RESEARCH PAPER

INTERNAL RESERVES OF CITIES: A NEW APPROACH TO ASSESSING THE TRANSFORMATION OF URBAN SPACE UNDER THE INFLUENCE OF BROWNFIELDS

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ABSTRACT. The disadvantage of the traditional approach to territorial planning of the past years is associated with an underestimation of the essence and multifaceted social brownfields and their importance in the sustainable development of urban areas in post-industrial society. The prospects for the development of the inner space of the city and the quality of life of people largely depend on the presence of brownfields since most of the brownfields can have a negative impact on the environment. This is especially noticeable in large cities and agglomerations. In this paper, we analyze the spatial distribution of brownfields in the largest agglomeration of Russia, comparing their prospects for redevelopment with the analysis of 10 dominant criteria of local priority affecting the transformation of the urban area. The article discusses in detail the reasons for making decisions about the nature of the impact of brownfields and the priority tasks of their elimination: the environmental situation and the economic interests of stakeholders. The study shows that the practice of making decisions on the liquidation of brownfields largely depends on their inclusion in the state register of objects of accumulated environmental damage, which makes it possible to accumulate environmental damage in the near future. However, the entry of accumulated environmental damage into the state register of objects is (1) a practiced procedure because it implies co-financing of the brownfield liquidation project by the federal authorities and (2) an insufficiently objective procedure for assessing the impact (lack of local priority criteria). Based on the conducted research, we believe that the elimination or urbanization of brownfields should be based on the analysis of local priorities in the transformation of urban areas (different from the criteria of modern practice of introducing the state register of brownfields), including the features of the territorial organization of public space, ecological and geographical environment, and public opinion.

KEYWORDS: brownfields, transformation of urban space, internal reserves, pollution, adaptation, redevelopment, accumulated environmental damage, comfortable city

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INTRODUCTION

The territorial aspects of the emergence of brownfields in cities are due to the economic development of the past few years. In the industrial era, many industrial facilities and often residential buildings for workers of these enterprises were located in the historical center of cities. In the post-industrial era, as urbanization processes intensified due to global migration and other factors, the issue of brownfields became increasingly prominent, impacting both the development of inner urban space and the social adaptation of objects and territories back into economic circulation. The spatial distribution of brownfields often depends on the economic specifics of the region and national environmental and sectoral legislation, which causes differences in the types of brownfields and approaches to their elimination. For example, in China, the industrial type of brownfields was the most dominant compared to the mining type, while the eastern part of China was the most "vulnerable" to the abundance of brownfields compared to its western part (Zhang et al. 2022). In the European Union, the dominant part of brownfields is associated with degraded agricultural land and municipal and industrial buildings (Van Liedekerke et al. 2013). In Russia, in the post-Soviet period, so many ruined and abandoned facilities appeared, a number of political decisions were taken to eliminate brownfield "hot spots": especially large landfills, oil and sludge storage facilities (Dregulo and Khodachek 2022). Nevertheless, the modern practice of inventorying of objects with signs of accumulated environmental damage in Russia is not effective enough (Dregulo 2023). Firstly, because it is largely based on the criteria for the spread of Brownfield influence at a high spatial level: 1. The territory's area measured in hectares per square meter;; 2. The number of individuals residing in the territory negatively impacted by the presence of brownfields, expressed in thousands; 3. The number of individuals living in the territory at risk of negative impact due to the brownfields'

location, expressed in thousands. In our opinion, it is ineffective at the local (municipal level) because it does not take into account the local priorities of the development of the city (municipality). At the same time, the inventory procedure is highly bureaucratic and requires significant funding already at the initial stage. The purpose of the article is to develop practices for the inventory of objects of accumulated environmental damage based on correlation signs of the significance of their impact on the transformation of urban space, subsequent clustering (ranking) and project preparation of measures to eliminate them. The novelty of this study lies in the author's new approach to identifying brownfields of accumulated environmental damage – identifying key and socially significant brownfields (high redevelopment potential) and their factors of influence on the transformation of urban space based on local urban development priorities. The local priority of urban development is understood as factors influencing the decision to recognize an object as an object of accumulated environmental harm, based on primary indicators directly or indirectly indicating the object as a source of accumulated environmental harm.2.

MATERIALS AND METHODS OF RESEARCH

Problem statement

The study was conducted on the territory of the St. Petersburg agglomeration, one of the largest in Russia with high rates of urbanization processes (Korshunov 2023; Solodilov 2021). A special place in the development of the St. Petersburg agglomeration as the largest economic hub in the Baltic region is occupied by the "quality of life economy" (Okrepilov 2021). This concept includes the whole spectrum of urban problems that are solved through key areas: the development of the transport network (Sokolova and Starshov 2022), the regional fuel and energy complex (Bondar 2021), including issues of ensuring the health of senior citizens (Safarova and Safarova 2022) and the digital transformation of urban governance and development (Kuznetsov and Gorin 2022). All of these aspects of regional development are closely related to the territorial structure of urban interior space. This causes the problems that have become increasingly obvious with the appearance of brownfields on the territory of the city and its periphery due to past economic (economic) activity. Industrial enterprises play an important role in this. After the extensive privatization of the 1990s, it became obvious that industrial enterprises make the greatest contribution to the negative development of environmental processes that change a favorable urban environment into an unfavorable one. Nevertheless, the studies conducted (Zamyatina et al. 2021) have shown that the enterprise management strives to implement the Sustainable Development Goals and intends to work with city authorities for this, which is likely to be a favorable basis for adapting the inner urban space burdened with industrial and other brownfields.

Understanding Distinction Designations

In the national Russian legislation, the term "objects of accumulated environmental damage" (AED) is used, which does not have the same meaning as Brownfield (B) the term is accepted in Western countries, but still has a fairly close similarity:

- "A brownfield is a property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant" (Overview of EPA's Brownfields Program);
- "AED – territories and water areas where accumulated environmental damage has been identified, capital construction facilities and waste disposal facilities that are a source of accumulated environmental damage" (Federal Law "On Environmental Protection").

