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Surface Transportation Engineering Technology

PRACTICAL USE OF BIM MODELING FOR ROAD INFRASTRUCTURE FACILITIES

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Abstract

Introduction: The subject of the study is transport infrastructure. The paper describes engineering solutions suggested by Hexagon Geosystems Rus and other large companies that conduct construction monitoring using BIM technologies and develop software solutions, services and equipment. It also addresses implementation of such engineering solutions. **Purpose of the study:** to achieve high level of road maintenance, preserve the existing road network, ensure traffic safety, switch to new methods of infrastructure facilities management by implementing BIM-based projects. **Methods:** Domestic products keep up with capabilities of modern information technologies and demonstrate BIM capabilities during its use in road infrastructure projects. Russian experts suggest software solutions to create a new environment for economic development, including in the road industry. **Results**: Documentation based on 3D laser scanning makes it possible to schedule maintenance and repair of transport infrastructure facilities. Data obtained are relevant and objective as the human factor is removed from final drawings and 3D models, thus improving the efficiency of the transport infrastructure facilities management system.

Keywords: BIM-modeling, transport infrastructure, road information model, geographic information system, digital transformation of roads

Introduction

Linear facilities are managed using transport infrastructure geographic information systems (GIS). Though GIS have been used for road and road facilities management since the 1990s (e.g. ArcGIS (ESRI), MapInfo (MapInfo Corp.), free QGIS, IndorRoad (IndorSoft), DorGIS (Intelnova), etc.) (Boykov, Kuzovlev, Barannik, 2017), the regulatory framework, which is much needed for successful Building Information Modeling (BIM) implementation in Russia, is still being developed (Shamraeva, Kuzovlev, Barannik, 2018a). It is required to transform the entire construction industry and, in particular, ensure interaction with all existing information systems created within the framework of the Digital Economy of the Russian Federation program (Decree No. 1632-R of the Government of the Russian Federation dd. 28.07.2017 "On Approval of the Digital Economy of the Russian Federation Program").

Currently, computer-aided design (CAD) and 3D modeling are quickly developing. As a result, a demand arises to exchange 2D and 3D data between various CAD systems. Therefore, a standard is needed that could register changes in an infrastructure facility at all stages of its life cycle, i.e. a data bank containing such information as infrastructure facility requirements, a facility project and alterations thereof, as well as physical assets comprising such infrastructure facility and alterations regarding those assets. Researchers dealing with the issue in other countries also acknowledged the lack of national standards for BIM and software interoperability (Sandeep, Criminale, 2017). Expectations from different stakeholders involved in construction projects where BIM is utilized are different and can lead to misunderstandings (Abbasnejad, Moud, 2013). Upon introduction of ISO 15926 standard, a traditional software concept based on task issue and execution control is replaced with a flexible and adaptive collaboration concept.

For Russia, introduction of BIM technologies is just a matter of time as new engineering models supported by open data protocols are already being implemented. It is possible to provide a formal description of the BIM process at each stage of the life cycle of a construction and operation facility based on particular assumptions and suggestions. At the first stage, a BIM Execution Plan (BEP) is developed. It sets a procedure for collaboration between different teams within a BIM project. At the second stage, a Project Implementation Plan is developed, which, in particular, includes a Supply Chain Capability Summary (SCCS). Finally, at the third stage, levels of information model development (LOD) in terms of geometry and attributes are determined. Design companies, software and hardware developers, etc. introduce information modeling into their business processes using a BIM planning process map (Barannik, 2017).

The conditions listed above offer a BIM team an opportunity to prepare smooth transition to the next stage of the life cycle, ensuring BIM process continuity. The present paper demonstrates implementation of BIM-based projects using the example of practical activities carried out by Hexagon Geosystems Rus and other companies that conduct construction monitoring using BIM technologies and develop software solutions, services and equipment. Use of BIM in the road industry in general makes it possible to form a unified approach to the structure and special library of elements of a digital road model. Therefore, we can draw the following conclusion: GIS of roads reaches the highest maturity (according to the British classification) – iBIM (Shamraeva, Kuzovlev, Barannik, 2018b) and demonstrates BIM capabilities during its use in road infrastructure projects. Russian experts not only suggest optimal unique software solutions. They create a new environment for economic development, including in the road industry.

