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Assessing the Need for and Environmental Acceptability of Infrastructural Facilities in Natural Areas with Special Management Status

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Abstract: (1) Background: The article discusses approaches to assessing the ecological acceptability of locating new facilities in areas with special natural resource management status. The presence of natural resources and environmental constraints determine the activity of such facilities. We selected the Central Ecological Zone of the Baikal Natural Territory as the object of study, where the fundamental principle of economic activity is ecological, namely through the prevention of the harmful impacts of production, population, and business on the Lake Baikal ecosystems and the surrounding environment, as well as the restriction of certain types of economic activities and more stringent environmental regulation. The study aims to develop a methodological approach for assessing the ecological acceptability of locating facilities in areas with environmental constraints. (2) Methods: We analyzed the possible risks of locating new facilities based on determining the environmental impact of economic activities and assessing the environmental and associated socio-economic consequences of this impact. We determined the ecological acceptability of existing types of economic activities within the proposed approach based on a multi-criteria analysis, including an assessment of the state and possible changes in pollution flows and natural potential of the territories, the anthropogenic state of natural complexes, external and internal costs, and compliance with the status of natural resource management and regulations. (3) Results: The research results indicate that in most of the Central Ecological Zone of the Baikal Natural Territory, the location of new facilities is acceptable in terms of the balance between ecological capacity, anthropogenic load, and economic damage from pollution. However, when locating, it is necessary to consider restrictions on pollutant and contaminant standards, hydrological risks in certain sections of the coast, and the limited labor resources in the Severo-Baykalsky district. (4) Conclusions: The obtained analytical results can be used to scientifically substantiate the location of new facilities in areas with special natural resource management status since the main criterion postulated is that the anthropogenic load on the territory should not exceed the self-recovery potential of the territory's natural complex.

Keywords: locational suitability; infrastructure facilities; ecological capacity; anthropogenic pollution; impact standards; economic damage; need

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1. Introduction

The development of approaches to locating and substantiating the acceptability of the construction of economic and other activities is a relevant scientific problem within the spatial development of countries and individual territories; solutions aim to ensure environmentally oriented economic growth, preserving a favorable environment, biological diversity, and natural resources. This study's practical significance is due to the high rates of urban agglomeration and rural areas' development, potential constraints on resources, high anthropogenic risks, and increasing social consequences.

Modern approaches to locating facilities for economic activities are interpreted to achieve environmental standards and norms, the principles of which do not always meet the criteria of "green" development, environmentally safe business, and environmental preservation. Therefore, for making managerial decisions on the creation of new economic structures implementing state environmental policy, it is necessary to use integrated research methods and conduct an expanded analysis of the potential impact of planned activities on the environment, determining the risks of making one decision or another, assessing cumulative impacts, and developing mechanisms for implementing corporate, regional, and national programs and projects.

Lake Baikal is a UNESCO World Heritage Site and a natural object of federal significance in Russia. The unique status of Lake Baikal as an ecological system implies the need to establish a special legal regime. Federal Law "On the Protection of Lake Baikal" dated 1 May 1999, No. 94-FZ, and other regulatory and legislative acts aiming to protect and preserve the lake's unique ecosystem enshrine the unique status of Lake Baikal and the Baikal Natural Territory. The special regime for conducting economic and other activities necessary to preserve the uniqueness of Lake Baikal as an ecological system includes restrictions on industrial activities, protection of natural resources and biodiversity, and control over pollution and environmental impact. A comprehensive set of environmental regulations, including land, water, forest, and mountain codes and legislation on specially protected areas, complements special environmental protection requirements already established for Lake Baikal.

The research hypothesis is that the current need for the placement of infrastructure facilities in the Central Ecological Zone (CEZ) of the Baikal Natural Territory (BNT) to ensure the safety, social and environmental sustainability of cities and settlements (SDG 11) is limited by the potential of natural resources and the environmental capacity of this territory.

Restrictions on economic activity in the territory of the Central Economic Zone of BNT have a decisive impact on the living conditions and standard of living of the local population. Most social facilities are worn out, some institutions are not connected to central heating, and many settlements lack centralized water supply and drainage systems.

Currently, there is a need to develop scientific foundations for optimizing the structure and modes of natural resource management, assessing the assimilation properties of components of the natural environment, and revising established norms of permissible impacts on the CEZ BNT. However, possible changes should maintain the balance between natural and anthropogenic systems, increase technogenic loads, and reduce economic losses. The formation of economic siting factors, i.e., economic losses, damages, and comparative cost assessments, affects economic entities.

2. Literature Review

The works of many well-known researchers, including geographers, economists, and regional specialists, reflect theoretical approaches to the siting of productive forces. Most studies consider this issue from the perspective of economic feasibility for entrepreneurial activities and the influence of environmental constraints on the cost of production [1–6]. For example, Grossman G.M., Krueger A.B., Copeland B.R., and Taylor M.S. examine the pollution haven hypothesis (PHH), which suggests that production "moves" to areas with lower environmental standards [7,8]. As noted by Shadbegian R. and Wolverton A., before the 1970s–1980s, the environmental factor did not play as significant a role in production siting as today [9]. The authors note that the principles of territorial planning for the siting of productive forces should consider balanced development, creating new industrial and residential complexes, expanding settlement systems, and involving large volumes of natural resources. However, in many countries, the siting of new infrastructure objects depends more on the development of the territory, transportation accessibility, and the availability and utilization of natural resource potential [10,11].

Factors affecting siting resulting from changes in the quality of the natural environment during the construction of new infrastructure objects can be assessed through indicators of environmental vulnerability. These indicators characterize the likelihood of adverse changes in the environment [12] when increasing anthropogenic impact leads to the inability of the natural complex to maintain structural and ecological integrity.

The experience of assessing natural-anthropogenic impacts from various sources involves determining the degree of accumulation of chemical elements and heavy metals in individual natural components [13]. The formation of new conditions and requirements for the implementation of national nature conservation policies and the development of mechanisms for implementing private and public–private programs and projects are determined, as some authors note, by the principles of "sustainable development", "green economy", and "green construction" through the improvement of environmental design, small architectural forms, and the creation of special trust funds for "green construction" [14].

Geographers, economists, landscape scientists, and limnologists have studied the balance of regional environmental development in the Baikal region [15–18]. Several studies have developed modern scientific foundations for assessing the technogenic consequences affecting the quality of the natural environment of residential areas and forecasting material–dynamic changes due to the siting of new objects of economic activity [19,20].

The limiting and increasing factors of the socio-economic development of any territory are not only the presence of natural resource potential but also the area's reproductive functions, the self-purification capabilities of components of the natural environment, the background pollution of natural objects, and the average annual concentrations of pollutants in the surface layer of the atmosphere of residential and recreational areas [21]; it is these properties that largely determine the siting of new infrastructural objects in areas with limited types of land use in the Baikal Basin. In the Baikal Natural Territory, certain types of activities that harm the unique ecological system of Lake Baikal are prohibited or restricted [22].

The assessment of the cost of environmental consequences, or the calculation of indicators of economic damage to the environment due to changes in its quality, allow for the identification and ranking of territories that incur the most significant economic losses in healthcare, utilities, agriculture, and forestry as well as the determination of priorities for nature conservation investment and conducting interregional forecasts for natural environments, local territories, and economic objects. Environmental regulations outlined in the institutional documents of the Baikal Natural Territory limit the scale and nature of natural resource use, make great demands within the application of production and purification technologies, and develop and implement environmental protection measures that need additional material and financial resources.