In the further text, we will use the abbreviation B/AED to designate these objects while implying all aspects inherent in both one term and the second.

Design research

Data collection and preparation for the study were carried out in several stages (Fig. 1). At the first stage, the spatial factors of the location of B/AED were determined (a map of the distribution of B/AED was compiled) in the inner and historical part of the city, the peripheral part of the city, and in remote territories included in the metropolitan agglomeration – defining projects in relation to the urban environment and transformational – referring projects to the category of transforming the urban environment, and the matrix B/AED is based on local significance criteria (determinants). Each object (B/AED) was assigned a designation number and a brief description of its location (Table 1).

Table 1. Designation and description of the B/AED location

Brownfield designation	Description
B1	MSW landfill (located in the northern part of Saint-Petersburg)
B2	Landfill of sewage sludge (located in the northern part of Saint-Petersburg)
B3	The territory of 'Tuchkov buyan' (the historical center of Saint-Petersburg)
B4	Territory 'Okhtinsky Cape' (St. Petersburg) (historical center of Saint-Petersburg)
B5	'Krasny Bor' landfill, Leningrad Region (Saint-Petersburg Agglomeration)
B6	MSW landfill Leningrad region, 'Sosnovy Bor' (Saint-Petersburg agglomeration)
B7	MSW landfill on the territory of the state nature reserve of regional significance 'Lake Shchuchye', Zelenogorsk (Saint-Petersburg agglomeration)
B8	Landfill of sewage sludge (located in the southern part of Saint-Petersburg)
B9	Open pits (St. Petersburg agglomeration)
B10	Landfill (in the North-western part of Saint-Petersburg)
B11	Hydro-ash dump (North-eastern part of Saint-Petersburg)

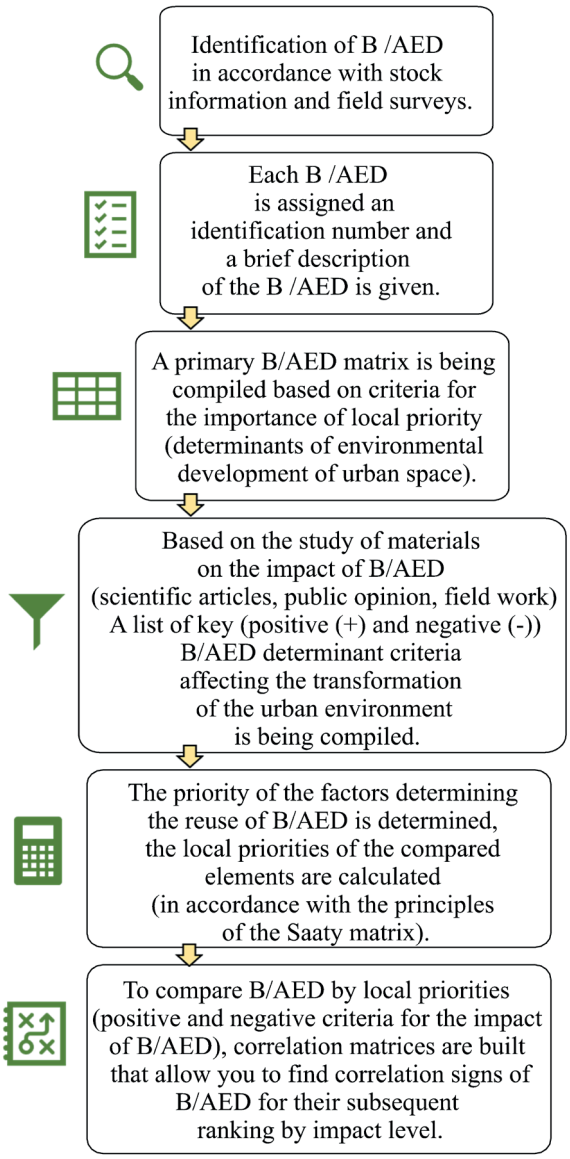

Fig. 1. A flowchart describing the methodology of the study

Table 2. Criteria B/AED impact on the urban environment transformation

Designation of criteria	The value of the criterion	Determinant criteria
C1	-	Has signs of accumulated environmental damage
C2	+	Included in the state register of Brownfields for subsequent liquidation/redevelopment
C3	-	Risks associated with soil pollution
C4	-	Risks associated with water pollution
C5	-	Risks associated with air pollution
C6	+	State property
C7	-	Private property
C8	+	Redevelopment | New (intended) use
C9	+	Public response
C10	+	Measures to eliminate / minimize harm

Among the positive criteria determining the possibilities of economic use of B/AED as a positive factor (+) of influence on the transformation of the urban environment, we included: C2, C6, C8, C9, and C10. Thus, the following criteria were attributed to the negative factors (-) B/AED: C1, C3, C4, C5, and C7. A description of all the criteria is given below.

• Criterion 1. Has signs of accumulated environmental damage. An object localized within the boundaries of a city or its periphery (B/AED). Only redevelopment projects

in certain urban areas, that is, projects related to the occurrence of potential environmental harm/damage, fall under consideration. Projects affecting the territories of the gray belt were not considered.

• Criterion 2. Included in the State register of objects of accumulated environmental damage. Inclusion in the register implies (1) recognition of B/AED as an object dangerous to the natural environment and humans; and (2) guarantees its liquidation.

• Criterion 3. Risks associated with soil pollution. The greatest contribution to this process is made by such types of B/AED as degraded industrial and agricultural enterprises, and MSW landfills. Heavy metals (arsenic, cadmium, zinc, copper, lead, chromium, mercury) get into the soil. Excessive content of these elements leads to diseases in humans, animals, and plants. In addition, soil contaminated with organic substances contributes to the development of rodents that are sources and carriers of pathogens for particularly dangerous infections (rabies, tularemia, plague and hemorrhagic fever with renal-pulmonary syndrome).

