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ІНФОРМАЦІЙНІ ТЕХНОЛОГІЇ. АВТОМАТИЗАЦІЯ

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H. Olekh[1],
K. Kolesnikova[2]**,** DSc, Prof**.,**
I. Prokopovych[1]**,** DSc, Assoc. Prof.,
O. Kozlov[1]
[1] Odessa National Polytechnic University, 1 Shevchenko ave., Odessa, Ukraine, 65044 e-mail: i.v.prokopovich@opu.ua
[2] Taras Shevchenko National University of Kyiv, 64/13, Volodymyrska street, city of Kyiv, Ukraine, 01601; e-mail: amberk4@gmail.com

METHODOLOGICAL ASPECTS OF THE "ENVIRONMENTAL IMPACT ASSESSMENT" CHAPTER MAKING PART OF THE PROJECTS FEASIBILITY STUDY

Г.С. Олех, К.В. Колеснікова, І.В. Прокопович, О.І. Козлов. **Методологічні аспекти розділу «оцінка впливу на навколишнє середовище» в складі техніко-економічного обгрунтування проектів**. У даній статті зроблена спроба гармонізувати підходи до розробки методичних аспектів розділу «Оцінка впливу на навколишнє середовище» у складі в складі техніко-економічного обгрунтування проектів. Розділ «Оцінка впливу на навколишнє середовище» є необхідним компонентом повної екологічної оцінки. Запропоновано підхід до виявлення екологічних проблем на ранніх стадіях розгляду проектів для включення в проекти заходів,спрямованих на поліпшення якості навколишнього середовища та запобігання, зменшення та компенсацію екологічної шкоди. Методологічні аспекти оцінки впливу на навколишнє середовище, які представлені у статті, базуються на побудові матриці Леопольда та створінні імітаційних моделей впливу. Первинний, найбільш загальний підхід до оцінки впливу на навколишнє середовище реалізується при складанні матриці Леопольда, яка характеризує якісні зв'язки в системі «причина-наслідок». У описуваної імітаційної моделі використані два класи моделей індикаторів «якість навколишнього середовища – вплив» і «лімітуючий екологічний фактор» (метод バтелле). Розробка розділу «Оцінка впливу на навколишнє середовище» в складі проектів розглядається як єдиний процес послідовної деталізації та уточнення кількісної та якісної оцінки впливу проектного рішення на якість навколишнього середовища. Для виявлення та прийняття необхідних і достатніх заходів щодо попередження можливих неприйнятних наслідків у процесі аналізу та оцінки впливу на навколишнє середовище розглянуті:цілі передбачуваного проекту; розумні альтернативи запланованій діяльності; відомості про стан навколишнього середовища на території передбачуваної реалізації проектної діяльності у відповідних просторових і часових рамках; характеристика проектних та інших пропозицій в контексті існуючої екологічної ситуації на конкретній території з урахуванням раніше прийнятих рішень про її соціально-економічному розвитку; можливі наслідки реалізації запланованій діяльності та її альтернатив; заходи щодо запобігання неприйнятних для суспільства наслідків здійснення прийнятих рішень; пропозиції щодо розробки програми моніторингу реалізації підготовлюваних рішень і плану після проектного екологічного аналізу.

Ключові слова: оцінка впливу на навколишнє середовище, матриця Леопольда, імітаційні моделі впливу, кількісна та якісна оцінка, цілі проекту

G. Olech, K. Kolesnikova, I. Prokopovych, O. Kozlov. **Methodological aspects of the "environmental impact assessment" chapter making part of the project feasibility study.** This article exposes an essay on harmonizing approaches to the development of methodological aspects used at "Environmental impact assessment" chapter integral to the projects feasibility study. The "Environmental impact assessment" chapter embodies a necessary component of the project overall environmental assessment. The suggested approach to identifying environmental problems at the project review early stages allows including to projects the measures aimed at improving the environment quality as well as at the environmental damage prevention, reduction and setting-off such impact. Methodological aspects of environmental impact assessment, presented in the article, depart from constructing the Leopold matrix with the creation of impact simulation models. The primary and most general approach to environmental impact assessment is implemented through building the Leopold matrix, which characterizes the qualitative relationships in the "cause-effect" system. In the described simulation model, two classes of indicator models are used: these of "environmental quality – influence" and "limiting environmental factor" (Battelle method). WHile project elaboration, the development of "Environmental impact assessment" chapter is considered as a single process of consistent detailing