Previous developments in the field of forecasting the development of natural-economic systems of the Baikal region based on specialized eco-economic-mathematical models of socio-ecological-economic systems and the development of territories (including numerical models of pollution of major water bodies, models of gas pollutant dispersion with the construction of concentration fields of pollutants around high and very high sources of atmospheric pollution, and models for assessing the effectiveness of the economic mechanisms of nature management) have served as the basis for assessing natural-anthropogenic impacts [23,24].

Diversifying the economies of coastal territories is necessary to preserve natural potential and increase economic sustainability through the expansion of production activities, primarily tourism and recreational activities, waste management, nature reserve management, forest restoration, and fisheries, in order to reduce socio-economic risks.

Thus, the study of human-environment interactions, the development of new territories, and the siting of infrastructure objects require the application of various methods of comprehensive research, allowing us to assess both the background states of natural environments, their anthropogenic transformations, areas of influence, and the likelihood of new economic and environmental risks. There are no universal approaches to scientifically justify the locating of new facilities since the land use regimes and the system for the regulation of economic activities determine the development of territorial formations and their specifications, features, and limitations.

3. Materials and Methods

3.1. Study Area

The Baikal Natural Territory (BNT) includes Lake Baikal, its water protection zone adjacent to Lake Baikal, the catchment area adjacent to Lake Baikal, specially protected natural areas adjacent to Lake Baikal, and the territory adjacent to the lake to the west and northwest up to 200 km away. The boundaries of the BNT and its ecological zones were approved by the decree of the Government of the Russian Federation, dated 27 November 2006, No. 1641-r.

The following ecological zones are distinguished within the BNT (see Figure 1 [25]):

- Central Ecological Zone;
- Buffer Ecological Zone;
- Atmospheric Impact Ecological Zone.

The green line on the map indicates the boundary of the BNT, and the red line indicates the Central Ecological Zone (CEZ) of the BNT. The CEZ includes five municipal entities of the Republic of Buryatia: the Kabansky, Pribaykalsky, Barguzinsky, Severo-Baykalsky districts, and the city of Severobaykalsk. Figure 1 also shows populated areas separated by their number of inhabitants, types of settlements (cities, urban, and rural settlements), and specially protected natural areas: reserves, national parks, wildlife refuges, natural parks, and research stations.

The Central Ecological Zone of the BNT includes the territories of the Republic of Buryatia and the Irkutsk Oblast. Within its boundaries, 129,000 people reside in 159 populated areas [26].

3.2. Methodological Steps

We developed a methodological approach to substantiate the siting of economic and other facilities that includes a multi-component analysis of the state and potential changes in pollution flows, as well as a comparative assessment of the natural potential of territories and the anthropogenic condition of natural complexes. It also involves analyzing the external and internal costs of existing and planned production and business structures in the service sector, as well as ensuring compliance with land use status and regulations. The level of ecological-economic parity, which is one of the criterion of environmental acceptability in Formula 1, is determined by the ratio of the ecological capacity of the territory, expressed in conventional tons, to the anthropogenic load, also expressed in conventional tons. Figure 2 shows the structure of the developed methodology.

We propose the following information-analytical toolkit for a multi-criteria assessment of the acceptability of locating new facilities, which includes a natural block, considering assimilation processes, environmental self-recovery, and the natural capacity of the territory; an anthropogenic block, determining the impact of past, present, and future economic activities on the state of natural complexes; a normative block, ensuring compliance with aggregated norms of permissible impacts; and an economic block, evaluating the possible economic consequences of placing new objects.

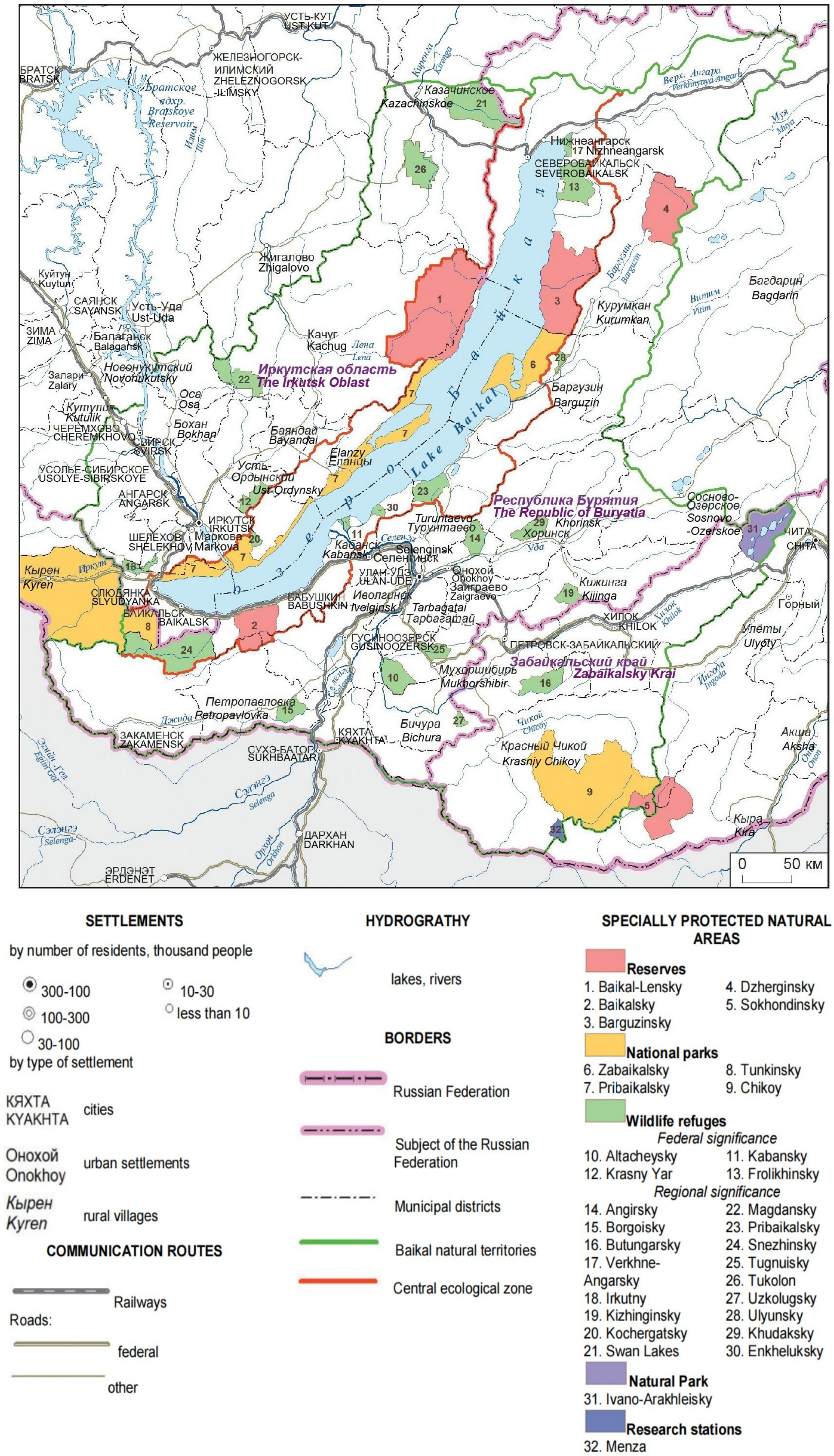

Figure 1. Scheme of ecological zones of the Baikal Natural Territory.