• Criterion 4. Risks associated with water pollution. Often, B/AEDs are located in the peripheral part of the city near water sources (rivers, lakes, streams). The increasing climatic risks associated with an increase in the average annual precipitation may provoke the entry of pollutants from surface runoff into reservoirs.

• Criterion 5. Risks associated with air pollution. This aspect is very important for B/AEDs where waste is accumulated or buried. Over a long period of time, the surface solid layers of waste form an isolated (anoxic) structure. The waterlogging of waste contributes to their rapid decay, which in turn is accompanied by the formation and emission of hydrogen sulfide, carbon dioxide, methane, and other greenhouse gases.

• Criteria 6,7. Affiliation. This criterion considers the affiliation of B/AED. This aspect is quite important to consider in light of the fact that, according to many B/AEDs in the post-Soviet space, after privatization, they became conditionally ownerless. The environmental damage caused by the brownfields as a result of the past years' economic activities became an encumbrance for the new owner. And as practice has shown, many were in no hurry to eliminate this environmental damage, as a result of which a new name appeared in the national legislation – "objects of accumulated environmental damage".

• Criterion 8. Redevelopment (changes in the functional purpose of a spatial object in the process of redevelopment). One possible solution is to change the project's concept during implementation. The most significant examples of environmental transformation projects are those that, due to circumstances, do not find a final result for a long time, even in the case of intervention by higher authorities. Such projects are able to form an assessment of the quality of urban environment management (adaptation or transfer of the project to a new location), arising in the process of conflict communication among various actors.

• Criterion 9. Public response. The public response in public discourse, mass media, and Internet media was considered. Increased attention to the problems of environmental safety and the quality of life of the population living in the vicinity or in the zone of impact of B/AED is associated with an increase in the number of publications in social networks, regional media, in which discussions are held related to the possible implementation of B/AED redevelopment projects.

• Criterion 10. Measures to eliminate / minimize damage or harm. This criterion considers that at the time of the study, measures were carried out (in whole or in part) at the B/AED facilities to reduce the negative impact on the environment (reclamation).

Data processing and formalization

In order to determine the priority of the determinants of the reuse of B/AED, an author's summary matrix of B/AED objects was compiled to assess the impact on the transformation of the urban environment, and a summary review was compiled in two areas – positive and negative determinants by the method (Šimková et al. 2020). For each matrix, the local priorities of the compared elements were calculated (assuming a generally acceptable condition). The values of the weights were quantified in terms of the principles of the Saaty matrix (Saaty 1987) with dimensions where m = 1...*i* and n = 1...*j*, given by the number of rows and columns subject to the condition m = n. This symmetric matrix also corresponds to the fact that the method is based on an interactive comparison of all predefined determinants of the same rank with an estimate (Table 3).

Values equal to 1 were taken on the diagonal of the matrix on the principle of comparing the same determinant, that is, their equivalence, and identified pairwise comparisons of individual factors. If the determinant was preferable to the determinant in the column, it was assigned the opposite value. Estimates of a single determinant were determined by the values of factors – partial positions – in accordance with as products of the values of all determinants. To each row of the matrix, and, consequently, to the corresponding element, we

Table 3. Evaluation of negative and positive criteria-determinants in the Saati matrix

The value of the determinant criterion	Description of the compared values of the criteria-determinants
1	Equal importance of the compared elements of the hierarchy. Both the compared elements *i* and *j* have the same significance for a higher-level element
3	Moderate superiority of the *i* element of the hierarchy over O. Previous experience and evaluation suggest that one element is slightly more important than the other.
5	Substantial or strong superiority of the *i* element. Previous experience and evaluation indicate a higher significance of one element compared to another.
7	Significant superiority of the *I* element.
9	The very high importance of the element has clearly manifested itself in the past.
2,4,6,8	A very significant superiority of the *I* element. We are talking about the maximum possible difference between the two elements.

associate the geometric mean of its elements. The values of the factors of partial positions were determined by the Eq. (1):

$$S_i = \sum C_i \quad (1)$$

In addition, the values for each criterion *i* (a finite number of criteria-determinants *c*, where *c*=5) were quantified by the Eq. (2):

$$R_i = (S_i)^{\frac{1}{c}} \quad (2)$$

Based on the calculations performed, the amount was determined by which the final value of the individual weights (local priority) of the criteria-determinants was calculated according to the Eq. (3):

$$a_i = \frac{R_i}{\sum R_i} \quad (3)$$

As a result, we obtained local priorities of the corresponding compared numerical values of weight (local priority of the determinant criterion) reflecting the interaction of various criteria for the influence of B/AED on the transformation of the urban environment and their priority in the process of restoring internal urban reserves. To compare B/AED, correlation matrices were constructed based on the binomial distribution (positive and negative criteria for the influence of B/AED), which allow us to find correlation signs of significance characteristics for their subsequent clustering (ranking) and project preparation of measures to eliminate them. Statistical data processing (construction of correlation matrices based on the Pearson correlation coefficient, which measures the linear relationship between variables of positive and negative criteria for the influence of B/AED on the transformation of the urban environment) was carried out using Seaborn libraries: statistical data visualization[1].

RESULTS

The results of the spatial inventory of B/AED have shown that currently eleven B/AED with different types of economic specifics can be distinguished on the territory of the St. Petersburg agglomeration. The main part of the B/AED is located on the peripheral part of the borders of St. Petersburg and its agglomeration (Fig. 2).

To systematize the criteria-determinants identified, a summary matrix B/AED was compiled that characterizes the potential impact on the transformation of the urban environment (Table 4).