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and refinement of quantitative and qualitative assessment as to the project decision impact on the environment quality. To identify and take necessary and sufficient measures on the potential unacceptable effects preventing in the process of environmental impact analysis and assessment considered shall be: the proposed project purpose ; reasonable alternatives to the planned activities; information about the environment condition in the proposed project activities' region with reference to the appropriate spatial and time frame; characteristics of project and other proposals in the context of current environmental situation on such specific territory, taking into account earlier taken decisions on its socio-economic development; the planned activities' possible implications and relevant activities' alternatives; measures to prevent unacceptable social consequences due to the project implementation; proposals on upcoming decisions' embodiement monitoring program elaboration and a plan for post-project environmental state analysis.

Keywords: environmental impact assessment, Leopold matrix, impact simulation models, quantitative and qualitative assessment, project goals

Introduction

The "Environmental impact assessment" (EIA) chapter is a necessary component of the thorough environmental assessment. The assessment of project activities impact on the natural environment is carried out using available materials and statistical data provided by the territorial Departments of the Ministry of Ecology and Natural Resources of Ukraine, as well as by various scientific and research institutions[1].

The projects' "EIA" chapter development should be considered as a single process of the consistent detailed elaboration and the refinement of the quantitative and qualitative assessment of project decision's impact on the environment quality [2].

This article formulates and suggests methodological aspects used when elaborating the "EIA" chapter, considering meanwhile the "EIA" structure, content and procedure in environmental projects implementation [3].

Recent publications analysis and problem statement

Assessment of the project's possible environmental impact is an important stage in the EIA process [4, 5]. Such assessment purpose is to identify environmental changes that may occur as a result of the planned activities and to assess these changes' significance [6, 7].

This assessment is based on the following [8 – 10]:

– project technical description;

– identification of environmental components falling under impact;

– experience gained from other projects.

The impact assessment is carried out by the natural environment's individual components.

Research purpose and objectives

This article purpose is to harmonize approaches to environmental impact assessment used in national and international practice [11, 12].

In order to identify and take necessary and sufficient measures for preventing the possible unacceptable consequences in the process of planned project activities' environmental impact analyzing and evaluating, the project developer provides validation with such documents [13 – 15]:

1) goals of respective plan or proposed project implementation;

2) reasonable alternatives to the proposed activities;

3) information about the environment condition on the planned activity intended implementation territory in the appropriate spatial and temporal framework;

4) project and other proposals characteristics in the context of the existing environmental situation in a particular territory, taking into account earlier decisions on its socio-economic development;

5) possible consequences of the planned activity implementation and its alternatives;

6) measures to prevent unacceptable social consequences from the implementation of decisions taken;

7) proposals on the development of a program for monitoring the elaborated decisions and plan implementation as a stage next to the project environmental analysis.

During the EIA chapter development as part of the feasibility study (FS) the following steps shall be carried out [13 – 15]:

– analysis of natural, climatic and technogenic conditions in the project construction area;

– comprehensive assessment of the existing and expected environment condition (based on the proposed methodology);

– developing and introducing to the project design solution a set of tools aimed at the natural landscape preserving, recultivating or transforming, protecting the population from industrial and transport-related environment contamination;

– controlling and managing changes in the existing environment expected to occur during the project implementation at the assessed design period end;

– preparing and submitting data on the habitat forecast quality in the planned project construction territory.

EIA main methodological aspects for projects feasibility study

When necessary, at the project agreeing and approval stage, carried out is the assessment of the project design adjustment results impact on the environment quality expected under design embodiement for the period of project construction and operation.

When justifying the object placement site, the initial data sources can include: materials from specially authorized state bodies in the field of environmental protection and their territorial divisions, published and reserved for publication materials from scientific organizations and departments, statistical reports and environmental monitoring data, engineering surveys and environmental data from analogical objects, calculations and forecast models [16 – 17].

As such data information source, one can use:

– cadastral maps of natural resources, maps and diagrams of the natural environment components structure (soil, geobotanical, animal world, etc.), maps of groundwater protection level, etc.;

– data bases on industrial production waste and consumption residues;

– in-situ natural complex arrangement layout;

– map of the project region engineering-geological zoning by areas of karst -suffusion processes activity;

– region hydrogeoecological zoning scheme;

– computer database on stationary sources of atmospheric air pollution;

– hydrological and water management materials;

– sanitary and hygienic information.

