Environmental problems of the development of transport in the transboundary region as exemplified by the Baikal basin and its cartographic study

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Abstract. Geoinformation support in the form of large cartographic atlases of complex content is intended to decide the issue of the Baikal region development, as the Lake Baikal catchment basin has a special nature management regime. Therefore transport maps among other industry maps are important for the analysis of regional development of the region. The compilation of transport maps requires presentation of all objects, processes, phenomena and interactions of the transport complex. In order to streamline the structure of thematic layer formation and the system of cartographic signs for displaying transport, a semantic classification of cartographic signs of transport systems was developed. Initially, we analyzed a large number of maps from various geographic atlases of various territorial levels. Then we generated a semantic database of transport maps. The developed classification streamlined the structure of thematic layers of transport maps and, generally, the system of cartographic signs for transport layer. In the event of compiling a map of transport impact on the environment, we selected several semantic parameters that characterize the transport complex and individual indicators of transport impact on the environment. Consequently we created a map of transport impact on the environment in the Baikal basin. Then we analyzed the transport impact within the Lake Baikal catchment area on the basis of the created maps, as well as other literature and statistical sources. This analysis enabled conclusion about the fact that the greatest pollution of the Lake Baikal catchment area comes from automobile and water transport.

1. Introduction
In today's society, transport is an integral part of the country's life. Transport within the Lake Baikal catchment area is one of the constituent links of the unified transport system of our country and the Republic of Mongolia. The transport impact on the environment is manifested mainly as a result of transport services for various economic activities. Transport service facilities also pollute the environment. The study of the development and functioning of transport systems is effective only in a contemporary information system based on digital thematic maps and atlases. Mapping the interaction of all elements of transport and the environment involves the establishment and analysis of factors affecting the current environmental state and its change.

2. Materials and methods
To map all objects, processes, phenomena and interactions of the transport system of the region, a huge number of conventional signs and methods of cartographic display are required. Therefore, it
becomes necessary to develop a special semantic classification of the sign display of transport systems. According to [1] “Cartographic semantics is a section of cartosemiotics that studies the relationship of signs, their combinations to designated objects, expressed in the map legend in a natural (verbal) language”. The semantic dependence of a sign and an object consists in the fact that these characteristic parameters must find their expression in the cartographic image. When designing sign systems, it is necessary to offer a graphic package that rationally and correctly identify the transmitted features of an object [2].

![Figure 1. Visualization of the layer displaying number of own cars per population and vehicle emissions in the cities, taken from a complex electronic map of the Lake Baikal basin](image)

Based on the development of scientists in the field of cartosemiotics [3, 1, 4, 5], we have created a semantic classification of territorial transport systems. And on the basis of the generated database, a
map of the transport impact on the environment within the basin of Lake Baikal was compiled (figure 1).

The initial parameters characterizing the transport of the Lake Baikal basin include the characteristics of different types of transport routes: railways and highways (main and others; hard-surface and unpaved roads). The next important parameters are the characteristics of road transport emissions at major transport hubs and other quality parameters of transport points, including airports, river ports and wharf. And, finally, we used an indicator of the number of own cars per population (per 1000 people).

Currently, we are creating an extensive database on the transport and environmental problem for the Lake Baikal basin. A part of this database has already been visualized in the form of electronic maps for the Ecological Atlas of the Lake Baikal Basin [6], and in general it will be included in the hypermedia database for the Atlas "Baikal Region: Society and Nature".

3. Results and discussion
Cartographic visualization testified that almost all types of transport are available in the Lake Baikal basin, except for sea transport. The specificity of the geographical position of the Lake Baikal basin lies in its transboundary nature: it covers the territories of two countries: Russia and Mongolia. Therefore, solution of environmental problems, including transport and environmental ones, associated with economic activities in this area, has a special interstate nature. The cities of Irkutsk and Chita, located outside the Baikal basin, are also considered, as they are important logistics points for the basin territory. Emissions in Russia are distributed by transport types as follows: 58% of the total emissions are accounted for road transport; 25% – for the railway; 14% – for the road construction complex; 2% - for air and less than 1% – for river and sea. The share in the total volume of emissions is 38%. The lands occupied for the needs of transport account for 12.5% of the total area of non-agricultural territories [7].