The two brownfields B3 and B4 were among the most discussed objects to be renovated, causing widespread discussion in the community. We pay special attention to them because the public opinion and public response that they received allowed them to subsequently adopt a public point of view on the new functional purpose of these B/AEDs. Objects B3 and B4 are located in the historical part of St. Petersburg (objects B3 and B4). The territory on which object B3 was located was an archipelago of small islands, on one of which a marina was built in the first half of the 15th century.

In the 19th century, a nursery of ornamental plants appeared here, followed by wine warehouses and a vodka factory. The channels between the islands gradually filled up. In the first half of the 20th century, architects repeatedly presented concepts for the development of this place: from the construction of a museum complex to the construction of a city park. At the turn of the 1950s and 1960s, buildings of the State Institute of Applied Chemistry were built here.

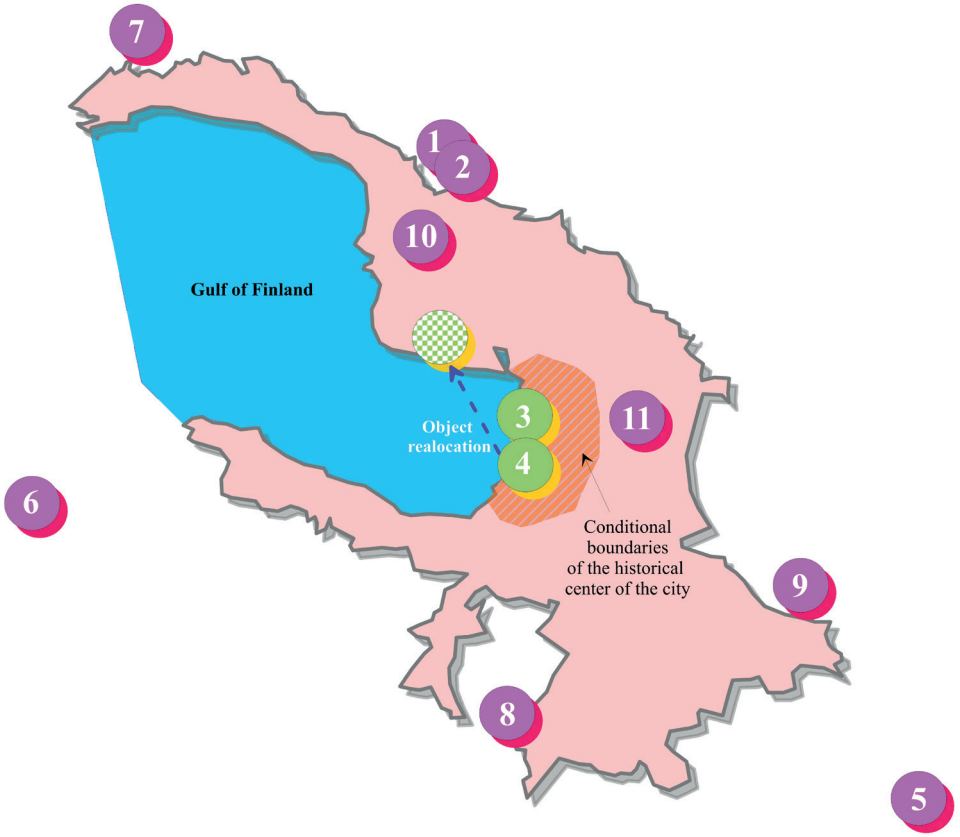

Fig. 2. Location of B/AED in the Saint-Petersburg agglomeration

[1] https://seaborn.pydata.org/

Table 4. Summary matrix of the B/AED impact on the transformation of the urban environment

Object designation	Has the signs of AED	Included in the state register of objects AED	Risks associated with soil contamination	Risks associated with water pollution	Risks associated with air pollution	Affiliation	Redevelopment H-high potential/ L-low potential
B1	yes	no					L (conservation/ reclamation backfilling with soil)
B2	yes	no					L (conservation/ reclamation backfilling with soil
B3							H
B4							H
B5	yes						L (conservation)
B6	yes						L (reclamation)
B7	yes						H
B8	yes	no					L
B9	yes	no					L
B10	yes						H
B11	yes						H
	Pollution risks (which were observed before the redevelopment or are currently being observed)						
	Public response						
	Measures to eliminate / minimize harm						
	State property						
	Private property						
	New (intended) use						
	There is no information / or there is no negative impact						

The rune buildings of the Institute (a redevelopment project involving a new function of urban public space. During the dismantling of buildings, a significant portion of the chemicals that were not removed (or stored for a long time on the institute's territory) contaminated the soil. Significant excavation was required to eliminate environmental damage and achieve environmental safety in public spaces. A full-scale development of cultural and leisure buildings, as well as a park area, is currently being carried out on the facility's territory.

Object B4 is in development after paleogeographic discoveries. During excavations carried out in 1993, artifacts of human habitation from the Bronze Age, the Early Iron Age, and the Neolithic era were found, dating from the end of the fifth millennium BC. This object was of great geographical importance for the defense and development of the northwest. At various times, 'The Landskrona' fortress was located here, built in 1300, and in 1611 the bastions of 'The Nienschanz' fortress were erected. Subsequently, the shipbuilding plants of the 'Okhtinsky Cape' were organized here. In the twentieth century, shipbuilding enterprises were repurposed for the production of technological equipment, and in the post-perestroika (difficult economic time for the country), the territories were planned to be sold for development for business or residential construction purposes.

In 2019, 'Gazprom Neft' acquired this site (1) and developed a new architectural concept for its development. Initially, the plan was to build the Gazprom Tower on this site (2); however, a long public outcry with the participation of many prominent figures of science and culture changed the new building project (3), leading the Gazprom Tower project on the shore of the Gulf of Finland in the northwestern part of Saint-Petersburg.

