



ORIGINAL ARTICLE

УДК 656.001.57

DOI: <https://doi.org/10.30932/1992-3252-2024-22-5-1>

Remote Sensing of Transport Infrastructure



Victor P. SAVINYKH

Victor P. Savinykh*Moscow State University of Geodesy and Cartography (MIIGAiK), Moscow, Russia.**Russian Science Citation Index SPIN-code: 9207–8148; Russian Science Citation**Index AuthorID: 70172.*✉ vp@miigaik.**ABSTRACT**

The article examines the use of remote sensing for controlling, monitoring and managing transport infrastructure. The basic role of remote sensing for forming a technology for space monitoring of transport is highlighted together with the need to integrate remote sensing with transport geoinformatics. The difference between fact-fixing and information models in remote sensing technologies is noted. It is also shown that information models serve as the basis for managing transport infrastructure. The study is based on the interpretation of the remote sensing of

transport infrastructure objects as of a comprehensive system. The content of this integrated system was subject to attributive analysis and a taxonomy of the characteristics of the technological complex of remote sensing was proposed. The features of transport infrastructure as of an object of remote sensing are described. It is suggested that remote sensing is a modern highly required tool for transport management. A taxonomy of attributes of transport infrastructure as of an object of monitoring and remote sensing is proposed.

Keywords: transport, control, management, monitoring, space research, remote sensing, transport infrastructure, taxonomy.

For citation: Savinykh, V. P. Remote Sensing of Transport Infrastructure. World of Transport and Transportation, World of Transport and Transportation, 2024, Vol. 22, Iss. 5 (114), pp. 128–132. DOI: <https://doi.org/10.30932/1992-3252-2024-22-5-1>.

**The original text of the article in Russian is published in the first part of the issue.
Текст статьи на русском языке публикуется в первой части данного выпуска.**

OBJECTIVE AND METHODS

The objective of the work is to study the application of remote sensing technologies for monitoring and managing transport infrastructure, the content of technologies of remote sensing of transport infrastructure, and the factors of spatial reasoning for the analysis of remote sensing results.

The main research methods are system, attribute, spatial and comparative analysis.

BACKGROUND

Remote sensing of transport infrastructure (RSTI) serves as the basis for integrated [1] differential control [2] of the transport system. RSTI in technological terms serves as the basis for formation of space monitoring of transport (SMT). The peculiarity of this monitoring is its global nature and the presence of a large volume of initial data [3], which complicates the analysis and slows down the processing of information. A model approach is used for selection and compression of information in SMT. The model approach consists in the use of models and observation, first of all, of the parameters of the models describing the process or object under study. For moving objects, it is typical to use a dynamic spatio-temporal model of railway management [4]. A feature of RSTI technology is that it not only conducts observation, but also creates geoknowledge [5]. A large amount of diverse information is accompanied by information uncertainty [6]. To reduce uncertainty, it is necessary to model it [7] and apply probabilistic measures based on inclusion indices in the case of an unknown utility function [8]. The presence of information uncertainty requires a transition from strict logical reasoning and sequential logical chains to a reasoning scheme that allows for contradictions and eliminates contradictions [9; 10]. Uncertainty in RSTI is reduced by three main methods: eliminating contradictions, filtering out unnecessary information, and clustering useful information [11; 12].

RSTI serves as the main source of obtaining spatial information, which is necessary for analysing the state and monitoring of the transport system. These technologies collect information in the entire spectrum of electromagnetic waves and are currently formed as complex systems that combine data from different ranges. RSTI is of great importance in global transport monitoring and in management using intelligent transport

systems (ITS) [13; 14] or technical cyber-physical systems (TCPS) [15; 16].

The development of a modern transport system and its spatial distribution is impossible without RSTI, the advantages of which are globality and the ability to monitor hard-to-reach territories. In particular, observation of Arctic territories [17; 18] and permafrost zones is possible only with the use of remote sensing. A feature of development of RSTI is the differentiation [19] in relation to applied problems.