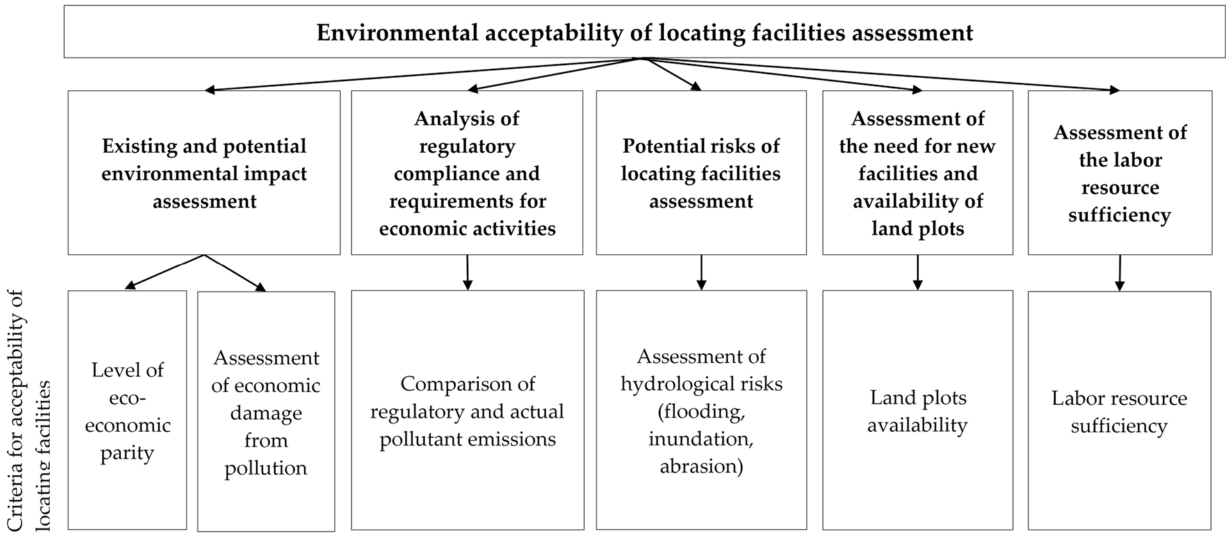

Figure 2. Scheme of assessment of the environmental acceptability of locating facilities.

3.2.1. Existing and Potential Environmental Impact Assessment

When justifying the acceptability of locating new facilities, a necessary condition is the ability of the natural environment of the territory to regenerate the resources extracted from it and to neutralize harmful anthropogenic impacts. The natural complex's ecological capacity depends on the volumes of the leading natural reservoirs—the air basin, water bodies, watercourses, land areas, and soil reserves—as well as the biomass of flora and fauna. Additionally, the capacity of biogeochemical fluxes that renew the contents of these reservoirs, including the rate of local atmospheric gas exchange, replenishment of clean water volumes, soil formation processes, and the productivity of biota, plays a crucial role [27]. Anthropogenic impact has pushed the natural complex of the territory to its limit of stability, which has resulted in excessive levels of variability. The integral indicator of the ecological capacity of natural complexes considers the ecological capacity of the atmosphere, water resources, and soil. The ecological capacity of the territory is calculated via Formula (1):

$$Ce_i = \sum_{j=1}^{3} Ce_{ij} * X_j * \tau_j, \quad (1)$$

where Ce_i—assessment of the ecological capacity of the i-th territory, expressed in units of mass anthropogenic load, conditional t/year; Ce_{ij}—assessment of the ecological capacity of the j-th environment, t/year; X_j—coefficient of variation for natural fluctuations in the content of the main substance in the j-th environment; and τ_j—coefficient of relative hazard of the j-th impurity (mass conversion coefficient to conditional tons).

To quantitatively determine anthropogenic pressure, an integral assessment method was used based on sources of impact. The first source is industry, through the volume of emissions into the atmosphere and into water resources, generation of production waste, and waste from the wood processing industry. The second is population, through the generation of waste from consumption, nitrogen and phosphorus runoff into water bodies, and emissions of pollutants into the atmosphere from households. Pollutants entering the natural environment have different levels of ecological and economic risk. The anthropogenic load of a territory can be expressed in total volumes of emissions and discharges of pollutants, measured in tons. When determining the total anthropogenic load, all pressure indicators were converted into conditional units [28]. In calculations, when assessing the anthropogenic load on atmospheric air, sulfur dioxide is taken as a reference impurity. In Russia, the average daily maximum permissible concentrations of pollutants in the atmospheric air of urban and rural settlements are as follwos: sulfur dioxide—0.05 mg/m^3, nitrogen dioxide—0.1 mg/m^3, carbon monoxide—3 mg/m^3, suspended solids—0.15 mg/m^3, respectively, the hazard coefficient of sulfur dioxide is 1, nitrogen dioxide—2, carbon monoxide—60, and suspended substances—3. The volumes of emissions into the atmosphere by pollutants according to statistics are converted into conventional tons in accordance with the hazard coefficients and are then summed up; this amounts to the total volume of anthropogenic load on the atmosphere. When analyzing the final indicator, "ratio of anthropogenic load to ecological capacity", ecological capacity is a standard measure equal to 1. We calculated the acceptability of locating new facilities in the area using the multiple excesses of ecological capacity (Formula (2)):

$$Me_i = \frac{U_i}{Ce_i}, \quad (2)$$

where Me_i—multiple excesses of the ecological capacity of the i-th territory; U_i—natural resource intensity of the industrial complex of the i-th territory, i.e., the total extraction and depletion of local renewable resources, including environmental pollution and other forms of anthropogenic pressure on recipients, in conditional tons per year; and Ce_i—ecological capacity of the i-th territory in conditional tons per year.

Depending on the nature of the factors of disruption, there are different gradations of Me_i, which are ranked by the level of concentration of anthropogenic impact. If the situation of $Me_i \leq 0.3$ is considered favorable, the siting of facilities is acceptable; if $Me_i \approx 1$ or $1 < Me_i < 2$, the situation is considered critical; if $Me_i \geq 10$, the siting of new facilities is not acceptable.

3.2.2. Analysis of Regulatory Compliance and Requirements for Economic Activities

Analyzing permissible impact norms and standards of natural environment components determines how aspects of ecological and natural resources are incorporated into the management system at any level. These indicators ensure the organic integration of ecological and resource-saving aspects into business activities and their relationship with the government, formalizing and standardizing the inclusion of ecological aspects in the business decision-making process. One of the areas for improvement of ecological norms and standards is the complexity with which their effectiveness is analyzed. The most simple and commonly used method of assessment is comparing impacts with universal standards, in our case with the norms of permissible impact on the ecological system of Lake Baikal and the list of substances classified as "particularly hazardous", "highly hazardous", and "hazardous" to Lake Baikal. Standards can be quantitative (e.g., the norms above) or qualitative (e.g., a list of particularly hazardous, highly hazardous, and hazardous substances, and a list of activities prohibited in the CEZ of BNT). Comparing the magnitude of impacts with norms and characteristic values is an "objective" method of assessing their significance. Economic feasibility refers to the monetary comparison of costs and benefits, which is calculated to select the best use of limited resources. In some cases, the cost-effectiveness ratio is often determined, which reflects the increase in the cost of benefits as a result of implementing any project.

3.2.3. Assessing the Potential Risks of Siting Facilities

Possible risks associated with locating new facilities can arise from both probable and existing events, leading to financial losses, additional expenses, loss of income, and disruption of project timelines. Forecasting the natural dynamics of the environment and the occurrence of natural and anthropogenic risks allows for informed decision-making during the construction of objects. Analyzing direct observations of anthropogenic changes, monitoring of natural environments, and historical examples reflect the probability of possible occurrences. Constraints in placing new objects may include geological and hydrological risks, such as earthquakes, landslides, soil erosion, areas with highly dissected terrain, floods, inundation, and abrasion. For hydrological risks, methods such as GIS modeling, field surveys, population and business surveys, territorial planning documents, orthophoto planes, and satellite imagery can identify areas susceptible to flooding, inundation, and abrasion.