"EIA" chapter structure

The EIA chapter should include the report main text, graphic and text appendices.

Report text:

I. *"Introduction"*

The introduction covers the following issues: the project area geographic and administrative situation, characteristics of topographic base used, works purpose and the exact job tasks, profile and characteristics of the designed facility, planned and actually completed volumes of all work types represented in a table, project work scheduling, brief description of works methodology. At this chapter, end the design and survey works main contractors, report compiling authors, managers and consultants names shall be specified.

This chapter is accompanied with the project works area overview map.

II. *"Current state of the natural environment"*

In this chapter, one must display thoroughly:

– current state of all ecosystem components, including the aquatic environment characteristics, descriptions of flora and fauna, recreational and other specially protected areas (forested areas, architectural ensembles, historical monuments) and other environmental characteristics;

– the current socio-economic structure in the area where the facility shall be located;

– brief information about the project site location territory current and future use (in accordance with development programs and layouts);

– restrictions on the natural resources use ;

– information on existing sources which influence various components of local ecology system.

In this section, one must expose the final information about the state of local environment in sufficient detail allowing the assessment as to all the significant environmental impacts inherent in the proposed project. The existing environmental conditions should be described in terms of their main

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characteristics, compared with their reference values during the proposed project operation (provided that project implemented).

The role of each environmental element in the project area as well as the impact likelihood shall determine the scope and depth of the main study.

In some cases, collecting the necessary data may require a large-scale analysis and / or long-term monitoring programmes carrying out.

It is particularly worth noting once again that the environmental impact assessment is -an independent scientific and production process often implying a special research, which should be carried out by qualified specialists in this field. The decision on the principal possibility and feasibility of project facilities construction depends on the correct interpretation as to such data obtained.

It should be emphasized that there are different research methods. Necessary is to carefully choose the optimal and practically feasible method for each specific geo-ecological situation.

At the beginning of “Current state of the natural environment” section required is to briefly describe the functional structure, concerned territory technogenic load, terrain geomorphology and geological structure of the site area

Information about the area technogenic load includes a brief description of its population, the territory functional structure, its technogenic change degree, etc.

When describing the terrain, specified shall be its nature, the degree of irregularities, absolute marks, the errain main forms’ height over the river valleys, general nature of landforms variation on the given territory.

Geomorphological characteristics include a brief description of landforms, characteristics of their dependence on the rocks composition as well as geological and structural features of the area. River terraces are covered in more detail, including terraces number and types, their width, height, and surface character.

The geological structure description should indicate the distribution, lithological-facial composition, conditions and depth of occurrence (in meters from the surface and in absolute marks), as well as the thickness of each horizon, it fracturing, cavernous character.

Further this section must provide a detailed description of the environmental components that will be affected during the project facilities construction and operation.

Below given is a list of environmental characteristics that may be affected due to construction and operation of underground structures and in which respect necessary is to collect main data in the process of environmental impact assessment (Environment study):

1. Contamination of soils;
2. Presence of other adverse geological phenomena (soil expansion, soil subsidence);
3. Quicksands;
4. Radiometric situation of the territory;
5. Conditions and relationship between ground and surface water (by horizons);
6. Ground water level (by horizon);
7. Ground water regime (by horizon);
8. Aggressiveness of ground water (by horizon);
9. Chemical composition of ground water (by horizon);
10. Conditions for underground water protection (by horizon);
11. Air quality;
12. Temperature;
13. Erosion;
14. Activity of karst-suffosion processes;
15. Activity of slope processes;
16. Availability of green spaces;
17. Species under threat of extinction;
18. Land animal;
19. Species under threat of extinction;

20. Recreational value of the territory;

21. Availability of protected areas (parks and forest parks, architectural monuments, urban-planning complexes and ensembles);

22. Landscape aesthetics;

23. Social amenities;

24. Water salinization;

25. Soil salinization.

Let we consider environmental characteristics in more detail referring to the list of items listed above:

1. Underground surface water

When describing underground waters, first of all a brief general description of hydrogeological conditions is given with a hydrogeological stratification scheme presented. It is followed by the description of selected water-bearing strata according to such scheme:

1) aquifers (water confinement complexes) attachment to geological formations; their distribution, the facial-lithological composition of water-bearing sediments, their occurrence nature and capacity ;

2) filtration, capacitance properties of water-containing rocks;

3) occurrence depth from the ground surface and absolute marks of water-containing rocks' roof and sole level;

4) occurrence depth from the ground surface and absolute marks of the ground water mirror and piezometric pressure water levels, the head value above the pressure water reservoir roof;

5) conditions for underground water movement and discharge;

6) aquifers' relation to each other and to surface waters;

7) chemical and bacteriological composition of underground water, assessment of its quality, aggressiveness towards materials used in the facilities' constructions;

8) groundwater regime;

9) aquifers protection degree .

