Analysis and dynamic visualization of logistics flows in the Arctic based on geoservices

A V Vicentiy¹,²

¹Institute for Informatics and Mathematical Modeling – Subdivision of the Federal Research Centre “Kola Science Centre of the Russian Academy of Science”, Apatity, Russia
²Apatity branch of Murmansk Arctic State University, Apatity, Russia

alx_2003@mail.ru

Abstract. The paper notes the importance of the Arctic and the Arctic zone of the Russian Federation as a promising source of mineral and biological resources necessary to maintain the pace of socio-economic development of modern society. However, for the integrated development of Arctic resources and the creation of a favorable environment for the life of the population in the Far North, it is necessary to solve the problems of logistics and transport accessibility of the Arctic regions. For the successful solution of logistic problems, various factors and features specific to the Arctic territories must be taken into account. In these conditions, multimodal transportation, which requires special attention to the analysis, control and monitoring of routes and delivery vehicles, is of particular relevance. In order to provide information support for solving logistics problems, an approach to creating a web-geoservice for analysis and dynamic visualization of logistics flows is proposed. A feature of the proposed approach is the use of external sources of cartographic information, which can significantly reduce the material and time costs for the design and development of web-geoservice. The paper describes methodological support, as well as stages of design and development of web-geoservice for analysis and dynamic visualization of logistics flows in the Arctic zone of the Russian Federation. As an example of the Arctic region, the Murmansk region, which is part of the Arctic zone of the Russian Federation, was chosen to test the main capabilities of the web-geoservice.

1. Introduction

At present, the Arctic in general and the Arctic zone of the Russian Federation (AZRF) in particular are the most important sources of mineral and biological resources of Mankind. Given the depletion of mineral and hydrocarbon reserves in the more southern parts of the planet, the importance of developing the Arctic is greatly increasing. For the integrated development of Arctic resources, ensuring the socio-economic development of the Arctic regions, as well as creating a favorable environment for the life of the population of the northern regions of the Russian Federation, logistics and transport accessibility issues are critical [1].

The Arctic territories are characterized by a number of factors that have a significant impact on the development of logistics and transport infrastructure. The most significant are the natural-geographical and climatic factors. In addition, the territories of the Russian Arctic are characterized by a considerable distance from large transport and logistics centers, focal nature of development, poor
development of transport infrastructure or its complete absence, as well as high sensitivity of natural ecosystems to anthropogenic impact [2], [3], [4].

To ensure normal functioning in such conditions, it is necessary to ensure the coordinated work of all modes of transport present in the Arctic region. In this context, the issues of multimodal transportation, which enable the use of various modes of transport for the delivery of goods, are becoming particularly relevant. [5, 6] In order to comply with acceptable delivery times and costs, it is necessary to be able to analyze existing and build new delivery chains, taking into account the characteristics of specific territories, transport infrastructure and natural and climatic factors. [7] Therefore, an effective solution to logistics problems is possible only with simultaneous consideration of many heterogeneous factors.

At present, it is customary to single out several main areas in logistics: physical distribution logistics, transport logistics, information logistics, production logistics, procurement logistics, etc. Each of these areas has its own methods and means of solving typical problems. In this paper, we will consider the problems that arise when organizing transport logistics in the difficult conditions of the Arctic zone of the Russian Federation (AZRF).

An important condition for the development and successful competition of enterprises whose activities are connected with transport logistics is the degree of their availability of modern information technologies. To increase the cognitive effect in the analysis, monitoring and adjustment of existing and generation of new logistics routes, it is necessary to provide a high degree of data visualization focused on the needs of the user and the task he solves [8, 9]. For example, a typical task for the operator of the information logistics system is to select the optimal vehicle depending on the specified parameters, such as the type of cargo, cargo volume, method of cargo packing, transportation distance, currently available transport, route, delivery time, depreciation cost vehicle and so on. The solution of such problems is associated with a large variation of initial conditions, which determines their high complexity. It is possible to increase the efficiency of solving such problems by integrating data analysis and visualization tools into logistics systems.

Thus, it can be stated that the tasks of analysis, control and monitoring of logistic flows and their visualization in real time are currently relevant for a wide range of stakeholders. Therefore, it is necessary to develop new methods, algorithms and software tools for transport flows analysis and visualization, which are based on the capabilities of modern geographical services.