RESULTS

Attributive analysis in any field includes the analysis of parameters or attributes. In the attribute analysis of RSTI, the following attributes are distinguished: objective, field, object or group of objects, methods, model as an observation system, model of the object of observation.

Models of the object of observation are used to compress information and improve the efficiency of decision-making. Pic. 1 shows the initial data in the form of a space image. Pic. 2 shows the information model built on the basis of the space image.

Pics. 1 and 2 show the difference between the original fact-fixing model and the information model obtained on its basis. The information model contains useful information supplemented with explanatory captions. RSTI is used to solve various problems, while qualitatively differentiating between models of stationary objects of transport infrastructure and models of mobile objects, which include observation, processing, interpretation and systematization of information.

Differentiation of RSTI allows choosing the range of electromagnetic waves applicable to the research problem or object of study. For example, when studying the thermal environment, the infrared range is chosen, when studying an area in the presence of clouds, radar images are chosen, when studying polar territories, spectrozonal images are chosen [20].

The variety of RSTI models and ranges of information collected requires the use of a whole set of modelling methods. The basic one is information modelling, on the basis of which other types of modelling are performed. In turn, information modelling gives rise to other types of modelling.

There is a close connection between RSTI and geoinformatics, and geoinformatics of





Pic. 1. Space image of Kazansky railway station (Google map).

transport. This led to integration of remote sensing methods and geoinformatics [21]. The basis for integration is geodata.

By objects of monitoring, it is possible to differentiate RSTI of mobile objects, engineering structures, environment, ecology, cadastre, transport infrastructure real estate management. The type of RSTI is determined by the research task, and the differentiation and taxonomy of tasks determine the differentiation and taxonomy of RSTI technologies.

According to activity/passivity, there are active RSTI and passive RSTI. Active remote sensing affects an object in the spectrum of electromagnetic waves (radar, laser). Passive RSTI does not affect an object, but perceives a reflected signal (photograph, thermal image). Passive ones include networks of electronic tags, the use of GNSS receivers (although formally receivers are used on the earth's surface).

According to RSTI field, we can differentiate situational, local, linear, intermodal, global sensing.

The situation can be moving (sliding) and stationary. Local RSTI includes the object of

observation and its environment. It is applied to stationary situations and mobile objects involving the installation of electronic tags on the cargo and an indicator device on the mobile object.

Linear RSTI is territorial observation. It is associated with a track section or a section of the railway. It can be designated as territorial observation of a mobile object and observation of the transported cargo. In this case, the transmission of satellite signals using GNSS is widely used, which makes it possible to determine the location of cargo and vehicle. GNSS allows for dual control over movement of cargo and operation of a mobile object. In this case, the integration of land mobile communications and satellite technologies is used. GNSS functions also make it possible to identify violations in operation of vehicles, control mobile objects in real time at the local and linear level.

Intermodal RSTI is associated with monitoring of cargo carried with different modes of transport. It can be referred to as cargo surveillance.

Global RSTI is used to monitor transportation between countries and continents, which