The surface waters description includes a description of lakes and rivers with their width and depth, hydrological regime features, and water quality.

2. Soils

The description of project construction works engineering and geological conditions should include a detailed description of rock massifs' engineering and geological characteristics , a comprehensive description as to the current state of engineering and geological processes on the studied territory.

Such characteristics shall include:

1) spatial variability of rocks serving in basis for project-erected structures, their elasticity properties and strength indexes ;

2) types, intensity, volume characteristics of danger susceptibility and risk category for objects of various geological and engineering-geological processes and phenomena;

3) project area geomorphological features and micro-landscape;

4) modern engineering-geological processes and assessment of these factors influence on engineering-geological and hydrogeological conditions.

Essential is to note the presence of buried and filled-in river valleys, streams and ravines on the project construction site.

The experience of facilities' construction and operation should be summarized in order to develop the most effective project design solutions and protective measures with reference to the site area actual conditions.

When describing soils, one need to specify the soil layer contamination, as well as the distribution of landfill and low-activity soils in this area and their radiometric characteristics.

3. Flora and fauna

The characteristic of woody, shrubby and herbaceous vegetation in the zone prone to the projected facilities' influence shall be given. Here a special attention is paid to rare and protected species, which list shall be attached to the map of local natural complex.

When describing the flora and fauna, never omitted shall be the spread of green spaces on the construction site, the presence of valuable trees therein, and the areal of various small animals, birds and insects on the territory.

4. Social sphere

This subsection should indicate the social, landscape, architectural, and aesthetic characteristics of territory concerned: the presence of protected areas, its recreational value, its association with one of the five landscape classes (natural, agricultural, urbanized, industrial, and damaged land), and the territory overall aesthetic perception.

When identifying the planned facilities' significant atmospheric impact, assessing the powerful acoustic (noise) and vibration fields thereby created, as well as in the case of areas with the population increased morbidity (according to sanitary and epidemiological surveillance data), it is advisable to assess the economic damage caused by the planned measures.

5. Atmospheric air

Information shall be provided about the peculiarities of surface air mass circulation in the construction area, about local air composition and air pollution in this area. The contribution of machines, mechanisms and other factors while project construction shall be assessed as well as the air basin pollution.

III. *"Impact on the natural environment during project facilities' construction and operation"*

This chapter should contain quantitative (or qualitative) indicators of the designed structure influence degree as to all the above-mentioned environmental characteristics.

The impact should be described in separate chapters individually by the environment components.

A separate and mandatory part of the environmental impact mechanisms consideration refers to the probability and possible consequences assessment as to the accidents while project facilities construction and operation.

IV. *"Predicted state of the natural environment"*

In this section, one must give a conclusion about the degree of impact produced by the projected facility on the environment.

Forecasts of the environmental condition are given on the basis of solving the necessary complex hydrodynamic, geomigration, thermodynamic and other problems in a deterministic or stochastic setting, departing from the models below (matrices, simulation models).

Building the Leopold matrix

The predictive assessment procedure included in the environmental impact assessment (EIA), is based on solving a wide variety of tasks, which diversity is determined by the specifics of processes and interactions under study, as well as by the levels of their study coverage and direct/indirect influence. Solving problems is fundamentally impossible for real-world, measured and very diverse natural conditions. Therefore these conditions are always simplified, generalized, and presented as a simplified scheme (model). The simplest and most accurate, at the same time, the most abstract are deterministic models where causes and effects are connected in a system of unambiguous algebraic, differential or finite-difference equations. More complex but less defined, and often less studied processes are described by stochastic, probabilistic models, which applicability and correctness is not fully justified in geoecology. Finally, for the most complex interactions within an ecosystem, only conceptual models can still exist.

Since for many interactions yet we have no good quantitative models, the EIA inevitably includes expert assessment methods that complement and adjust the calculation methods.