2. Problem statement
Effective delivery of goods to many areas of the Arctic zone of the Russian Federation is possible only with the use of multimodal transportation and complex logistics schemes. At the same time, it is necessary to promptly synthesize new routes, assess their efficiency, as well as monitor and visually control the delivery, taking into account the Arctic conditions. To solve these problems, various information systems for decision support in logistics are being created. Many modern information systems intended for information support of logistic activity have modules for visualization of transport flows [10]. The functionality of such modules in existing information systems is very different. Some of them allow only simple display of objects and basic characteristics on the monitor screen. Other systems have advanced built-in tools for modeling, analysis and optimization [11].

Development of information systems or specialized services for analysis and dynamic visualization of logistic flows, taking into account specific conditions of the Arctic from scratch, is associated with huge financial and time costs. Therefore, we offer an approach to solving problems of analysis and dynamic visualization of logistic flows, based on the possibilities of existing geoservices. In this paper the problem of developing a web-geoservice for analysis and dynamic visualization of logistic flows using one of the existing geoservices as a source of spatial data was raised. The approach based on the use of external data sources for logistic tasks allows to significantly reduce labor costs and time resources required for web-service development. In connection with this formulation of the problem it is necessary to analyze the functionality of existing geoservices in order to select the most appropriate one to achieve the goals. To solve this problem were analyzed three popular geo-services that
currently have the most functionality. These are Yandex.maps [12], Google Maps [13] and OpenStreetMap [14]. The results of this stage of work, as well as features of web-geoservice development for analysis and dynamic visualization of logistic flows are presented below.

3. Materials and methods

Depending on the problems that were raised in the study, the understanding and definition of the geoservice (mapping service) may vary. This paper uses a generalized definition of geoservice as a specialized information system that provides spatial data in the form of an interactive map through an application programming interface (API - Application Programming Interface). Availability of an up-to-date API in a geoservice is the most important factor for its use. It is with the help of the API that it becomes possible to use the main functions of a geoservice in third-party web applications, to which the web geo-service developed within this work for analysis and dynamic visualization of logistic flows belongs. The three different geo-services are briefly discussed below in terms of their capabilities to create their own maps, set them up and place additional information important for data analysis and visualization on them.

The first web geo-service we analyzed was Yandex. Maps. Yandex.Maps is a cartographic service from the Russian company Yandex. The service started working in 2004. At the moment Yandex.maps provide an opportunity to get detailed maps of most cities and countries of the world, information about various organizations. This geo-service has the means to build routes, including taking into account traffic jams. Developers are provided with a powerful API and all necessary tools for working with it, including a map designer, geocoder, a set of components for placing maps on third-party web resources, an interface for setting parameters and other tools of the developer [15].

A number of conditions and restrictions are imposed on the use of the Yandex.map service. Among the most significant from the point of view of web-geoservice development for analysis and visualization of logistic flows we can mention the following. Before starting to use the service, it is necessary to register. Use of the service is possible only for sites and applications that are publicly available for free use. Besides, the number of calls to geocoder, router and panoramas from a third-party resource should not exceed 25000 per day.

Google Maps service was created by Google in 2005. The service includes a direct mapping service, satellite imagery and a tool for viewing the streets (Google Street View). Google Maps API allows placing map images on third-party resources and managing them based on JavaScript. The developer tools include several separate APIs. In particular, this is the Android API for working with maps in Android-based applications. There is also a Javascript API for creating and managing maps on third-party websites. The Geocoding API provides access to geocoding services for static addresses to place content on the map. Directions API provides an opportunity to create routes, calculate travel time, determine distances, etc. Google Maps also provides the user with the ability to use the Places Web Service API to retrieve information about places defined in this API, such as organizations, geographic sites, sights, etc.

Like Yandex.Maps, Google Maps has a number of restrictions, including the need to register, a limit on the number of requests per day for some features, as well as a ban on using the service for commercial use in the free version.

The OpenStreetMap project was founded in 2004. Currently, the project is supported by the OpenStreetMap Foundation, a non-profit organization, and is an open, non-profit mapping service existing with user donations. Within the framework of the project, a common world map is being created and constantly updated. Cartographic data are collected, processed, and published on a wiki basis by project members themselves, free of charge.

Thus, as sources of cartographic geoinformation can be various data - from satellite images and aerial survey results to data from drones, personal portable devices, and simply graphical images of any geo-objects [16]. It should also be noted that due to the original non-commercial orientation of the project, the use of data from commercial sources without appropriate permits in the project is
prohibited. To work with cartographic information within the service, access to the official JOSM project editor is provided.