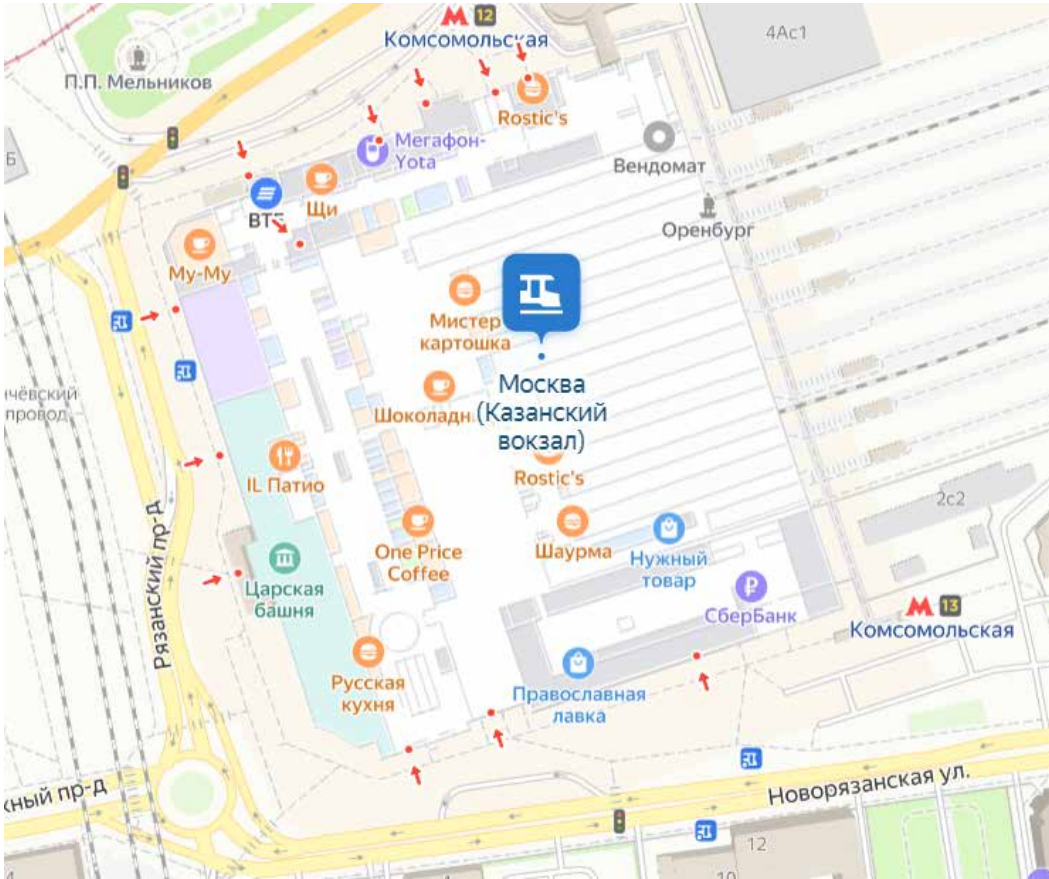


Fig. 2. Information (cartographic) model (Yandex.Maps).

includes cargo surveillance, territory surveillance, starting from the loading point, intermediate transshipment points and final unloading points.

By mode of transport, RSTI regarding railway, road, air, water and pipeline transport can be differentiated.

By object, RSTI regarding object and cargo can be differentiated.

By speed, normal traffic RSTI, speed (accelerated) traffic RSTI, and high-speed traffic RSTI can be highlighted.

By space reference, there are RSTI with ground support, RSTI with aircraft support, RSTI with helicopter support. RSTI with UAV support, and RSTI without ground support.

CONCLUSION

Summing up, it should be noted that transport infrastructure [22] has specific features as an object of monitoring and management. When monitoring and analysing transport infrastructure, it is necessary to apply spatial logic [23], which

is also a feature of transport infrastructure.

Remote sensing of transport infrastructure objects from a systemic standpoint is a complex technological system that meets systemic principles. From a scientific standpoint, modern remote sensing of transport infrastructure objects can be considered as an independent research direction. It is developing on the basis of integration of technologies using conventional geoinformatics and transport geoinformatics. As a technological system, RSTI also requires geodetic support, especially with regard to surface conditions. As an information collection system, RSTI uses fact-fixing models to build information models on their basis and includes not only observation and statement of the situation, but also forecasting and decision-making support. The great importance of reasoning methods in remote sensing should also be highlighted since this is part of management technologies and solves auxiliary problems linked to, e.g., the condition of a railway or highway, resource consumption, optimisation of



the operation of a rolling stock, transport security, and safety of special cargo. These problems lead to the need to apply various mathematical methods, including discrete optimisation and fuzzy set theory.

Thus, remote sensing is an important component of development of the transport system undoubtedly requiring further research and innovative advancing.

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Information about the author:

Savinykh, Victor P., D.Sc. (Eng), Academician of Russian Academy of Sciences, Professor, President of Moscow State University of Geodesy and Cartography (MIIGAIK), Moscow, Russia, vp@miigaiik.

Article received 21.09.2024, approved after reviewing 10.10.2024, accepted 12.11.2024.