3.2.4. Assessment of the Need for New Facilities and Availability of Land Plots

The assessment of the territory's need for new facilities is proposed based on calculating the demand for additional facilities of social institutions and engineering infrastructure. The need is determined based on the difference between the calculated indicators of normative provision, calculated according to regional standards, and the indicators of the designed capacity of existing facilities. The standards are differentiated for urban and rural settlements according to natural–climatic zones.

$$NSI_i = MALRS_i - DSESI_i, \tag{3}$$

$$MALRS_i = P_i * masi_i, \tag{4}$$

where NSI_i—the need for social infrastructure institutions; $MALRS_i$—the minimum acceptable level of normative provision for the i-th territory; $DSESI_i$—the capacity of the existing social infrastructure of the i-th territory; P_i—the population of the i-th territory; and $masi_i$—the minimum acceptable provision indicator for the i-th territory.

We determine the required land area based on the need for infrastructure and correlate it with the available vacant land plots in the given territory.

3.2.5. Assessment of the Labor Resource Sufficiency

We propose a methodology based on the coefficient of labor resource provision to assess labor resource sufficiency, which represents the ratio of the number of job vacancies to the number of unemployed individuals in each territory.

$$K_{lab\ i} = \frac{V_i}{U_i}, \tag{5}$$

where $K_{lab\ i}$—coefficient of labor resource provision for the i-th territory; V_i—number of job vacancies in the i-th territory; and U_i—number of unemployed individuals in the *i*-th territory.

Depending on the value of the coefficient of labor resource provision, we distinguish two types of territories: if $K_{lab\ i} \geq 1$, it indicates labor-deficient territories characterized by insufficient labor resources; if $K_{lab\ i} < 1$, it indicates labor-surplus territories characterized by an excess of job vacancies over the number of available labor resources.

Based on the obtained criteria for the permissibility of locating objects, conclusions are drawn regarding the presence or absence of restrictions in the given territory, considering environmental, regulatory, and socio-economic factors. Thus, the proposed methodology for environmental assessment of the acceptability of economic activities considers various potential environmental impacts by comparing indicators characterizing the magnitude of the impact with sanitary–hygienic standards, background values, indicators of the environmental condition at the time of the planned activity's commencement, and regional indicators.

4. Results and Discussion

We tested methodological approaches on the territory of the Central Ecological Zone (CEZ) of the Baikal Natural Territory (BNT), which has special status regulating the use and protection of natural resources. The CEZ includes five municipal entities of the Republic of Buryatia: the Kabansky, Pribaykalsky, Barguzinsky, Severo-Baykalsky districts, and the city of Severobaykalsk. The CEZ of the BNT includes the coastal territories of Lake Baikal, which have been among the Republic of Buryatia's most economically developed areas, with residential housing, infrastructure objects, and subsistence farming for the local population. Areas with developed agriculture and forestry and a dynamically growing service sector—i.e., tourism, catering services, and transportation companies (Table 1)—remain attractive to investors. The data in Table 1 were obtained based on statistical data [29–31].

Table 1. Ecological and economic development of CEZ BNT territories.

Indicators	Severobaykalsk	Kabansky	Pribaykalsky	Barguzinsky	Severo-Baykalsky
Population density, people/km^2 (2021)	211.85	4.08	1.69	1.15	0.20
Area of cropland per capita, hectares/person (2020)	0.01	0.23	0.10	0.11	0.02
Livestock population in farms of all categories per capita, livestock units/person (2020)	0.003	0.30	0.17	0.58	0.08
Retail trade turnover (excluding small businesses) per capita, thousand rubles/person (2021)	43.98	43.17	48.29	21.33	no data
Catering turnover (excluding small businesses) per capita, thousand rubles/person (2021)	0.35	0.50	0.26	0.50	1.05
Volume of pollutant emissions into the atmosphere, kg/person (2020)	103.5	187.5	41.8	37.2	17.7
Volume of discharge of polluted wastewater, m^3/person (2020)	43.1	19.8	3.8	No data	8.8

We utilized statistical reporting on air, water management, and waste management to evaluate the state of natural environmental components, potential risks associated with emissions of pollutants from stationary and mobile sources, and wastewater discharges in the Central Ecological Zone (CEZ). We carried out predictive calculations of emissions and discharges from residential, social, recreational, and other heating systems and compared the normative and actual emissions of pollutants in the Baikal Lake Basin.

The highest proportion of total stationary emissions in the CEZ of the BNT is attributed to the activity type “production and distribution of electricity, gas, and water”, mainly represented by boilers in the considered area. The primary sources of air pollution are the boilers in Severobaykalsk (Severobaykalsk Heating and Power Plant). Some pollutants come from urban settlements such as Nizhneangarsk, Ust-Barguzin, Tankhoy, and Babushkin. The primary heat energy supplier to facilities in Severobaykalsk is the Central Heating Plant, with an installed capacity of 166 Gcal/h (190.7 MW). The primary type of fuel consumed is coal. The Central Heating Plant in Severobaykalsk operated its boilers from 1984 to 1987, except for the last two, which were commissioned in 1990 and 1999, respectively. They exceeded their calculated service life by two times, averaging 30 years each. The primary and auxiliary technological equipment of the Central Heating Plant in Severobaykalsk has suffered wear and tear ranging from 65% to 70%.

The maximum volumes of water resource use and wastewater discharge are observed in the housing and utilities sector. The primary sources of organized wastewater discharge are located in Severobaykalsk (Severobaykalsk Sewage Treatment Plant), Babushkin (Babushkin Wastewater Treatment Plant LLC), and Vydrino (VKS LLC). Water users in Severobaykalsk discharge the most polluted wastewater into surface water bodies (1 million m^3 in 2022). A centralized water supply for recreational facilities is absent in all settlements except Severobaykalsk and Nizhneangarsk, with water intake from surface water bodies and deep wells. In Severobaykalsk, Babushkin, Goryachinsk village, and Tankhoy, recreational facilities utilize centralized wastewater systems, which, according to the inspection by Rosprirodnadzor (the Federal Service for Supervision of Natural Resources) in the Republic of Buryatia, do not meet the approved quality standards for wastewater treatment [32].

Domestic sewage is treated using “TOPAS” and “TOPAERO” deep biological treatment stations in the settlements of Sukhaya, Enkhaluk, and Goryachinsk. The degree of wastewater treatment reaches up to 98%. Table 2 presents the assessment of possible wastewater discharge in the settlements of the Central Ecological Zone of the BNT. The calculations also used data from the Scheme for the integrated use and protection of water bodies in the river basins of the southern part of Lake Baikal [33] and data according to the state statistical reporting form 2-TP Vodkhoz [34].

Table 2. Assessment of possible wastewater discharge in the CEZ BNT RB municipalities.

Settlement	Sewage Treatment Plant Capacity, m^3/day	Treatment System	Wastewater Receiving Body	Possible Volume of Wastewater, Thousand m^3/year
Kababnsky district				
Babushkin (Mysovaya station)	375	Biological treatment	River Mysovka	136.875.
Kultushnaya tourist base	150	Complete biological treatment with post-treatment	Filtration fields	54.75
Vydrino village	1250	Complete biological treatment	River Snezhnaya	456.25
Vydrino station	100	Biological treatment	Filtration fields	36.5
Pereemnaya station	25	Biological treatment	Filtration fields	9.125
Posolskaya station	800	Treatment facilities	Filtration fields	292
Pribaykalsky district				
Goryachinsk village	103.3	Biological treatment	Stream Goryachiy	37.7045
Turka village	1500 *	Complete biological treatment with post-treatment		547.5
Severo-Baykalsky district and Severobaykalsk city				
Severobaykalsk city	1650	Biological treatment	River Tyya	602.25
Kichera settlement	146	Biological treatment	River Kichera	53.29
Nizhneangarsk settlemen	48.9/450 *		Stream Goryachiy	17.85/164.25 *

* capacity of the planned treatment facilities.