Despite the openness and free-of-charge nature of the project, according to various tests and comparisons, the accuracy of OpenStreetMap maps for densely populated areas often exceeds the accuracy provided by commercial mapping services. The service provides a large number of ready-made tools for viewing, editing, rendering, exporting cartographic images, as well as solutions for routing and navigation using OpenStreetMap maps.

Having compared functionality of available geoservices, it is possible to draw a conclusion that any of them does not surpass others on all parameters. In this connection it is expedient to choose this or that geo-service based on requirements of a solved problem. For the decision of a problem of the analysis and visualisation of logistical streams mainly in territory of Russia the most suitable geo-service is geo-service Yandex.maps.

4. Results
The main results of work are related to the design and development of a web geo-service for the analysis and dynamic visualization of logistic flows using the Yandex.map geo-service. At the design stage were formalized and designed the internal structure and functional filling of the project on a "top-down" principle. At designing of geoservice for the decision of problems of the analysis and dynamic visualisation of logistical streams it is critically important to define features of reception, processing and representation of the cartographical data [17], possibility of operative reception of the data from large and small carriers in various locations, an arrangement of transport and logistical nodes, weather conditions and probability of cancellation and delay of flights, as well as used methods of construction of routes and calculation of their cost.

Besides at a design stage questions of division of privileges of various groups of users on access to the basic data and functions of geoservice, protection, encryption and backup of the information are solved. As part of the web geo-service being developed, three main user groups have been identified: system administrator, unprivileged user, operator (privileged user). The operator has access to the largest number of functions. Figure 1 shows the Use-case diagram in UML notation.

![Use-Case diagram for a web-service operator](image-url)
To visually display the structure and interaction of the most important elements of the system, we have developed the class diagram shown in Figure 2. The following classes have been selected as the main ones:

- Database - a class for working with databases;
- Registration - a class for implementing the functions of registration and accounting of users;
- Login - a class that provides the implementation of login and separation of authorities;
- Find - functions for searching heterogeneous data;
- Map - a class that is responsible for the processing of cartographic information and implements the basic functions of the system to work with maps;
- Map_Operator - a class that allows to implement additional functions of working with the map, designed for the logistics service operator;
- Transport - responsible for the choice of transport and its use on a certain route;
- Type_Info - the class provides information about parameters, allowing to use more characteristics and parameters of objects.

Figure 2. Web service class diagram
The next stage is the stage of web-geoservice development for analysis and visualization of logistic flows. The main development tools were:

- hypertext markup language (HTML);
- cascading style sheets (CSS);
- multi-paradigm programming language JavaScript (JS);
- software library for work with maps in browsers and applications JavaScript API from the company Yandex (JSAPI);
- freely distributed relational database management system MySQL;
- general purpose scripting language (PHP).

As a methodological basis for the development were used sections of the documentation for the developers of Yandex site, describing the capabilities of the modules to work with maps (heat map, search for organizations, calculation of delivery costs, geocoding, geopoints, etc.).

The possibility of using a large number of ready-made modules, presented to developers by Yandex, allows to simplify and accelerate the development of our own projects. The deliveryCalculator.js module was chosen as one of the main modules used in this development. With its help it is possible to carry out primary calculation of the cost of cargo delivery and a route depending on various factors. To use this module in a project, you just need to connect it, as shown in Figure 3.

![Figure 3](https://api-maps.yandex.ru/2.1/?lang=ru_RU&amp;)

**Figure 3.** One way to connect the deliveryCalculator.js module

The general interface of the developed web-geoservice for analysis and dynamic visualization of logistic flows is shown in Figure 4.
Figure 4. General view of the interface of the developed web-geoservice for analysis and dynamic visualization of logistic flows

The developed web-geoservice allows to lay the routes of cargo delivery through any number of intermediate points, calculate material and time costs, the total length of the route, the distance between individual points, the optimal sequence of their visit and other actions. Due to the possibility of more fine-tuning of routes (taking into account vehicle type, fuel consumption, depreciation cost, weight and type of cargo packing, cargo peculiarities, etc.) it is possible to model and compare different delivery options by different vehicles under different initial conditions and choose the optimal delivery method depending on conditions and limitations of the task.