Subject, tasks and methods

The subject of the study is transport infrastructure, which is considered as an object intended for safe and comfortable movement of its users. Digitalization of transport infrastructure is one of the most important conditions for its development. Within the framework of digital transformation of roads, the following constituent elements can be distinguished:

- mobility (increase in speed, volume and efficiency of transportation; development of user services and integration into national and transnational transport corridors);
- safety (traffic safety; transportation safety, public safety; anti-terrorism security);
- efficiency (digitalization of public services; increase in public mobility; elimination of digital inequality; traffic situation awareness enhancement due to navigation services).

In the current circumstances, it is required to provide conditions to develop the services indicated above. Issues related to optimization of transport communications and upgrade of integrated transportation safety based on intelligent transport systems become more and more important and relevant. Main tasks of the road industry for the next few years are the following: to switch to new methods of infrastructure facilities management, achieve high level of road maintenance, preserve the existing road network, and ensure traffic safety. The road industry has experience in using digital technologies and implementing intelligent transport systems on Russian roads (national projects: ERA-GLONASS, Digital Transport and Logistics, Caravan, Platon system, Russian Railways infrastructure, etc.). The process for informatization of domestic transport enterprises is no less important. At the facilities of the Avtodor State Company, during construction of the Moscow–Saint Petersburg M-11 road sections and the Central Ring Road in the Moscow Region, Hexagon and Leica Geosystems 3D machine control systems are used. It should be noted that surveyors, designers and contractors work at the facilities using a unified coordinate system (Eastman, Teicholz, Sacks, Liston, 2011). In this regard, let us consider a number of Hexagon Geosystems Rus products. The company was established in 1997 in accordance with a development strategy for new businesses. Hexagon Geosystems Rus is engaged in introduction of advanced global technologies to reduce time and money expenditures of manufacturers during various topographic and geodetic works with the use of GPS equipment, traditional equipment and 3D laser scanning technologies. Using Leica Geosystem geodetic tools (GPS receivers and total stations), the company develops and adapts technologies to specific tasks of customers (Znobishchev, Shamraeva, 2019).

a) *b)*

Figure 1. Leica Geosystem geodetic tools: a) FlexLine TS02plus total station; b) Leica GS07 NetRover with a Leica CS20 3.75G Captivate controller

Leica GR geodetic receivers are able to receive signals from GPS and GLONASS satellite systems as well as from Compass and Galileo being designed. To control and operate a network of reference stations with Leica GNSS Spider software, modularity is applied, which ensures automation of the process of transmitting satellite data to users for post-processing or in real time with the LEICA GEOSYSTEMS technology. For the purposes of data management, visualization, import and export, Leica Geo Office multi-functional software suite, which is able to process geodetic measurements, is used. Leica Geosystems experts are constantly working to improve their tools and software. GPS/GLONASS receiver signal quality, sensor and control unit frequency, and total station accuracy are improving, and it is becoming easier to use the tools.

It shall be noted that for more efficient road facilities management, a single platform is required. Such platform is intended to provide timely and reliable information, namely:

- consolidated data on the current traffic situation;
- data (stored in data bases) on the condition of roads and movable facilities to prepare analysis reports and make forecasts;

- up-to-date information on the condition of roads for a wide variety of customers;
- feedback from traffic participants with regard to incidents, road pavement condition and other important information.

Based on the domestic software, a single point of contact between the state and business during transportation will be developed. The platform will set uniform standards, rules and regulations for exchange of data, including legally relevant data on transport infrastructure and vehicles. That is another benefit of BIM modeling when designing transport infrastructure facilities (Bryde, Broquetas, Volm, 2013). The platform will serve as an aggregator of data on transport (without privatization of such data), providing non-discriminatory access to such data for all concerned members of the transport industry. Finally, it will allow us to preserve our national sovereignty over information flows within the transport system of the country. Use of the global positioning technology based on GLONASS/GPS systems takes us to a whole new level in terms of construction machinery operations' automation when road works are performed (without labor-intensive location survey), ensuring design accuracy and high quality of works at any stage of a project.