The situation is more complicated with other objects. Firstly, a significant part of B/AED has high risks

of contamination with environmental components. The vast majority of B/AEDs are located in the Gulf of Finland's catchment area. In particular, these include landfills of solid municipal waste and sewage sludge, which were put into operation in the 1970s and 1980s . Since then, the city's borders have expanded significantly, including as a result of urbanization (construction of residential buildings and the opening of industrial enterprises, including foreign capital). At the same time, a significant part of the B/AED is not included in the state register, while all of them have signs of environmental harm (effects on soil, water bodies and atmospheric air).

It is important to note that only 4 of the submitted objects (B5, B6, B7, B10) are included in the state register of objects of accumulated environmental damage. Half of the studied objects have low redevelopment potential, both in terms of the implementation of engineering and technical measures and in terms of the lack of interested parties. For such facilities, the most likely design solution would be their conservation. At the same time, it should be noted that for some of them there was a public outcry due to the various negative environmental impacts felt by citizens (pollution of soils, water bodies, or atmospheric air) (B1, B2, B5, B6, B8, B9, and B10) (with the exception of objects B3 and B4, the public outcry was caused by location, architecture, including building height restrictions in the historical center). Using the comparative characteristics of brownfields according to the above criteria based on the binomial distribution (yes = 1/no = 0) (Table 5).

• Objects B3 and B4 were intentionally removed from the list after the redevelopment. Based on the comparative characteristics of the binomial distribution, a correlation matrix was formed (Fig. 3), which allows us to identify the most similar objects (B/AED).

The similarity of B/AED can be divided into 3 potential groups: (1) high similarity, a correlation value of 0.8 and more; (2) average similarity, a correlation value of 0.79 to 0.6, and (3) slight similarity, a correlation value less than 0.6. According to the obtained correlation values, in (1) group objects B1-B2, B5; B2-B8; B6-B10; B9-B7, B8. A characteristic feature that unites these objects is waste management activities (burial, warehousing, processing):

• Objects B1, B2. The facilities are located near the nearest "neighbor" of the sewage sludge landfill 'Severny' was commissioned in 1986. The total area of B1, and B2 is more than 150 hectares. In the draft general plan of St. Petersburg approved in 2005, in the period up to 2010, the municipal

Table 5. Comparative characteristics of B/AED according to local criteria based on binomial distribution

Designation of local priority	B1	B2	B5	B6	B7	B8	B9	B10	B11
C1	1	1	1	1	1	1	1	1	1
C2	0	0	1	1	1	0	0	1	1
C3	1	1	1	1	1	1	1	1	1
C4	1	1	1	0	1	1	1	0	1
C5	0	0	0	0	1	0	1	0	0
C6	1	1	1	1	1	1	1	1	1
C7	0	0	0	0	0	0	0	0	0
C8	0	0	0	0	0	0	0	0	1
C9	1	1	1	1	0	0	0	0	0
C10	1	0	1	0	0	0	0	0	0

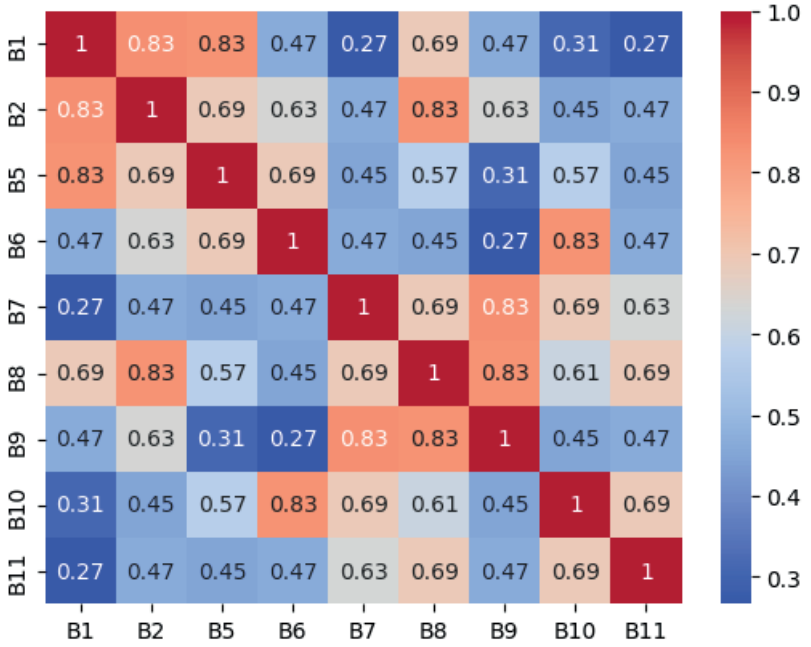

Fig. 3. Correlation matrix of positive and negative criteria-determinants of B/AED based on binomial distribution

authorities had to carry out the reclamation of landfills. However, to date, Facility B1 has been managed, Facility B2 is currently in operation, and there are clear signs of accumulated environmental damage (Dregulo et al. 2022; Dregulo and Bobylev 2021, 2021a). Over the years, there have been a significant number of complaints from the public about the smell of landfills. However, the "neighborhood" of these objects was often used by the management of the objects in blaming each other. Considering the high anthropogenic load in this part of the city, the city authorities have provided for the organization of a specially protected natural area. 'Levashovsky forest', which should be implemented by 2025. The question of how, when, and by whom the procedure for the rehabilitation/ reclamation of landfills is envisaged and what status these territories will have remains open. To date, changes in the law "On the General Plan of St. Petersburg" are "migrating" from one version of the law to another, but there is still no comprehensive solution to the problem.

• Object B5. The 'Krasny Bor' landfill, where waste of the 1st hazard class was buried. The territory of the landfill is subject to reclamation in order to completely eliminate the negative impact on the environment. During the period of operation, the waste in the depths of the landfill mixed and not only did not reduce their danger, but it also turned into a set of decomposition products and the transformation of the original highly toxic substances. This mass of toxicants is located in open maps (partially overgrown with grass and shrubs (1)), not protected from atmospheric precipitation. During the rainy and floody periods, there is intense flooding of waste, which causes the maps to overflow. To date, part of the work has been carried out to cover several maps (2). The general unfavorable situation is further aggravated by the fact that the existing storm water treatment facilities are not operating normally. Currently, the facility has been mothballed and included in the state register of objects of accumulated environmental damage for subsequent reclamation.

