GIS in the study of transport infrastructure of technogenic-deformed territories

V O Penkov¹, V N Astakhov², A S Sayapin³, N V Bielikova², E A Bielikov²,³

¹O.M.Beketov National University of Urban Economy in Kharkiv, 17, Marshal Bazhanov Street, Kharkiv, Ukraine, 61002
²Ukrainian State University of Railway Transport, Feierbakh Square, 7, Kharkiv, Ukraine, 61050
³E-mail: belikov.e.a@kart.edu.ua

Abstract. Timely application of GIS technologies is determined by the need to create an intelligent digital control system for spatial surveying and road data in combination with information resources about the real state of infrastructure facilities. It is necessary to use the techniques of data collection, processing, and analysis corresponding in accuracy, reliability, and efficiency, such as the tasks set for the GIS, as well as modern capabilities of computer technology and software. The current lack of the concept and methods of geoinformational support for the functioning of the transport infrastructure of cities in technogenic-deformed territories (TDI) makes the solution of this issue relevant. Today, it is technically feasible to create a space-time model of deformation processes based on data from many years of field studies also using methods of mathematical modeling of mining processes and surveying calculations. The main method of research is the analysis of field studies using GIS modeling, using mathematical and statistical methods. The source data are published materials of long surveying and geodetic observations and statistical materials created in previous years by various organizations of Ukraine.

1. Introduction

A significant number of city streets and roads of coal mining regions are located in areas where mining is carried out by underground technique. Under the influence of the consequences of underground mining, the last ones are often in unsatisfactory condition. The main problem in ensuring the quality functioning of such roads is the lack of methods for assessing the impact of underground mining on their current condition, and thereby a clearly planned strategy for their maintenance. Therefore, for a holistic understanding of this problem and its successful solution, a clear understanding of the object of study and the use of a systematic approach and the latest developments in science and technology in solving the problem are necessary.

Each city is characterized by many features that should be taken into account in the process of its research, design, and management. From the position of a systematic approach, a large city is considered to be simultaneously as a system consisting of a finite set of elements, and as an element of a more general system – a region, a country [1].

Transport infrastructure (TI) is a part of the urban body, on which the quality of life of the urban community and the fulfillment of its socioeconomic functions depend. The quality of the urban
environment is largely determined by the quality of TI functioning. The latter has a spatial aspect and the specificity of its elements, determined not only by their qualitative and quantitative composition, but also by their territorial relationship with respect to each other. In the course of the change, the transport infrastructure moves from one state to another. Therefore, using the definition of “state of TI”, the moment of reaching a certain level of its development is recorded [2-4].

Deterioration of the work of the transport infrastructure elements is possible for various reasons, especially in an already anthropogenic-changed environment, where there are a number of specific factors that affect the nature of the urban lifestyle and public health.

In Ukraine, significant changes in the spatial position of the earth’s surface, causing deformations of buildings and structures, also occur after the cessation of the development of mineral deposits by underground technique [2].

As a result of analysis and assessing the condition of the streets and roads of cities located in technogenic-deformed territories, it was found that today, at the stage of decline in the mining industry of Ukraine, they largely suffer from the consequences of underground mining (UGM) and other factors associated with them, and require additional costs to maintain them in a satisfactory condition.

The spatial distribution of transport infrastructure facilities and places of manifestations of technogenic deformations made it inevitable to use the means and methods of geoinformational technologies when considering their interaction.

In mine surveying, in municipal services, and road construction, GIS of various levels – enterprises, municipal, and industrial – have been created for quite some time. In the mining and road industrial sectors, they are partially unified. Therefore, it is inevitable to include the results of studies of the UGM impact on the transport infrastructure as topics, layers in GIS of the appropriate purpose and level, and expand the possibilities of using GIS technologies. Necessary research for developing programs to determine the quantitative and qualitative impact of UGM, both on individual elements of streets and roads and on the transport infrastructure of settlements, to assess damage and develop measures to eliminate and mitigate the technogenic impact; the ways of rational use, ensuring sustainable functioning and development [1].