The environmental impact of railway transport is reflected in the state of the atmosphere in the regions where diesel locomotives are operated. The mainline diesel locomotives emit smoke into the atmosphere, which is similar in composition to the exhaust of automobile engines. Every year, up to 200 m$^3$ of wastewater is poured out of passenger cars for each kilometer of track and 12 tons of dry waste are thrown away. Potentially dangerous is the transportation of explosive, chemical and other dangerous goods.

The railways of the basin within Russia are part of the East Siberian Railway. The railway provides services in the southern and northern Baikal region. The Baikal-Amur Mainline is located along the northern coast and further along the valley of the Upper Angara River. A small section of the Transsiberian railway goes along the southern coast of Lake Baikal and further to the east. Two railway branches originate from it: the Circum-Baikal railway (84 km long) and the Ulan-Ude – Naushki railway (253 km); then it goes to the border with Mongolia, where it connects with the Ulan-Bator railway. In Mongolia, the main railway line runs from the Russian border through Ulan-Bator to the border with China, and then the road leads to Beijing. Branches to Erdenet, Sharyn Gol and Baganuur originate here.

The greatest pollution occurs along the Transsiberian Railway, as the train traffic is very high here. However, the Ulan-Ude – Naushki railway branch and the railways in Mongolia are not electrified, so pollution here is supplemented by emissions from diesel locomotives.

Automobile transport is the most active source of environmental pollution. One car annually absorbs about 4 tons of oxygen from the atmosphere, while emitting about 800 kg of carbon monoxide, 40 kg of nitrogen oxides and almost 200 kg of various carbons in the exhaust gases [7]. As a percentage, the content of the main toxic substances is as follows: carbon monoxide – up to 10%; hydrocarbons – up to 3%; nitrogen oxides – up to 0.5%; aldehydes – up to 0.03%; soot – up to 0.04 g/m$^3$; benzo(a)pyrene – up to 20 μg/m$^3$ and sulfur dioxide – up to 0.008%. The main toxic component of the exhaust gases emitted during the operation of gasoline engines is carbon monoxide [8]. The
increased environmental impact of transport is due to the high growth rate of car numbers (table 1). In all regions, there is an increase in motorization of the population except for Irkutsk oblast.

**Table 1. Number of own cars in subjects of the Baikal region and Mongolia (per 1 thou pers).**

| Subjects            | 2014   | 2015   | 2016   | 2017   | 2018   |
|---------------------|--------|--------|--------|--------|--------|
| Republic of Buryatia| 239.2  | 243.3  | 247.7  | 253.2  | 256.9  |
| Zabaikalskii krai   | 247.5  | 253.6  | 260.0  | 260.1  | 272.1  |
| Irkutsk oblast      | 270.5  | 271.3  | 242.7  | 245.6  | 245    |
| Mongolia            | 146.1  | 157.6  | 159.9  | 184.6  | 195    |

The most significant pollution is observed in settlements. Increased pollution in large cities is associated with heavy traffic. Traffic overload on the streets creates another problem - formation of traffic jams. Slow traffic on the streets leads consequently to the increase in travel time and emissions into the atmosphere. Human health is also affected by transport noise, which has significantly more negative consequences for population than industrial or household noise. Noise above 80 dBA is harmful to humans, and all vehicles have high levels of noise exposure (table 2).

