex of the Russian Federation.

5. Conclusions (Summary / Conclusion)
In the process of scientific research:
- the analysis of the current state of methods of construction of the infrastructure of geospatial data for the transport system;
- studied the problems of Russian transport инфраструктуры4
- the article describes reasonable solutions for the development and research of geospatial data infrastructure for roads, the introduction of which makes a special contribution to the development of technologies for creating geospatial data for such objects and in other areas of the Russian economy;
- the basic principles of geospatial support of the transport system are formulated;
- considered the technology of design elements of the transport system-roads-in the representation of 2D, 3D;
- a model of a single urban space is proposed;
- the element of transport infrastructure of the unified urban space model was created, which is a digital model of land plots of the territory of the linear object of transport infrastructure of regional importance: surrounding the Tyumen road on the section from the Tyumen – Khanty-Mansiysk road through Tobolsk, Surgut, Nefteyugansk to the Tyumen – Borovsky – Bogandinsky road.

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