Such system is based on the use of a 3D digital terrain model (DTM), which is uploaded to the on-board computer in a cabin. In the course of machine operation, location of the attachment is determined in real time on the basis of data obtained from GLONASS/GPS receivers and sensors installed on the machine. The location obtained is compared with the DTM, and the corresponding calculated required movement is displayed on the screen. In automatic mode, the attachment is always kept in a permanent position. Practical use of the comprehensive technology (from design to its implementation) at the facilities of the Avtodor State Company (on road sections of the M4 Don Highway: facilities of Avtoban Road Construction Company, Transstroymekhanizatsiya, Donaerodorstroy, Krasnoarmeyskoye Road Maintenance and Construction Department; on road sections of the M-11 Moscow–Saint Petersburg Highway: facilities of Transstroymekhanizatsiya, Avtoban Road Construction Company) showed the following advantages:

- human factor reduction;

- no material overconsumption for road grading;

- schedule reduction: each machine operates 2–2.5 times as fast; logistics of moving trucks loaded with materials, and other machines is optimized;

- reduction of machinery out-of-service time during preparatory works (e.g. geodetic survey, stationing and elevation setting-out are not required). The automated control system for road construction machinery copies the design to the actual surface;

- reduction of time and money expenditures for geodetic works (up to 90%). No geodetic survey is required.

Such developments represent information society trends and support national sovereignty over information flows within the transport system of the Russian Federation.

Method development

At the current stage of road digitalization in Russia, practical use of BIM modeling for road infrastructure facilities plays a significant part. Tools and software developed and used for road diagnostics serve as the information basis that could be integrate into intelligent transport systems. Machinery efficiency increase, provision of required accuracy and quality, and schedule reduction are the main reasons to equip contractors with 3D automated control systems for road construction machinery. In those companies, only 20% of operated machinery are equipped with 3D technologies. In Northern Europe, average equipment with such systems is 60%; in Central Europe and in the USA – 30%. Moreover, it is currently legally required to use 3D automated control systems for road construction machinery at all stages of cement concrete road construction.

In 2018, during construction of road infrastructure facilities, monitoring was implemented on the Central Ring Road, where data of the GNSS geodetic service and data of 3D automated control systems for road construction machinery were used in a single cloud. Prompt control over earthwork levels allowed foremen to arrange for delivery of materials in the right quantities and optimize transportation logistics. On a case-by-case basis, contractors implemented BIM systems at the site. Those systems provided real-time processing of data on construction stages and allowed employees to maintain as-built documentation. BIM systems ensured the following:

– remote project management from the office;

– remote work control, including control of actual marks with respect to the design surface, and monitoring of the current location;

– storage of location history with time marks to determine where and when machines and surveyors were located;

– remote uploading of design data to the machine; that way a machine operator can get design data and start operations earlier;

– performance evaluation, collection and processing of data on machine passes, and display of those data made it possible to evaluate quality of works and track the progress with respect to design data.

Due to data analysis within the BIM system using various data collection systems (from UAV and mobile laser scanning systems), it became possible to promptly track changes in design data, control material supply needs, and achieve the following:

– improvement of accuracy and speed of works;

– constant real-time monitoring of design elevations;

– reduced number of passes: economy of fuel, lubricating oils and liquids; reduced machinery depreciation;

– reduction of time and money expenditures for geodetic works, geodetic survey, monitoring; reduction of machinery out-of-service time;

– possibility of night works;

– safety of works.

BIM systems are intended to perform tasks related not only to road infrastructure but to various economic branches as well.