**Table 2. Intensity of transport noise.**

| Transport mode                             | Sound level, dBA |
|--------------------------------------------|------------------|
| Personal vehicle                           | 70-80            |
| Bus                                        | 80-85            |
| Truck                                      | 80-90            |
| Metro train                                | 90-95            |
| Railway train (7 m from the track)         | 95-100           |
| Railway train (at the wheels)              | 125-130          |
| Jet aircraft taking off                    | 130-160          |

Outside settlements, along highways, there is an impact of vehicles on the environment. The content of heavy metals along the roads increases 10-20 times relative to the background level. Another factor of the transport impact is formation of dust in the surface air layer. When car tires come into contact with asphalt, they wear out; wear products are mixed with solid particles of exhaust gases. All this mixes with the soil cover and rises into the air in dry weather. However, more dust is generated on dirt and gravel roads. On gravel roads the dust consists mainly of quartz particles, the rest is made up of oxides of aluminium, iron, calcium, etc. Significant land areas are alienated during the construction of highways. Thus, the construction of 1 km of a highway requires up to 10-12 ha land. Additional sites are allocated for transport equipment, warehouses, temporary facilities, etc. [8].

Pollution from vehicles in the Baikal basin is the largest type of transport impact on natural environment and especially on public health. Among the highways, the most significant is the federal highway Irkutsk – Ulan-Ude – Chita (section of the Moscow highway), which runs parallel to the Transsiberian Railway. Additionally, there are sections of the following highways in this territory: Kultuk – Mondy; Irkutsk – Listvyanka; Magistralnyi – Severobaikalsk – Uoyan – Taksimo; Taksimo – Bodaibo; Bayandai – Elantsy – Khuzhir; Ulan-Ude – Turuntaevo - Kurumkan; Ulan-Ude – Kyakhta with a branch to Zakamensk; Ulan-Ude – Bichura; Ulan-Ude – Sosnov-o-Zerskoe – Bagdarin; Chita – Bagdarin; Chita – Aginskoe and others. On the territory of Mongolia, there are hard-surfaced motor roads from the border with Russia to Ulan-Bator and further to the border with China, as well as a branch from this road, Darkhan – Erdenet – Bulgan. Two highways originate from Ulan-Bator – to Arvaikheer and Underkhaan. Other roads in Mongolia are gravel roads or unpaved. The main highways on the map indicate the main federal roads in Russia and the main interregional highways in Mongolia.
The most significant transport pollution is observed in large cities. Specifically, in Irkutsk it is 59%, in Ulan-Ude – 58%, and in Chita – 72% of total emissions. In steppes of Mongolia and on the Lake Baikal shore there is a problem of off-road traffic, which damages vegetation cover and leads to local transformation of landscapes. Also, on the territory of Russia and Mongolia, there are many unpaved roads, which lead to linearly areas of increased dust pollution.

The water transport impact is associated with the loss of oil products during loading on board ship, as well as with the discharge of polluted waters. When the engines are running, oil, unburned fuel and other substances get into the water. The most common pollutants that are introduced into waters by transport are oil and oil products.

Navigable water bodies in this area are: lakes Baikal and Khubsugul, the rivers Angara and Selenga. The fleet operating on Lake Baikal and in 2018 included in the classification records of the East Siberian Branch of the Russian River Register (table 3) is represented by: personnel vessels, leisure boat, search and rescue vessels; dry cargo, passenger, expeditionary, research vessels; freight and cargo-passenger ferries; self-propelled tugs; dynamically supported ships; and buoy tenders [9].

**Table 3. Indicators for the classification of ships on Lake Baikal, units.**

| Indicators                                           | 2015 | 2016 | 2017 | 2018 |
|------------------------------------------------------|------|------|------|------|
| 1. Identity of a vessel:                             |      |      |      |      |
| corporate                                            | 52   | 43   | 54   | 53   |
| commercial                                           | 131  | 135  | 137  | 148  |
| private                                              | 56   | 65   | 89   | 100  |
| Total                                                | 239  | 243  | 280  | 301  |
| 2. Types of ships: incl. motor vessels:              |      |      |      |      |
| tug boats                                            | 26   | 14   | 17   | 20   |
| personnel vessels and leisure boats                  | 102  | 116  | 118  | 110  |
| buoy tenders                                         | 5    | 5    | 4    | 6    |
| passenger and cargo vessels                          | 25   | 29   | 60   | 94   |
| research vessels                                     | 6    | 3    | 4    | 7    |
| others                                               | 75   | 76   | 77   | 64   |
| Total                                                | 239  | 243  | 280  | 301  |
| 3. Type of shipping:                                 |      |      |      |      |
| transportation of people                             | 34   | 29   | 60   | 75   |
| economic activity                                     | 205  | 214  | 220  | 226  |
| Total                                                | 239  | 243  | 280  | 301  |