To build a model, one need to schematize the environmental characteristics that are affected and the impact characteristics properly.

The primary, most general approach to EIA is implemented when preparing the Leopold matrix, which characterizes the qualitative relationships in the "cause-effect" system. In fact, this matrix is just a form that arranges data in some ordered sequence. The forecast and rating are given using expert assessment through ranking within fairly broad and not strictly defined limits (from 1 to 10 points).

In this case, 1 means the influence presence and 0 means the influence absence.

As a starting point and as an example, we took the matrix, developed on the basis of analogue existing and used in the world practice when this kind of works performing.

The Leopold matrix applied to the specific conditions of Project "Lakes reclamation in the area of Odessa-Sorting r/w station of the Odessa railways" has the form as shown in the Table 1.

Table 1

Leopold Matrix

Affected object		Influence	Specific weight of characteristics	A. Mode modification				B. Transformation of the landscape, transport					B. Pollution									D. Accidents		
				Sinking	Stacking the soil and vegetation layer	Dewatering and drainage	Artificial freezing of soils	Construction of temporary roads	Backfill of soils	Presence of buried and filled-in river valleys, streams and ravines	Placement of erected structures in the underground water flow	Soils chemical fixing	Removal of soil to landfill, temporary storage	Soil contamination (fuel and lubricants)	Exhausts	Noise, vibration	Warming effect	Availability of landfills on the territory	Waste disposal	Scrap dispoal	Drainage water discharge	Environment situations	Leakage from water supply systems	Operational errors (human factor-related errors)
Physical and chemical objects	Earth	Contamination of soils	6-9	0	1	1	0	0	0	0	0	0	1	1	1	1	1	0	1	0	1	1	0	1
		Presence of other negative engineering-geological phenomena (soils expansion, subsidence of soils)	6-9	0	1	1	1	0	0	0	0	0	1	1	1	1	0	0	1	0	0	0	0	1
		Quicksands	8-10	0	1	1	0	0	1	1	1	0	0	0	0	0	0	1	0	0	1	0	0	0
		Radiometric situation in the territory	6-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Water	Conditions of interrelation between ground and surface water (by horizon)	1-5	0	0	1	1	0	0	0	0	0	1	1	1	1	0	0	1	0	1	1	0	1
		Ground water level (by horizon)	5-9	0	1	1	1	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	0	1
		Ground water regime (by horizon)	3-6	1	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0
		Aggressiveness of underground water (on the horizon)	5-9	1	1	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chemical composition of underground water (by horizon)	2-9	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	1	1	0	0	1
		Conditions for underground water protection (by horizon)	6-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Atmosphere	Air quality	7-10	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0
		Temperature	1-5	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
	Processes	Erosion	1-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
		Activity of karst-suffusion processes	8-10	0	1	1	0	0	0	0	0	0	1	2	1	0	0	0	0	0	1	1	0	1
		Activity of slope processes	8-10	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Biological objects	Flora	Availability of green spaces	3-8	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
		Species under threat of extinction	4-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fauna	Land animals	3-8				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
		Species under threat of extinction	4-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Objects prone to anthropogenic impact	Land use	Recreational value of the territory	4-8	1	1	0	0	0	0	0	0	0	1	0	1	0	0	1	1	1	0	0	0	1
	Aesthetic needs and human habitudes	Availability of protected areas (parks and forest parks, architectural monuments, urban-planning complexes and ensembles)	8-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Landscape aesthetics	1-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Social amenities	1-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Some environmental dependencies	Water salinization	3-6	3	2	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	1
		Soil salinization	3-6	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	1

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Its preparation was preceded by the formation of two control lists: the environment characteristics and the characteristics of environmental impact during the underground structures construction and operation.

As a result of the alternative project options impact analysis, on the matrix of environmental elements interaction with project characteristics, the environmental elements susceptible of being affected are found. Naturally these elements' significance varies.

The matrix is arranged in the following order. The horizontal lines contain the environmental characteristics that can be affected by the underground structures construction and operation.

A total of 26 characteristics have been identified as a result of this work. These parameters are represented in the Table 2.