In order to support interoperability, generation of various reports and export of data on the stages of modeling, the developed web-geoservice has the possibility to upload data in the format of Excel tables and other common data transfer formats.

5. Conclusion and discussion
The following conclusions can be drawn from this work.
1. The use of existing geoservices for solving problems of analysis and dynamic visualization of logistic flows is promising, as it allows to significantly reduce financial and time costs through the use of ready-made modules;
2. Selecting a specific geoservice as a source of spatial data is a non-trivial task. Comparison of the main features of popular geoservices leads to the conclusion that it is impossible to select among them the only one that surpasses all the others in the set of parameters.
3. At a choice of the concrete geoservice as a source of the spatial data it is necessary to be guided, first of all, by requirements of a solved problem, and only then to estimate features of realisation of this or that functions inside geoservice.
4. To solve the problems of analysis and dynamic visualization of logistic flows on the territory of the Russian Federation, the optimal geoservice for providing geodata is Yandex.maps.
5. Development of a web-based geoservice for analysis and visualization of logistic flows comparable in functionality to some commercial analogues (including visualization of geodata, input and storage of own geodata, saving and loading routes, calculation of various route parameters, separation of user privileges, data encryption and database operation) is possible using freely distributed software without using proprietary software products.

6. The developed web geoservice for analysis and dynamic visualization of logistic flows is valuable from the point of view of practical application. The service allows not only to visualize already developed routes, but also to model and compare the effectiveness of promising routes on several parameters, making it possible to find the optimal route for further use.

References
[1] Romashkina G F, Didenko N I and Skripnuk D F 2017 Socioeconomic modernization of Russia and its Arctic Regions *Studies on Russian Economic Development* 28(1) 22-30
[2] Didenko N, Rudenko D, Skripnuk D 2015 Environmental security issues in the Russian Arctic *Conf. Proc. of Int. Mult. Sc. GeoConf. Surveying Geology and Mining Ecology Management, SGEM* 3(5) 267-274
[3] Edward B 2009 A Global Green New Deal, *UNEP-DTIE* p 42
[4] Bolsunovskaya Y et al 2016 *IOP Conf. Ser.: Earth Environ. Sci.* 43 012099
[5] Kozmenko S, Ulchenko M 2019 *IOP Conf. Ser.: Earth Environ. Sci.* 302 012123
[6] Kozmenko S et al 2018 *IOP Conf. Ser.: Earth Environ. Sci.* 180 012009
[7] Vicentiy A, Dikovitsky V, Shishaev M 2019 Automated Extraction and Visualization of Spatial Data Obtained by Analyzing Texts About Projects of Arctic Transport Logistics Development *Advances in Intelligent Systems and Computing* 1046 419-433
[8] Vicentiy A 2019 Development of methods and tools to support regional management in the Arctic zone of the Russian Federation based on cognitive interfaces *IOP Conf. Ser.: Earth Environ. Sci.* 302 012139
[9] Vicentiy A, Vicentiy I 2019 The method of dynamic visualization of spatial data for cognitive interfaces of information systems supporting regional management *International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM* 19(2.1) 667-672
[10] Release of version 3.0 of the configuration "TMS Logistics. Transportation Management" on the platform "1C: Enterprise 8.3" 2017 *1C: Enterprise Information for users and partners* 9 1-16
[11] Bulankin A, Bagaeva A 2016 The study of geographic information systems *Actual problems of aviation and astronautics* 9 421-422
[12] Official site Yandex.Maps Available from: https://yandex.ru/maps/ [Accessed 20 March 2019]
[13] Official Google Maps site Available from: https://www.google.com/maps [Accessed 20 March 2019]
[14] Official OpenStreetMap website Available from: www.openstreetmap.org [Accessed 20 March 2019]
[15] Kochitov M 2019 Using interactive maps using the Yandex.Maps JavaScript service *Postulate*, 1 19-26.
[16] Vicentiy A, Shishaev M, Oleynik A 2016 Dynamic Cognitive Geovisualization for Information Support of Decision-Making in the Regional System of Radiological Monitoring, Control and Forecasting *Advances in Intelligent Systems and Computing* 466 483-495
[17] Vicentiy A., Shishaev M, Vicentiy I 2017 The Development of Dynamic Cognitive Interfaces for Multisubject Information Systems (on the Example of Geosocial Service) *Advances in Intelligent Systems and Computing* 575 449-459