Passenger traffic is carried out from Irkutsk to Peschanaya Bay, also to Bolshiye Koty, Shumikha and to Listvyanka. In addition, several sections of the Selenga (274 km), Barguzin (138 km) and Upper Angara (254 km) rivers are potentially suitable for navigation. Navigation on Lake Baikal lasts 163 days, the length of waterways on Lake Baikal is 2356 km. The largest shipowner engaged in economic activity on Lake Baikal is OJSC East Siberian River Shipping Company (OJSC VSRP). In 2018, 59 units of the fleet belonging to the JSC VSRP operated (on Lake Baikal and in the Angara River), including, passenger ships – 17, tugs – 9, dry cargo barges – 25, and auxiliary vessels – 8. 561.4 thousand passengers were transported, including the transported passengers to the village of Sakhyurta by ferry. 1,800 tons of cargo were transported across Lake Baikal.

The vessels of JSC "VSRP" deliver contaminated domestic and sub-sewage waters for treatment to the integrated waste processing vessel (SKPO) "Samotlor" in the port Baikal. The fleet of third-party organizations is serviced on a contractual basis considering the collecting sub-seam waters (table 4).
The numerator indicates the total amount, the denominator – the amount of oily water. The amount of water supplied for the treatment of domestic and sub-sewage water in 2018 increased by 31% compared to 2017. The rest of the vessels make uncontrolled discharge of these waters throughout the entire water area of the lake. This problem has become a priority among the other ecological problems of the lake.

Table 4. Amount of contaminated domestic and slush water delivered for treatment in 2015-2018, tons.

| Polluter            | 2015   | 2016   | 2017   | 2018   |
|---------------------|--------|--------|--------|--------|
| PJSC "VSRP":        | 564.55 | 535.9  | 579.7  | 698.5  |
| Third party fleet   | 42.45  | 64.92  | 80.41  | 166.4  |
| Total               | 607.0  | 600.82 | 660.11 | 864.9  |

The centers of the State Inspection for Small Vessels (GIMS) of the Central Administration for the Ministry of Emergency Situations of Russia in Irkutsk oblast and the Republic of Buryatia exercise control over small vessels in the water area of Lake Baikal. At the end of 2018, 271 small vessels were registered in the water area of Lake Baikal, including: 68 vessels in Irkutsk oblast and 203 in the Republic of Buryatia.

The bulk of air traffic is carried out by four international airports: Irkutsk, Ulan-Ude, Chita and Ulan-Bator. Direct connection is carried out through these ports both for domestic interregional air transportation (Moscow and other cities of Russia) and international (China, Japan, South Korea and Germany). The main problem of air transport is noise, which significantly degrades the life quality in areas close to the airport. According to existing standards, the noise of aircrafts flying over densely populated areas should not exceed 112 dBA in the day time and 102 dBA at night [10]. Emissions from aircraft in the area of airports during takeoff and landing operations is 56 thousand tons, and at cruising altitudes – 118 thousand tons [7].

4. Conclusion
Our research has found that road transport is a significant polluter of the environment. The most significant pollution is in large cities, since the main share of cars is concentrated here. Outside settlements, pollution from road transport occurs along highways. On unpaved roads, there is a problem of dust pollution. Railroad pollution occurs mainly along railways, as well as at railway junctions. The negative impact of water transport occurs when reloading oil products in ports and discharging waste water. Air transport is mainly responsible for noise pollution.

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