In 2022, the largest volume of waste was generated at enterprises in the Kabansky district—2,156,000 tons, Pribaykalsky district—17,417,000 tons, Severo-Baykalsky district—131,000 thousand tons, Barguzinsky district—5300 tons, and Severobaykalsk—4600 tons.

We calculated the emissions of pollutants into the atmospheric air from heating the residential sector for all urban and rural settlements. We assumed that all settlements, except for the towns of Severobaikalsk and Nizhneangarsk, use wood, coal, gas, and electric heating.

When determining fuel consumption, data on the forecasted population and the calculated housing provision of 18 square meters of total apartment area were considered, with a wall thickness conventionally assumed to be 0.3 m and a house height of 5 m. Annual fuel consumption for heating purposes was calculated based on the average building volume and the fuel consumption rate, with emissions calculated taking into account the number of days in the heating period and the average duration of combustion per day (wood—5.5 h, coal—16.5 h, gas—24 h, and electric heating—24 h). Similarly, we calculated emission volumes for other infrastructure facilities. The areas of preschool educational institutions, secondary schools, pharmacies, bank branches, daily trading enterprises (food and non-food stores), sports and leisure complexes, and outpatient clinics were calculated based on the forecasted population proposed by the Regional Urban Planning Standards of the Republic of Buryatia, which were developed and approved as part of Paragraph 4 of Article 24 of the Urban Planning Code of the Russian Federation, Article 5 of the Law of the Republic of Buryatia No. 2425-III of September 10, 2007, "On the Urban Development Charter of the Republic of Buryatia". The results of forecasting calculations of emissions of pollutants allow us to conclude that emissions will increase overall by 29.9%.

Thus, the assessment of the possible impact of discharges and emissions on the CEZ of the BNT in the Republic of Buryatia was carried out based on population-based forecasting of municipal entities, discharges, and emissions from households, traffic flows, tourist activities, stationary emission sources, and local treatment facilities.

The main criterion for the environmental acceptability of locating facilities is the level of eco-economic parity, which determines the conformity of the integral anthropogenic load to the maximum natural capacity.

Figures 3 and 4 show the results of the comparative assessment of the anthropogenic load and environmental capacity of the territories of five municipal entities of the CEZ.

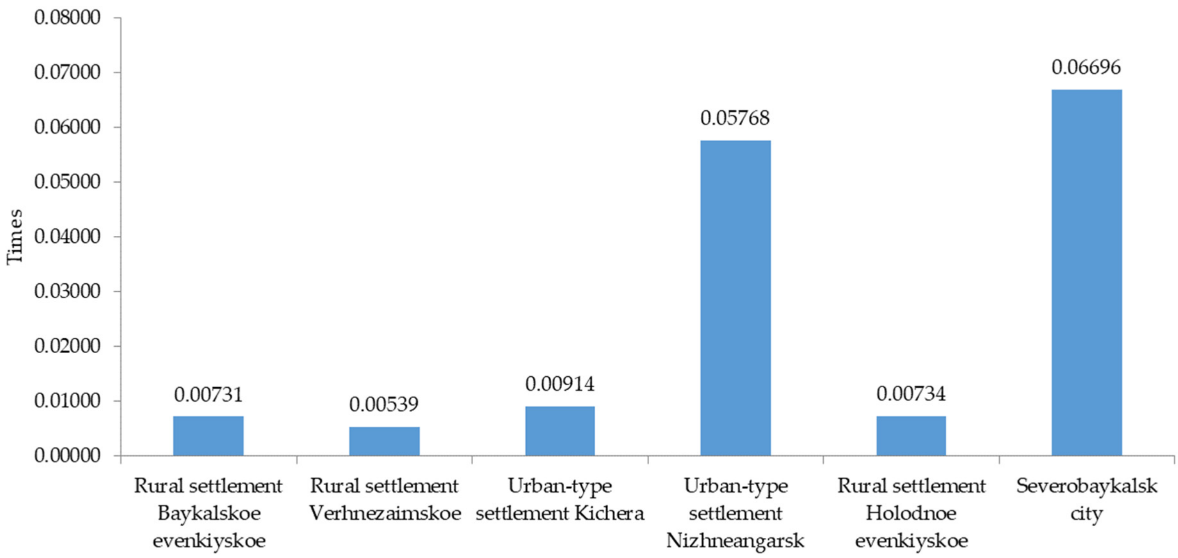

Figure 3. The ratio of anthropogenic load and ecological capacity of municipalities of the Severo-Baykalsky district and the city of Severobaykalsk.

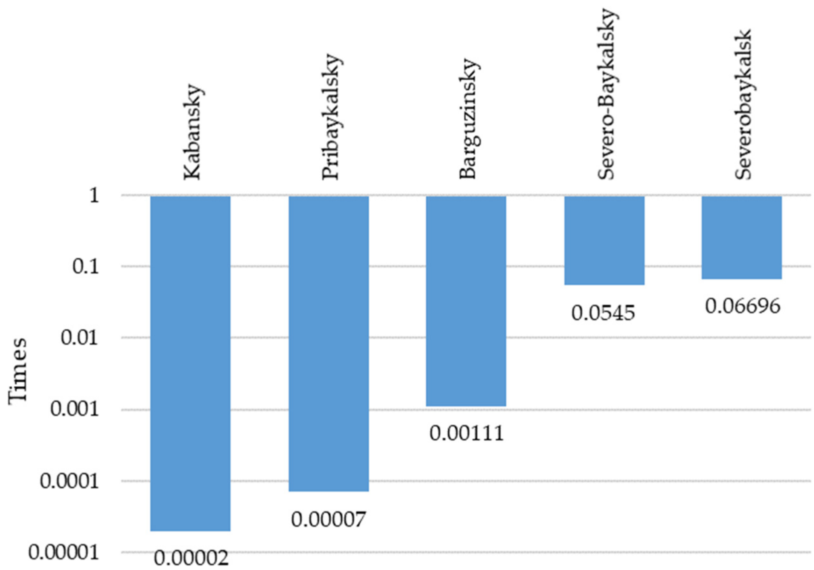

Figure 4. The ratio of anthropogenic load and ecological capacity of municipalities of the CEZ BNT (logarithmic scale), with times.

The environmental acceptability of existing types of economic activity, which can be characterized as corresponding to natural properties and having no limiting constraints, was calculated based on multicriteria analysis. The values obtained for the anthropogenic load ratio to the environmental capacity of the territories provide evidence for this. For most municipal entities, the multiplicity of environmental capacity is less than 0.3, and according to the generally accepted classification of eco-economic systems, the environmental situation is considered favorable. In the municipal entities of the Republic of Buryatia, there is a significant reserve of environmental capacity for placing new objects of various types of activity.

We carried out economic assessments to determine past, existing, and potential cost losses from the siting of infrastructure facilities for the CEZ of the BNT, where there are no large industrial enterprises. Therefore, the economic damage to the environment caused by economic activities is insignificant. When determining the scale of the environmental damage caused by the components of the natural environment, we considered the level of the environmental situation, the environmental significance of the territories, and the degree of danger of pollutants. All indicators were converted into conditional units to determine the total anthropogenic load. The calculations used eco-economic assessment indicator values of specific damage per one conditional ton of pollutants emitted into air and water resources. The calculations also used the Ministry of Natural Resources and Ecology of the Russian Federation guidelines for developing draft waste generation standards and disposal limits [35]. The criterion for the acceptability of placing new objects in the territory is the insignificance of past and potential environmental damage due to the territory's economic structure and the strategic trends in the development of coastal municipal entities of the Republic of Buryatia.