Table 2

Environmental "Objects"

A. Physical and chemical objects	Earth	Contamination of soils
		Presence of other negative engineering-geological phenomena (soils expansion, subsidence of soils)
		Quicksands
		Radiometric situation in the territory
	Water	Conditions of interrelation between ground and surface water (by horizon)
		Ground water level (by horizon)
		Ground water regime (by horizon)
		Aggressiveness of underground water (on the horizon)
		Chemical composition of underground water (by horizon)
		Conditions for underground water protection (by horizon)
	Atmosphere	Air quality
		Temperature
	Processes	Floods
		Erosion
		Activity of karst-suffusion processes
		Activity of slope processes
B. Biological objects	Flora	Availability of green spaces
		Species under threat of extinction
	Fauna	Land animals
		Species under threat of extinction
C. Objects prone to anthropogenic impact	Land use	Recreational value of the territory
	Aesthetic needs and human habitudes	Availability of protected areas (parks and forest parks, architectural monuments, urban-planning complexes and ensembles)
		Landscape aesthetics
		Social amenities
	Some environmental dependencies	Water salinization
		Soil salinization

The vertical lines contain the environmental impact characteristics that will be displayed during the underground structures construction and operation. In total, 21 impact characteristics have been identified (Table 3).

The next step was to rank the characteristics of the environment (affected by the projected structures) and the resulting specific weights (or, in other words, the significance) of environmental elements, which are used to calculate the number of points for each of the project alternatives in the final comparative impact table. These scores for each environmental characteristic are shown in a separate column in the table. According to the results of section III "Impact on the natural environment during the construction and operation of structures", the matrix cells located at the intersection of the graph of influence characteristics and those environmental characteristics susceptible to this influence are filled in.

Table 3

Impact envisaged by the project

Influence	Components of influence
A. Mode modification	Sinking
	Stacking the soil and vegetation layer change of residence
	Dewatering and drainage the creation of artificial surfaces
	Artificial freezing of soils
B. Transformation of the landscape, transport	Construction of temporary roads
	Backfill of soils
	Presence of buried and filled-in river valleys, streams and ravines construction of dams and Zagat
	Placement of structures in the underground water flow
	Chemical fixing of soils
C. Pollution	Removal of soil to landfill, temporary storage
	Contamination of soils by fuel and lubricants (POL)
	Exhausts
	Warming effect of underground utilities
	Noise, vibration
	Availability of landfills on the territory
D. Waste disposal and recycling	Waste disposal
	Scrap disposal
	Drainage water discharge
E. Accidents	Environment situations
	Leakage from water supply systems
	Operational errors (human error)

The next step was to rank the environment characteristics (affected by the projected structures) and the resulting specific weights (or, in other words, the significance) of environmental elements, used to calculate the number of points for each of the project alternatives in the final comparative impact table. These scores for each environmental characteristic are shown in a separate column in the table. According to the results of section III "Impact on the natural environment during the construction and operation of structures", the matrix cells located at the intersection of the influence characteristics graph and those environmental characteristics that are susceptible to this influence are filled in.

Construction of impact simulation models

The model of project options impact on the environment is a function of several variables, which are indicators of the environment condition. In turn, the state indicators are determined from models of environmental indicators that are built for each element of the environment that is affected by the project.

In the described simulation model, two classes of indicator models are used: "quality of NS-influence" and "limiting environmental factor" (Batellet method).

In fact, such a dependency can be represented by a function defined graphically. The ordinate axis reflects the quality of NS, which value is determined by the above dependencies.

The environment quality varies from 0 to 1. The value 1 corresponds to the worst quality of the NS, 0 – the best.

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Table 4

NS SPSG quality

Categories of soil contamination	SPSG
Clean	0
Permissible	≤16
Moderately hazardous	16..32
Dangerous	32..128

On the x-axis, that is, the argument is taken one or another indicator (for example, groundwater salinity, depth of groundwater level, the intensity of karst-suffosion processes and so on.), which is crucial by this component environment quality.

The environment quality values obtained in this way for each environment characteristic are included in the final impact matrix.

The order of consideration and choice of environment characteristics as variables of the simulation model was determined by the characteristic significance and the number of impacts on it.

1. Contamination of soils

The quality of environment by this component is estimated by the total indicator of soil contamination (spcg) see Table 4. The model looks like this (Fig. 1). Contamination indicator is shown on the 0*X* axis.

2. Presence of other adverse geological phenomena (puchan, subsidence soil)

The environment quality by this component is assessed by the number of negative geotechnical phenomena on the territory. The model looks as below shown (Fig. 2).These phenomena number is shown on the 0*X* axis.