• Object B6. Landfill of municipal solid waste. It has been in operation for about 40 years. The work included land restoration; the surface of the landfill was covered with a special insulating membrane; a protective mineral layer and a layer of vegetable soil were laid, followed by the sowing of perennial grasses. The reclamation area spanse 9 hectares. To date, the landfill has been reclaimed.

• Object B7. The dump was formed in the 1960s. The landfill in the reserve appeared on the site of a former sand quarry. In the early 1980s, it was closed and covered with soil. Now the dump is overgrown with bushes and grass. In 2011, the state nature reserve of regional significance 'Lake Shchuchye' was established, the boundaries of which included the territory where the landfill of the former landfill is located. 'Druzhinnoye Lake' is located near the landfill. Twenty years later, the territory was closed, covered with soil, and used an area of 1.2 hectares for snow removal after cleaning the territories in winter. The composition of the landfill is soil, sand screenings, and construction waste. At the same time, the landfill masses contain polyethylene, plastic, cardboard, and textiles, as is stated in the draft. The total volume of waste disposed of is more than 80 thousand m3. The facility is planned to be reclaimed within several years.

• Object B8. A sewage sludge landfill located in the southern (peripheral) part of the St. Petersburg agglomeration. This facility has been operating since the 1980s and is practically identical to the B2 facility in terms of technology. Unfrozen sewage sludge from the southern aeration station was exported to the landfill. Since the late 2000s, raw (unfrozen) sewage sludge has not been exported to landfills, but ash (1) from the combustion of sewage sludge has been disposed of. Prolonged accumulation of sediment flooding at landfill sites (2) provoked the entry of pollutants into the surface layers of soil and groundwater. The facility is an operating landfill and is not included in the register of state facilities for accumulated environmental damage.

• Object B9. A complex of small sand mining facilities located in the border zone of the southeastern part of St. Petersburg in the catchment area of the Neva River. In the 1980s and 1990s, the practice was widely used after the extraction of minerals, solid municipal waste was buried in the "bowl" of the dump. According to data (Kulibaba et al. 2016), about 200 such objects have been identified in the Neva River catchment area, many of which are flooded, which poses a threat of pollution entering groundwater and surface waters. At the reclamation sites, foci of soil pollution and highly toxic drainage runoff (heavy metals, ammonia, nitrites, nitrates, petroleum products and other organic pollutants) arise from dumps similar to the filtrate from MSW landfills flowing through the local hydrographic network into the Neva River. The objects are not included in the state register of objects with accumulated environmental damage.

• Object B10. A large, closed landfill with a height of up to 30 m, located in the northwestern part of St. Petersburg, has a total area of more than 20 hectares. The landfill operated from 1933 to 1977. Even after the closure, construction, household, and industrial waste was taken to the landfill. In 1993, the landfill was localized, and the garbage was collected in a separate landfill that was sheltered and mothballed in the early 2000s. Since 2008, it was planned to reclaim the landfill and build a business complex on the vacated territory, but the project was not implemented due to detected chemical (radiation) contamination. The developer refused to implement the project due to the impossibility of completely eliminating pollution and, as a result, a lack of liquidity for future housing commissioning in this area. In 2010, the Government of St. Petersburg discussed the possibility of selling the land at auction for construction, but it was never implemented. In accordance with the general plan of Saint-Petersburg, this landfill belongs to the zone of recreational facilities, with the inclusion of engineering infrastructure facilities related to the maintenance of the zone. Since 2021, the facility has been included in the state register of objects with accumulated environmental damage. It is assumed that the liquidation will be carried out in two stages: (1) the accumulated waste will be taken to the existing landfill; (2) and after that, reclamation works will be carried out at the landfill site (restoration of a fertile soil layer, planting of grass, trees and shrubs).

• Object B11. The decommissioned hydro-ash dump B11 is located in the southeastern part of St. Petersburg, with a total area of 28 hectares. In the 1930s of the last century, ash from locomotive furnaces at the nearest railway stations was brought to this territory. As a result, the hydro-ash dump received ash from several thermal power plants in the city. In 1977, the facility was decommissioned. After the closure of the hydro-ash dump, its territory was used as a snow dump. Since the decommissioning of the ash dump, a layer of turf has formed on its surface (1), trees and shrubs have grown (2), and a reservoir has formed in the southeastern part (3). According to materials published on the official websites of the city authorities and local media, object B11 has been included in the state register of objects of accumulated environmental damage since

2021. However, in the materials of the official list of objects of accumulated environmental damage, object B11 was not found (is not listed) in the register.

Another dominant factor for all these objects is the presence of signs of accumulated environmental damage/harm. They are all included in the pool of state-owned objects; there was a public outcry for almost every one of them, but not all of them are included in the state register of objects of accumulated environmental harm. For some facilities, measures have been taken to minimize environmental harm, but it is not possible to completely eliminate environmental harm. This determines the need to consider in more detail the influence of positive and negative criteria and their significance and usefulness (hierarchical significance) in solving urban development problems. Among the negative factors, the most significant was the factor of influence on atmospheric air (C5 = 0.227) (Table 6).