Table 3 provides the results of the economic assessment of environmental damage by municipal entities of the CEZ of the BNT. We identified that the most significant economic damage from anthropogenic impact is in the Kabansky district, and the smallest is in the Barguzinsky district. The assessment of potential damage slightly exceeds the actual damage (2–5%) due to the prohibition of economic activity in the CEZ of the BNT, the connection of new social objects to existing communal facilities, and the use of electric heating and gas boilers in collective accommodation for tourists.

Table 3. Actual economic damage from environmental pollution in CEZ BNT municipalities (2022).

Municipalities	**Emissions Volume, t**	**Economic Damage, Thousands of Rubles**	**Volume of Polluted Wastewater Discharge, Million m^3**	**Economic Damage, Thousands of Rubles**	**Total Economic Damage, Thousands of Rubles**
Barguzinsky district	0.7	264.5	-		264.50
Kabansky district	9.9	3740.7	1.1	30,465.2	34,205.93
Pribaykalsky district	1.3	491.2	0.1	2769.6	3260.77
Severo-Baykalsky district	2.3	869.1	0.1	2769.6	3638.67
Severobaykalsk city	1.6	604.6	1	27,695.7	28,300.26

In 2022, we identified the greatest damage from air pollution caused by stationary sources in the CEZ BNT from the placement of enterprises providing electricity, gas, and steam air conditioning (64.3%). Economic damage to water resources was caused by the activity of "Water supply, wastewater disposal, waste collection and disposal, pollution cleanup" (91.2%).

Federal Law No. 94-FZ of 1 May 1999, "On the Protection of Lake Baikal" provides normative support and regulations for economic activity within the unique environmental system of Lake Baikal. Norms for releasing substances into the atmospheric air are determined for the Baikal Basin, which is morphologically divided into three basins: Southern, Central, and Northern. The boundaries between the basins are located as follows: between the Northern and Central Basins, the eastern shore is at 53°52′351″ N, 109°08′600″ E and the western shore is at 53°46′512″ N, 107°58′773″ E, and between the Central and Southern basins, the eastern shore is at 52°17′575″ N, 106°06′940″ E, and the western shore is at 52°14′907″ N, 105°42′850″ E.

The Southern Basin stretches from the southern tip of the lake to the delta of the Selenga River, where the lake bottom is much higher than the adjacent areas (Selenga dam). The Southern Basin includes a large part of the territory of the Kabansky district. The Central Basin is located between the Selenga River and the Ushkany Islands archipelago. Morphologically, it is closed off from the northwest by a significant extension at the bottom, linearly extending from Olkhon Island to the Ushkany Islands and further to the northeast. This basin includes the territory of the Pribaykalsky district, most of the Barguzinsky district, and parts of the Kabansky district. The Northern Basin stretches from the Ushkany Islands to the lake's northern end. The territory of Severobaykalsk, Severobaykalsky, and parts of the Barguzinsky district belong to the Northern Basin.

At present, there are problems associated not only with the presumed volumes of wastewater discharge but also with their quality and compliance with existing regulations, since water users who carry out or will carry out activities in the BNT territory must comply with the "Norms for the Maximum Permissible Impact on the Unique Environmental System of Lake Baikal" (from now on referred to as "Norms. . ., 2020") [36]. These norms were developed by Federal Law No. 94-FZ of 1 May 1999 [37] and approved by Order of the Ministry of Natural Resources of the Russian Federation No. 83 of 21 February 2020. The "Norms. . ., 2020" requirements regarding wastewater quality are stringent and complex.

Table 4 compares permissible masses according to the approved "Norms. . ., 2020" with the actual masses of pollutants based on data from 2-TP Water Management in the Lake Baikal Basin for 2017 and the state report "On the state of Lake Baikal and measures for its protection" [34,36,38]. According to the data in Table 4, in the Southern Basin, the actual masses of pollutants already exceed the permissible masses established by the "Norms. . ., 2020", especially for chlorides (by 17.5 times), nitrates (by 19.4 times), and PHCs (by 9.3 times), which limits the further water management activities of new water users in the CEZ BNT.

Table 4. Comparison of permissible masses according to the approved "Standards. . ., 2020" with the actual masses of discharged substances in the Lake Baikal Basin within the CEZ BNT for 2017 (Southern Basin).

Substances	Southern Basin (Baikal Pulp and Paper Mill Area)		
	Permissible Mass of Discharged Substances, tons/year	**Actual Mass of Discharged Substances in 2017, tons**	**Exceedance of Actual Discharge over the Norm, Times**
Total suspended solids	5	16.63	3.3
Sulfates	25	65.66	2.6
Chlorides	2	34.94	17.5
Nitrates	3	58.21	19.4
Nitrites	0.06	0.23	3.8
Ammonium nitrogen	0.4	0.67	1.7
COD (chemical oxygen demand)	34	38.62	1.1
Petroleum products	0.022	0.04	1.8
PAHs (polycyclic aromatic hydrocarbons)	0.015	0.14	9.3

The allowable emissions into the atmosphere in the CEZ BNT are defined in the regulations on the maximum permissible impacts on the unique environmental system of Lake Baikal, which give the following volumes:

- Emissions into the atmosphere over the Northern Basin of Lake Baikal from anthropogenic sources during the year should not exceed 1200 tons of sulfur dioxide and 540 tons of nitrogen oxides;
- Emissions into the atmosphere over the Central Basin of Lake Baikal during the year should not exceed 1000 tons of sulfur dioxide and 500 tons of nitrogen oxides from anthropogenic emission sources located in the Central Ecological Zone of the Baikal Natural Territory;
- Emissions into the atmosphere over the Southern Basin of Lake Baikal during the year should not exceed 2500 tons of sulfur dioxide and 1200 tons of nitrogen oxides from anthropogenic emission sources located in the Central Ecological Zone of the Baikal Natural Territory.

A comparison of the data in Table 5 shows that an increase in emission volumes for regulated pollutants in the southern basin of Lake Baikal is acceptable, providing a basis for introducing new infrastructure facilities. In the Central and Northern Basins, actual emission volumes for some pollutants exceed the norms; therefore, locating new facilities is not advisable. Data on actual emissions were taken based on information from Rosprirodnadzor for 2022 [39].

Table 5. Actual, forecast, and standard emission volumes for the Baikal Basins (t/year).

Baikal Basins	**SO_2**			**NO_x**		
	Existing Norm, t	**Actual Volume of Emissions *, t**	**Ratio/Impact Level**	**Existing Norm, t**	**Actual Volume of Emissions *, t**	**Ratio/Impact Level**
Northern Basin	1200	407	The norm exceeds the actual volume of emissions by almost 3 times; weak impact	540	870	The actual volume of emissions exceeds the norm by 1.6 times; moderate impact
Central Basin	1000	5143	The actual volume of emissions exceeds the norm by 5.1 times; very strong impact	500	981	The actual volume of emissions exceeds the norm by almost 2 times; strong impact
Southern Basin	2500	950	The norm exceeds the actual volume of emissions by 2.6 times; weak impact	1200	441	The norm exceeds the actual volume of emissions by 2.7 times; weak impact

* according to data for 2022.

To assess hydrological risks, we mapped high-water-impact zones on natural and socio-economic objects along the coast of Lake Baikal in the Republic of Buryatia. The main materials used were the topographic base of Roscartography at a scale of 1:100,000, the cartographic database "Land plots", and orthophoto plans of key areas.