2. The analysis of studies and publications
The implementation of the geospatial data infrastructure (GDI) and the use of GIS technologies can contribute to a high-quality solution to the problem to the greatest extent.

In order to create and develop the geospatial data infrastructure in the quality management of adjusted streets and roads, the following tasks are solved:
- analysis and assessment of the state of reconstructed streets and roads;
- definition of the basic principles of the formation of the geospatial data infrastructure on the reconstructed streets and roads;
- classification of reconstructed streets and roads;
- determination of factors of influence on reconstructed streets and roads;
- substantiation of the choice of characteristics and the construction of a hierarchical model of their functioning;
- development of recommendations on the management of reconstructed streets and roads using GIS technologies and an industry geospatial data set [6-7].

A study of the state of the formation of the geospatial data infrastructure has shown that Ukraine is working on the introduction of geodata sets at different levels in various fields of activity, including mining and municipal economy.

As for the streets and roads being reconstructed, the initial stage of the formation of the geospatial data infrastructure is being determined. The proposed structural model of the system for ensuring the quality functioning of reconstructed streets and roads, which shows the hierarchy of factors influencing the provision of the original goal – the quality functioning of reconstructed streets and roads [7].
3. The basic part

The research structure includes:
- consideration of the principles and approaches of information support for monitoring the transport infrastructure of the cities in TDT;
- presentation of the geoinformational system as the basis for the operational study of the basic parameters of the urban environment;
- development of the concept and methodology for creating the GIS subsystem of the “transport infrastructure in TDT” and its elements.

As a result, a methodology for geoinformational mapping of the state of the transport infrastructure of restored cities, in which the capabilities of geoinformational analysis are established based on the methodology for reproducing special synthetic electronic maps, is being created; the sequence and content of the stages of creating the theme of the transport infrastructure of the restored territories are being substantiated. The developed technology and methods of geoinformational mapping allow quickly reflecting and evaluating the state of the transport infrastructure of the urban environment of the restored cities. Given the intersectoral state of the “Restored Streets and Roads” (RSR) system, a comprehensive analysis of the situation and a full assessment of the current and forecasted condition of the facilities are significantly complicated. Therefore, a qualitative, reliable assessment of the existing situation is possible only with a joint analysis of the influence of various factors and heterogeneous data [7].

The main goal of the study and all the factors affecting its achievement are distributed among the levels depending on the degree and nature of their impact.

In the system for ensuring the quality functioning of the restored streets and roads, hierarchy levels are highlighted, which are conditional to some extent.

Level 1. The goal is to ensure the quality functioning of the restored streets and roads.

Level 2. The main factors of influence in ensuring the quality of the restored streets and roads functioning, which directly affect the achievement of the goal. They are inherent in many systems and are generalizing factors influencing the functioning of the entire system: environmental; natural; organizational and legal; socioeconomic; technical; geoinformational factors [8].

Level 3. At this level, grouping of elements is carried out according to factors affecting the quality functioning of the restored streets and roads:
- public authorities and local authorities;
- specialized departmental governing bodies;
- research and design organizations;
- industry enterprises, institutions, organizations; RSR owners and users;
- the environment.

Level 4. The factors affecting the quality functioning of the restored streets and roads:
- monitoring the RSR status;
- planning development strategies and project documentation development;
- planning and rational distribution of the transport infrastructure;
- measures to streamline the functioning of the restored streets and roads:
- financing and investment policy;
- legislative, regulatory, scientific, and methodological support;
- RSR design, RSR operation, cadastral work, monitoring of UGM and other adverse processes and meteorological phenomena;
- creation of a database of geodetic data in the territory of the city and region;
- introduction of modern technologies of geodetic surveys (GS) and GIS;
- a single technical process throughout the country;
- formation of geospatial data sets;
- land forms;
- use and protection of land;
- the choice of the business pattern and specialization of the enterprise, ensuring the functioning of the restored streets and roads.