The significance of C3 and C4 turned out to be slightly less; the value of local priority 0.223 and 0.204, respectively. However, these criteria are highly variable, as their value heavily depends on the specifics of the economic activity of the object B/AED. This is true only for the proposed list of objects considered B/AED, and it may not be the same for other objects in a different city. This is evidenced by the low indicator of the local priority of criterion C1 (the object has signs of accumulated environmental damage). The criterion (C7) of the ownership of B/AED that is not in state ownership has a low local priority of determination. In the case when the object is of particular interest to stakeholders (investors-developers), the process of its renovation causes more confidence that this object will acquire a new function in the urban space because the expected result for them will be the benefit received after the introduction of the object into economic turnover (sale, leasing, etc.). Regarding the value of positive criteria, we see that the inclusion of B/AED in the state register is the most important determinant criterion (C2 = 0.22) affecting the further transformation of urban space (Table 7).

This is understandable due to the fact that inclusion in the register guarantees subsidies to the federal government for measures to eliminate accumulated environmental damage, which, in fact, is confirmed by their equal value with the criterion C10 = 0.22. At the same time, we note that objects B3 and B4 have never been included in the state register of objects with accumulated environmental damage. Nevertheless, their importance in the formation of urban space was of particular importance for the city, primarily in terms of their historical and location aspects. As a result, the decision to redevelop these facilities was made based on other criteria than those mentioned above, particularly political and social factors. Criterion C8 had an average value of local priority among the list of positive determinants. The local priority of public resonance (C9) and the affiliation of B/AED under state jurisdiction (C6) had the lowest indicators of 0.19 and 0.17, respectively. The correlation between criteria (determinants) influencing the transformation of urban space (Fig. 4) shows that there is a strong correlation between such factors as the sign of accumulated environmental damage (C1) and the risks of environmental impact (C3, C4, and C5) which are equal to 0.81, 0.72, 0.59, respectively. And therefore, the environmental factor is a top priority.

The value of the C5 criterion of influence on atmospheric air is still more correlated with the C4 criterion (0.96), compared with C3 (0.86). The higher local priority of the C5 factor is probably due to the public resonance of the past years, when uncontrolled emissions of landfill gases reached residential areas, which caused a high number of complaints from the population to regional authorities, including on social networks. This mainly concerns peripherally located B/AEDs. This indicates that when making decisions about the nature of the impact of B/AED, and the priorities for their elimination are more determined by the environmental situation and the economic interests of stakeholders. Criterion C7 showed a negative correlation with the "ecological" criteria C7 – C5, C4, at the same time C7 – C3 weak correlation, C7 – C1 average correlation.

Table 6. Quantitative assessment of negative criteria (determinants) of the impact of B/AED on the transformation of urban space

Criteria	C1	C3	C4	C5	C7	S_i	R_i	a_i	Weight coefficients (%)
C1	1	1/5	1/5	1/3	1/3	2.06	1.156	0.149	14.9
C3	5	1	1/2	1/2	9	16.0	1.74	0.223	22.3
C4	5	2	1	2	1/4	10.2	1.59	0.204	20.4
C5	5	2	1/2	1	9	17.5	1.77	0.227	22.7
C7	3	1/9	4	1/9	1	8.22	1.52	0.195	19.5
Total	19	4.51	4.64	4.78	19.58	53.98	7.776	1	100

Table 7. Hierarchical significance of positive criteria-determinants of B/AED influencing the transformation of urban environment

Criteria	C2	C6	C8	C9	C10	S_i	R_i	a_i	Weight coefficients (%)
C2	1	7	9	5	1/3	22.33	1.86	0.22	22.0
C6	1/7	1	5	1/9	1/9	6,362	1.45	0.17	17.0
C8	1/9	1/5	1	5	7	13.31	1.68	0.2	20.0
C9	1/5	9	1/5	1	1/9	10.51	1.6	0.19	19.0
C10	3	9	1/7	9	1	22,14	1,86	0.22	22.0
Total	4.45	26.20	15.34	20.11	8.55	139.48	8.45	1	100

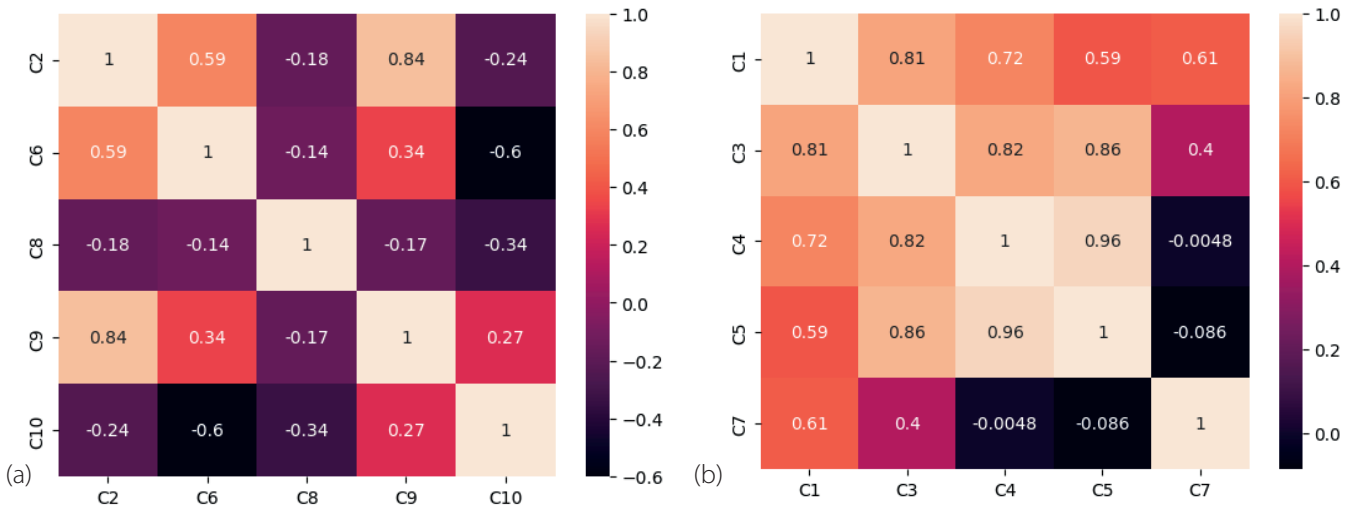

Fig. 4. The ratio of positive and negative criteria-determinants of B/AED influencing urban environment transformation