GIS modeling identified and listed the boundaries of flooded/submerged/eroded territories and natural and socio-economic objects susceptible to flooding/submersion/erosion (construction sites, transportation, energy, households, household plots, and tourist bases). By overlaying layers of flood/submersion-affected objects, land plot boundaries, and digital terrain models, areas of potential flooding were determined based on eight water level marks of Lake Baikal. Hydrological constraints were identified in the coastal areas of Posolsky Bay, in the villages of Gremyachinsk in the Pribaykalsky district, in Maksimikha in the Barguzinsky district, and in the delta of the Selenga River, Upper Angara, and Kichera [40].

The need for social infrastructure objects in the CEZ BNT RB was calculated for 30 municipal entities (urban and rural settlements) based on the current urban planning norms of the Republic of Buryatia, considering methodological recommendations [41]. As of the beginning of 2023, there are 68 educational institutions (30 preschools and 38 schools), 58 healthcare institutions (41 rural medical stations, 7 hospitals, 6 outpatient clinics, and 4 polyclinics), 95 cultural institutions (43 libraries, 46 cultural and leisure centers, and 6 children's art schools), 3 children's and youth sports schools, and 6 social service institutions in populated areas within the CEZ BNT RB. According to our calculations, the need for preschool education facilities exists in 17 settlements within the CEZ BNT RB; for general education facilities exists in the urban-type settlement of Ust-Barguzin and the village of Gusikha; and for healthcare facilities exists in the Barguzinsky, Kabansky, and Pribaykalsky districts and Severobaykalsk city (Table 1).

One of the main limiting factors for the placement of new social and engineering infrastructure objects is the insufficient availability of land resources meeting regulatory requirements, considering restrictions on the placement of economic activities such as the prohibition on converting forest lands occupied by protective forests into lands of other categories (except for converting such lands into lands of specially protected territories and objects near them). According to the research results, out of 72 populated areas within the boundaries of the CEZ BNT RB, only 27 have land plots for constructing life support facilities (53 objects). However, an additional 424 hectares of land are required to place the necessary infrastructure objects in the CEZ BNT RB. For instance, in the Barguzinsky district, more land plots are needed for infrastructure objects. At the same time, there is significant demand for plots for waste management facilities, treatment plants, sewage systems, and water supply systems, totaling 174.9 hectares (Table 6).

Table 6. Assessment of the need for land plots for siting facilities in CEZ BNT RB (Barguzinsky district).

Settlement	Availability of Land Plots for Infrastructure Construction	Land Plot Requirement for Locating Infrastructure Facilities, ha
Ust-Barguzin	No land plots available	Waste disposal facility—15.925 ha Waste disposal facility—0.8 ha Wastewater treatment facilities—1.7 ha Wastewater and water supply systems for Ust-Barguzin—155 ha
Adamovo *	No land plots available	Waste disposal facility—0.26 ha Water intake—0.25 ha
Zhuiravlikha *	No land plots available	Water intake—0.25 ha
Zorino *	No land plots available	Waste disposal facility—0.11 ha Water intake—0.25 ha
Makarinino *	No land plots available	Waste disposal facility—0.11 ha Water intake—0.25 ha

* Part of the rural settlement Adamovskoye.

The increase in the total area of municipal settlements did not solve the problem of the shortage of land for infrastructure development within and beyond the boundaries of settlements, as the expansion of settlement areas mainly occurred at the expense of forest land (except for the municipal entity "Baykalskoye Evenkiyskoye"), the conversion of which into lands of other categories (except for the category of specially protected areas and objects) is prohibited by Paragraph 2 of Article 11 of Federal Law No. 94-FZ of 1 May 1999, "On the Protection of Lake Baikal".

In addition to the shortage of arable land, there is a high probability of hydrological emergencies occurring in the CEZ, which affects economic entities and the population of coastal territories.

An analysis of archival and expeditionary materials to elucidate the impact of fluctuations in the level of Lake Baikal on the socio-economic condition of coastal territories identified the main environmental risks associated with flooding and inundation of households, economic facilities, safety provision, nature conservation, and other activities operating in the CEZ of the BNT. The territories most vulnerable to the adverse effects of fluctuations in the level of Lake Baikal on socio-economic systems are the delta of the Selenga River (with an affected area ranging from 321.5 to 818.8 ha), the villages of Gremyachinsk and Maksimikha, and the coast of Posolsky Sor Bay (Pribaykalsky, Barguzinsky, and Kabansky districts).

We calculated the labor resource provision coefficient based on data on the number of unemployed individuals [42] and the number of job vacancies by territories [43] to address the problem of providing labor resources for new facilities in the CEZ of the BNT in the Republic of Buryatia. Based on the coefficient values obtained, as illustrated in Figure 5, we discovered that the Severo-Baykalsky district needs more labor resources. At the same time, the Severobaykalsky, Barguzinsky, Kabansky, and Pribyalsky districts have a surplus of labor resources.

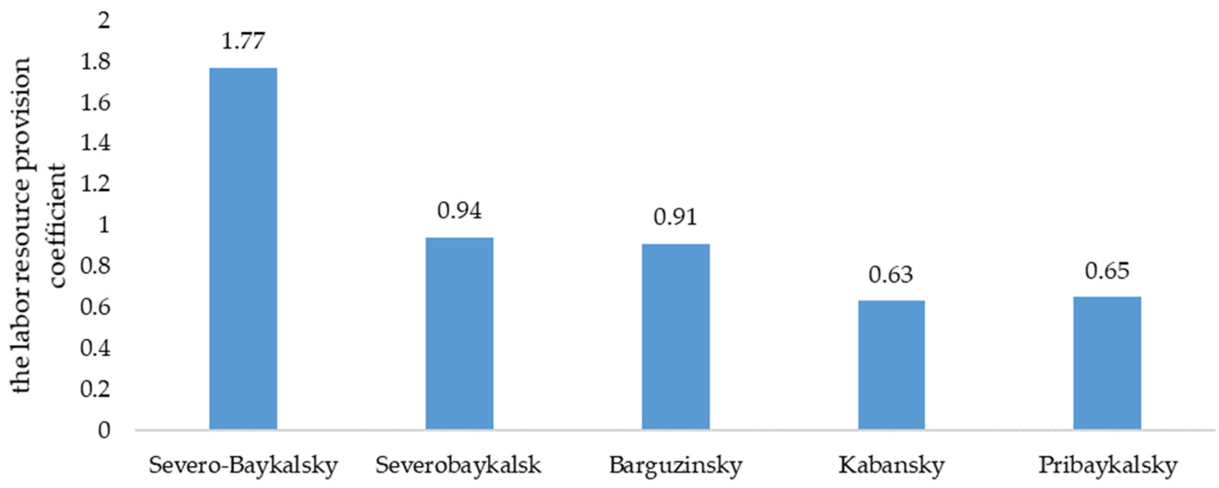

Figure 5. Assessment of the provision of labor resources in the CEZ BNT RB territories.

Thus, the scientific justification for locating social, transportation, energy, and communal infrastructure; recreational facilities; nature conservation sites; and other activities in the Central Ecological Zone (CEZ) of the Baikal Natural Territory (BNT) is based on existing strategic and territorial planning documents of the Republic of Buryatia, municipal entities, and rural settlements. Table 7 shows the criteria and limitations for locating facilities in the CEZ BNT of the Republic of Buryatia.

Table 7. Results of assessment of the environmental acceptability of locating facilities in the CEZ BNT.