Level 5. Geospatial data to ensure the quality functioning of the restored streets and roads, based on the study of which Level 6 is being formed:
- coal industry (mining, mine surveying, and geodesy)
- municipal economy (transport infrastructure, land management, and cadastre)
- technical and environmental monitoring of the RSR and UGM state.

Level 6. The standard of the set of geospatial data to ensure the initial goal – the study of the restored streets and roads quality functioning [8-9].

In order to achieve this goal, the studying the influence of the individual factors of the hierarchy lower levels on the top of the system have been carried out [10].

4. Conclusions
The influence of these factors is uneven, so it is necessary to establish the intensity of the impact of each of them and determine their priority, affecting the main goal.

1) As a result of analysis and assessment of the restored streets and roads, it was found that today, when the coal industry of Ukraine is in a recession phase, the streets and roads of cities located in restored territories are largely affected by UGM and other related factors and require additional costs to maintain them in satisfactory condition.

2) A study of the state of the forming the geospatial data infrastructure has shown that Ukraine is working on the introduction of geodata sets at different levels in various fields of activity, including in the mining industry and the municipal economy.

3) Regarding the restored streets and roads, the initial stage of the geospatial data infrastructure formation has been defined.

4) The classification of research objects allows identifying the main factors affecting the quality functioning of the restored streets and roads. A structural model of the qualitative functioning of the restored streets and roads has been built and a study of factors using system analysis methods, by which a group of the most important ones was determined, has been carried out. As a result of research by the hierarchy analysis technique, it was found that the formation of geospatial data sets is a significant factor and it is almost on a par with the factor of financing and investment policy. The decisive factors are the factors of planning development strategies and the project documentation development, as well as legislative, regulatory, scientific, and methodological support.

5) Based on the factors that have the greatest influence on the formation of a profile set of geospatial data, geospatial data sets are being formed to ensure the quality of the restored streets and roads.

6) Processing each set using the mathematical apparatus of the hierarchy analysis technique (HAT) allows to create a geospatial data standard to ensure the high-quality functioning of the restored streets and roads.

References
[1] Bilatinsky O A, Penkov B O, Shilin I B 1996 Concept of scientific and technical program «Highways on man-made deformed territory». Road car of Ukraine, 3 p 35-37
[2] Order on approval of the Safety Rules for the development of ore and non-metallic minerals in the underground 23.12.2016 № 1592. Ministry of social policy of Ukraine https://docs.dtkt.ua/doc/1220.501.0.
[3] Concept of the Draft Law of Ukraine "On National Geospatial Data Infrastructure" of 21.11.2007
[4] Concept of formation of national geospatial data infrastructure of Ukraine. Approved Cabinet of Ministers of Ukraine of 15.05.2006
[5] Karpinsky Yu O, Lyashchenko A A 2004 Geospatial data infrastructure: principles and methods for forming a basic set of geospatial data. Bulletin of Kryvyi Rih Technical University, 3 p 72-77
[6] Penkov B O 2014 Gis in assessing the status of fake streets and roads of young people. «Science and innovation. Proceedings of the Second All-Ukrainian Scientific and Technical Conference of Students, Graduate Students and Young Scientists» Dnepropetrovsk December 02-03 2014 State VNZ “NGU” 5. http://science.nmu.org.ua/ua/conferences/molod-nauka-ta-innov/pdf-2014/20150204-06.pdf.

[7] Penkov B O, 2015 To the development of urban streets and roads research in man-made and deformed territories Urban development and territorial planning. Kharkiv p 398-404

[8] Chernyag P G, Kornilov L V, Melnychuk O Y 2005 Once again about land management «Modern achievements of geodetic science and production. Collection of scientific works» p 336-345

[9] Lischinskaya Y A Geospatial data infrastructure to ensure the sustainable development of reclaimed land http://bal.znaimo.com.ua/docs/26926/index-10654-1.html.

[10] Saati T, Cairns K 1991 Analytical planning. Organization of systems. «Trans. with. eng. Vachnadze R G» – M Radio and communication 224 p

Acknowledgments

The authors express their gratitude for the support and patience to their families, colleagues and friends who helped in writing this article.