DISCUSSION

In this study, we have addressed the important problem of considering local priorities in urban space development. B/AED – how historical imprints of past economic activity and the gradual development of territories associated with cleaning processes become protracted problems affecting the transformation of urban space. Decision-making tools for the B/AED inventory are ineffective and require expanding the list of local priorities for sustainable development and public control (expression of opinion, discussion, etc.) to make decisions in shaping a new look of urban space after the elimination of B/AED. For example, in India, the problem of eliminating B/AEDs has not yet been fully understood in terms of what they are essentially B/AEDs, and which are identified by the criterion of "state of the earth" (Verma and Banerji 2023). For many countries, the problem of B/AED renovation turns out to be not a financial but a mental component of the market (Trouw et al. 2020). Developers often do not want to risk being "pioneer enthusiasts", although this factor is probably the driving force (example) for other developers. It is important to understand not only the benefits for the authorities but also the commercial benefits that will be possible if B/AEDs become socially (socially) attractive objects after renovation / elimination of environmental harm. Thus, studies (Vojvodíková et al. 2021) show that the most important criterion for the restoration of B/AED territories is their departmental affiliation. The participation of public investments may not always be enough for the redevelopment of B/AED. In fact, we have seen from this study that the criteria for the ownership of an object (private / state property) have a low weight of local priority in making decisions on their liquidation. Nevertheless, we know that the B/AED redevelopment projects that have been implemented in a number of the most developed countries in the world, including China, the USA, Canada, Germany, and England (Lin et al. 2019) are quite successful, but at the same time, they differ in key aspects and may often not be economically feasible for other countries. This means that there is no single approach to solving the problem. The ranking of B/AED into categories does not always coincide for different authors, depending on the central focus: "fast or slow renovation", "technical or environmental aspects", "urban or agricultural", "public or private", etc. (Ray et al. 2021). The elimination of B/AED, and therefore, there is a need for research on a combination of best practices based on considering the interests of all groups of the population (government-business-citizens). We also pay particular attention to the fact that public response is one of the most important factors to consider. Our research on B/AED assessments and rankings based on local priorities helps identify the most important aspects of priority actions for spatial needs. At the same time, we note that this approach will have an optimal effect only in synthesis with other practices, which determines further research in this direction (comparative, predictive, etc.).

CONCLUSION

In this study, the author proposed a new approach to B/AED inventory based on the identification and comparison of local priorities (criteria-determinants) of urban space transformation under the influence of B/AED for environmentally balanced urban development. The pilot implementation of this approach allowed us to formulate some final theses:

• The practice of inventory and inclusion of potential B/AED objects in the state register of objects of accumulated environmental damage (hereinafter the register) for subsequent liquidation is ineffective at the municipal level in terms of further development of urban space. Of the eleven objects with B/AED signs, only 4 are included in the register. Probably, this is largely due to the political will of the state authorities (landfills on the territory of specially protected natural areas, for example), the economic interests of large investors (the territory of 'Tuchkov Buyan' and 'Okhtinsky Cape'), or the lack of necessary resources ('Krasny Bor' landfill, etc.). Most of the discovered B/AED have low redevelopment potential (landfills, landfills waste), and therefore, it is not possible to attract stakeholders for the further development of these territories;

• The proposed criteria of local priority allowed us to identify the dominant factors (their weight values) influencing the transformation of St. Petersburg's the urban space. Of the five negative criteria for local priority:
1. Impact on the atmosphere (22.7%); >
2. Risks associated with soil pollution (22.3%); >
3. Risks associated with water pollution (20.4%); >
4. Ownership of the facility (private property) (19.5%); >
5. The facility has signs of accumulated environmental damage (14.9%). Positive criteria: there were two criteria in the first place. 1 The object is included in the state register (22%) = 1. Measures have been taken at the facility to eliminate/minimize damage (22%) ;> 2. Possibility of redevelopment (20%); > 3. Public response (19%); > 4. Ownership of the object (private/public) (17%). The weight values of local priorities show that the most

important positive factor (the local priority of the territory's development) is the fact that the object is included in the B/AED register. This is obvious because funds from the federal budget will be allocated for its liquidation. The effect on the atmosphere was the most significant negative priority. This negative impact factor is most easily detected and causes a public outcry, therefore increasing attention to the problem of eliminating B/AED;

• It is advisable to make predictive estimates of the impact of B/AED by identifying similarities of B/AED. The study shows that even with a characteristic feature combining these objects (waste management activities), local priorities have different "weights": (1) high similarity, correlation value from 0.8 and more, (2) average similarity, correlation value from 0.79 to 0.6, and (3) slight similarity, correlation value correlations are less than 0.6. And therefore, approaches to the elimination of objects of the same type of B/AED should not be universal;

• Subjectivization of the perception of local priorities and forecast estimates in the transformation of urban space (which are taken into consideration for the B/AED inventory) is one of the key factors in making decisions to eliminate them, and therefore, for the selection of local priorities, territorial development plans should be guided, starting from the municipal level, considering public opinion (including in the preparation of an inventory plan B/AED public hearings). Despite the fact that the criterion of public resonance is not dominant, it cannot be ignored (the history of public resonance in St. Petersburg with the objects 'Tuchkov Buyan', 'Okhtinsky Cape' clearly testifies to its effectiveness, including for redevelopment purposes).

Thus, the study shows that the proposed approach can be successfully used for the inventory of objects and their subsequent liquidation in order to effectively search for factors of spatial development in inner urban areas (on a local level). Nevertheless, the author notes that the effectiveness of this approach can be significantly higher if it is used in conjunction with current practices, but this requires further research in this direction (comparative, predictive, etc.).

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