Criteria of the Acceptability of Locating Facilities	Presence/Absence of Restrictions
Ecological capacity to anthropogenic load ratio	No restrictions
Economic damage from pollution	No restrictions
Comparison of regulatory and actual pollutant discharges	Restrictions in the Southern Basin of Lake Baikal
Comparison of regulatory and actual pollutant emissions	Restrictions in the Northern and Central Basins of Lake Baikal
Hydrological risks (flooding, inundation, erosion)	Restrictions in the territories along the coast of Posolsky Sor Bay, in the villages of Gremyachinsk, Maksimikha, and in the deltas of the Selenga River, Upper Angara, and Kichera
Availability of land plots	Restrictions along the entire coast of Lake Baikal
Sufficiency of labor resources	Restrictions in the Severo-Baykalsky district

The assessment of the environmental acceptability of locating facilities using the ratio of ecological capacity to anthropogenic load showed a significant reserve of ecological capacity for locating facilities of various activities in the territory of five municipal entities in the BNT's CEZ.

The assessment based on economic damage from pollution showed that the magnitude of potential damage slightly exceeds the actual damage (by 2–5%). Under the conditions of compliance with requirements for permitted economic activities in the CEZ of BNT and using environmentally safe technologies, siting new facilities is possible.

At the same time, the comparison of regulatory and actual pollutant discharges revealed a significant exceedance of actual pollutant masses over permissible values in the Southern Basin of Lake Baikal (chloride by 17.5 times, nitrates by 19.4 times, and synthetic surfactants by 9.3 times), limiting further water management activities for new water users in the CEZ of the Republic of Buryatia. A comparison of regulated and actual pollutant emissions showed that the actual volumes of some pollutant emissions exceed norms in the Central and Northern Basins of Lake Baikal, thus limiting the placement of new objects.

In contrast, in the Southern Basin, norms are not exceeded, which provides a basis for the possible introduction of new infrastructure objects.

We identified risks associated with flooding, inundation, and abrasion for the territories on the coast of Lake Baikal (Posolsky Sor Bay); in the villages of Gremyachinsk of the Pribaykalsky district and Maksimikha of the Barguzinsky district; and in the deltas of the Selenga River, Upper Angara, and Kichera.

Restrictions on locating new facilities in the CEZ BNT are also mainly related to insured sources. The study identified an insufficiency of land resources that meet regulatory requirements, meaning restrictions on siting types of economic activities should be considered in 62.5% of settlements located within the CEZ of the BNT of the Republic of Buryatia. The territories of the Severobaikalsky district need more labor resources, while the other districts have sufficient labor resources to locate new facilities.

The obtained values of the acceptability of placing facilities in the CEZ BNT of the Republic of Buryatia indicate that in most of this territory, locating new facilities is acceptable given the ratio of ecological capacity to anthropogenic load and economic damage from pollution. However, it is necessary to consider restrictions on pollutants and pollutant standards, hydrological risks in some sections of the coast, and the limited labor resources in the Severobaykalsky district.

5. Conclusions

This study considered the environmental acceptability of locating new facilities in areas with environmental restrictions. We developed a methodological approach to substantiating the placement of economic and other activities, which includes (1) a multi-component analysis of the state of natural potential, primary sources of pollution, and impacts on natural complexes; (2) analysis of compliance with norms and requirements for economic activities; (3) assessment of potential risks based on determining the external and internal costs of existing and planned production and service enterprises in areas vulnerable to adverse water impacts; (4) assessment of the need for additional social infrastructure and engineering infrastructure, determined as the difference between normative provision and the capacity of existing facilities considering their wear and tear, as well as the assessment of the need for land plots for new facilities; and (5) assessment of labor resources' availability.

This approach allows for a comprehensive assessment of the feasibility and necessity of locating new facilities, which can contribute to making informed decisions in planning the development of territories with a special regime of nature management.

Validation using the example of the Central Ecological Zone of the Baikal Natural Territory will help to identify possible directions for developing municipal territories, forecast the environmental impact of economic and other activities, and assess the environmental and associated socio-economic consequences. This study revealed that the main limitation of the socio-economic development of these territories is the lack of land plots that meet the regulatory requirements for infrastructure placement. In these circumstances, improving federal laws regulating land and forest relations in the Baikal Natural Territory is necessary.

The authors acknowledge that this study, applied to the Central Ecological Zone of the Baikal Natural Territory as a territory with a special regime of nature management, may need more generalization regarding the applicability of the results to territories with other regimes.

In further research, we plan to conduct assessments using this methodology on territories with different nature management regimes. The methodological approaches and conclusions proposed in this study are scientifically novel. Various stakeholders can use them in management, and they may also be used by governments and researchers in future developments.

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Appendix A

Table 1. Assessment of the need for social infrastructure facilities in the CEZ BNT RB.

	District	Municipal Entity	Number of Institutions, Units	Degree of Wear and Tear, %	Calculated Indicators of Normative Provision *	Designed Capacity **	Indicators of Actual Provision **/***	Needs
				in preschool institutions				
1	Severobaykalsk city	Urban settlement "Severobaykalsk City"	7	No data	1475 places	1265 places	1477 places	210 places
2	Severo-Baykalsky district	Rural settlement "Baykalskoye"	1	100	31 places	25 places	29 places	6 places
3		Urban settlement "Nizhneangarsk"	2	100	256 places	150 places	250 places	106 places
4	Barguzinsky district	Rural settlement "Adamovskoye"	-	-	30 places	-	-	30 places
5		Urban settlement "Settlement Ust-Barguzin"	3	36–100	454 places	367 places	446 places	87 places
6	Pribaykalsky district	Rural settlement "Nesterovskoye", village Kika	-	No data	30 places	-	-	30 places
7	Kabansky district	Urban settlement "Babushkinskoye"	2	12–96	300 places	245 places	239 places	55 places
8		Rural settlement "Bolsheretchenskoye"	1	No data	76 places	50 places	36 places	26 places
9		Rural settlement "Klyuevskoye"	-	-	68 places	-	-	68 places
10		Rural settlement "Kolesovskoye"	-	-	51 places	-	-	51 places
11		Rural settlement "Korsakovskoye"	-	-	31 places	-	-	31 places
12		Rural settlement "Krasnoyarskoye"	-	-	36 places	-	-	36 places
13		Rural settlement "Oymurskoye"	1	90	108 places	56 places	56 places	52 places

Table 1. *Cont.*

	District	Municipal Entity	Number of Institutions, Units	Degree of Wear and Tear, %	Calculated Indicators of Normative Provision *	Designed Capacity **	Indicators of Actual Provision **/***	Needs
14		Rural settlement “Ranzhurovskoye”	-	-	60 places	-	-	60 places
15		Rural settlement “Tankhoyskoye”	1	54	63 places	43 places	39 places	20 places
16		Rural settlement “Sherginskoye”	1	90	78 places	28 places	23 places	50 places
17		Rural settlement “Sukhinskoye”	-	-	63 places	-	-	63 places
				in general education facilities				
1	Barguzinsky district	Urban settlement “Ust-Barguzin”, Ust-Barguzin	1	100	907 places	710 places	1078 places	197 places
2		Urban settlement “Ust-Barguzin”, village “Gusikha”	1	47	34 places	No data	52 places	17 places
				in healthcare facilities				
1.	Barguzinsky district	Barguzinsky district, 21072	1 Central district hospitals	77	297 beds	No data	142 beds	155 beds
2.	Kabansky district	Kabansky district, 54528	3 Central district hospitals	40	769 beds		550 beds	219 beds
3.	Pribaykalsky district	Pribaykalsky district, 25878	1 Central district hospital (beds)	78	365 beds		124 beds	241 beds
4.	Severobaykalsk city	Severobaykalsk city, 23411	1 Polyclinic	No data	316 visits per shift	No data	176 visits per shift	140 visits per shift

* calculated according to data from [44]. ** calculated based on reports based on the results of self-examinations of educational institutions. *** calculated based on data [45].

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