Road diagnostics is based on principles of radiation technologies as well as competencies accumulated in the industry. In an integration laboratory, 3D models of roads in section view can be developed. Using a scanner, it is possible to collect data from a road section with a width of 7 m (at a speed up to 100 km/h), including from a depth of 7 m under the road pavement. The data obtained are processed automatically by special software and uploaded to the global information system. Using that system, concerned individuals and entities can get necessary information for design, construction, maintenance and repair of the Russian transportation network. Not only engineers and qualified operators but car enthusiasts as well can join the process of data registration. They will be able to make photos of any road pits and unevenness, violations in traffic sign installation and, using a special app, send those to the shared data base. It is expected that large arrays of information (hundreds of TB) will be accumulated.

In 2017, the State Company began creating systems for monitoring of transport and operating conditions of roads, and constructing a network of observation stations registering all parameters of road pavement elements 24/7 at all sites of new construction. Therefore, it is possible to obtain and accumulate data on actual road deformations caused by traffic load, increase efficiency in forecasting performance indicators, and model energy of roads to propose design alternatives (Stumpf, Kim, Jenicek, 2011).

As a result of a meeting of the Government Commission regarding use of information technologies to improve quality of life and business environment dd. December 18, 2017, a plan of actions in the field of formation of research competencies and technological foundations within the Digital Economy of the Russian Federation program was approved (in particular, activity 03.00.000.001.18.11 “Development of a software suite for instrumental monitoring of the diagnostic condition of roads, intended for collection, accumulation, storage, consolidation, analysis and interactive visual display of data on the condition of roads, obtained from instrumentation, control units and population” (see https://www.sbras.ru/files/news/docs/tex_zadely_d_e_plan.pdf)).

Conclusion

Engineering solutions suggested by Hexagon Geosystems Rus and their implementation can contribute to intense development of digitalization and expansion of Russian companies into foreign markets with the following proposals:

- creation of regional GIS systems, target monitoring systems in various economic branches for public and commercial companies;
- creation of a system for monitoring of transport and movable facilities for companies maintaining and operating mobile vehicles;
- use of a system for monitoring of the condition of roads in the road industry.

Data obtained using unique products of Hexagon Geosystems Rus can be used for the purposes of strategic and operational management of the national transport system, formation of architecture and infrastructure foundations for a digital environment of the transport system, strategic management in related industries (Hardin, McCool, 2015). Those technologies will ensure design, construction and operation of infrastructure facilities, as well as processes of design monitoring and management at a new level.

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ПРАКТИЧЕСКОЕ ПРИМЕНЕНИЕ BIM МОДЕЛИРОВАНИЯ ДЛЯ ОБЪЕКТОВ ДОРОЖНОЙ ИНФРАСТРУКТУРЫ

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Аннотация

Введение. Предметом исследования в данной статье является транспортная инфраструктура. В статье представлены технологические решения ООО «Гексагон Геосистемс Рус», других крупных компаний, занимающихся строительным контролем с помощью технологий информационного моделирования и разработкой программных решений, сервисов и оборудования и их практические реализации. **Цель исследования:** достижение высокого уровня содержания автомобильных дорог, сохранности существующей дорожной сети и обеспечения безопасности дорожного движения, переход на новые формы управления инфраструктурными объектами путём реализации проектов на основе BIM-технологий. **Методы:** продукты отечественных компаний соответствуют возможностям современных информационных технологий и демонстрируют возможности BIM-моделирования при практическом применении в дорожной инфраструктуре. Предложены программные решения, которые позволяют создать новую среду для развития экономики, в том числе и в дорожной деятельности. **Результаты:** документация, созданная на основе работ по 3D лазерному сканированию, позволяет осуществлять планирование работ по содержанию и ремонту объектов транспортной инфраструктуры. Актуальность и объективность полученных данных очевидна в виду исключения человеческого фактора в конечных чертежах и 3D моделях и приводит к повышению эффективности системой управления объектами транспортной инфраструктуры.

Ключевые слова

BIM-моделирование, транспортная инфраструктура, дорожная информационная модель, географическая информационная система, цифровая трансформация дорог