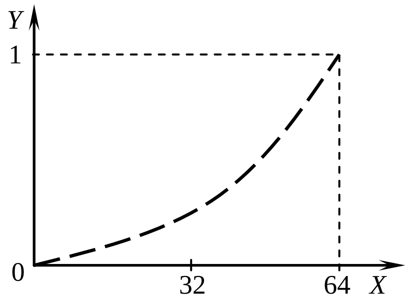

Fig. 1. Model describing soils contamination

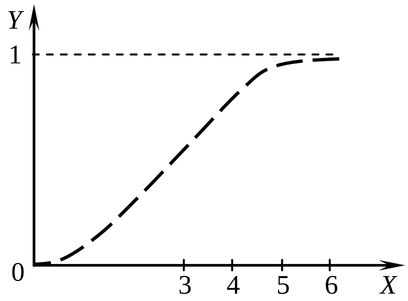

Fig. 2. A model describing other negative geotechnical phenomena presence

3. Quicksands

The presence of soil in the work area, for example, worsens the environment quality. The environment quality will be determined by the change in the amount of internal soil cohesion under the influence of construction. Soil adhesion is measured in kg/cm^2 and is shown on the abscissa axis. The model looks like below (Fig. 3).

4. Radiometric situation of the territory

The quality of environment can be assessed by the degree of radiometric contamination of the territory. The 0*X* axis indicates the maximum allowable concentrations (MPC) of some chemical elements in the soil, which are measured in mg/kg. In this case, the model will look like this (Fig. 4).

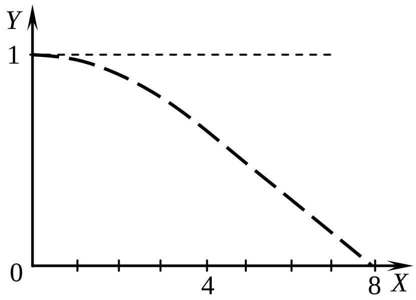

Fig. 3. A model describing the presence of swimmers

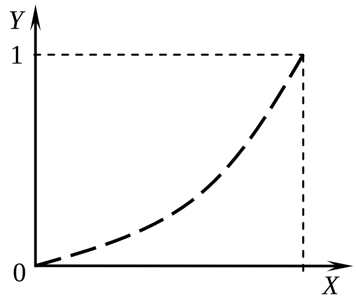

Fig. 4. A model describing the radiometric situation of a territory

5. Conditions for the relationship between ground and surface water (by horizon)

The quality of environment by this component is assessed depending on the degree of change in the amount of groundwater runoff (Δ*Q*) in surface water bodies (as a percentage of the existing). These percentages are located on the 0*X* axis. The model looks like below (Fig. 5).

6. Ground water level (by horizon)

The type of dependency is shown in Fig. 6. As an argument for the function, the depth of the underground water level from the earth's surface is taken. The units of measurement are meters.

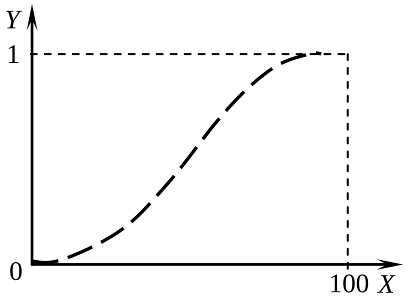

Fig. 5. A model describing the relationship between ground and surface water (by horizon)

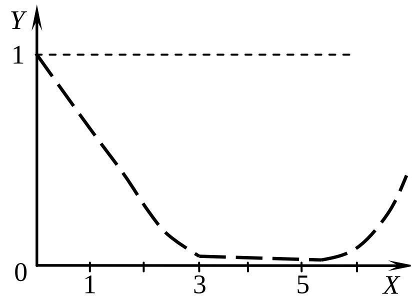

Fig. 6. Model describing the level of underground water (by horizon)

When the depth of the ground water level is up to 3 meters from the ground surface, the territory is considered to be flooded (for different areas) and the environment quality will be low for this characteristic. The interval of occurrence of the ground water level from 3 to 6 m from the earth's surface can be considered favorable. On the graph, this area of the function has minimal values, which corresponds to the environment highest quality for this characteristic.

If there is a significant depth of the ground water level caused by construction water loss, flooding or other reasons, the environment quality will deteriorate, and the function values will approach the maximum.

7. Ground water regime (by horizon)

The quality of the emergency according to this characteristic is assessed to the degree of change in the amplitude (ΔH) of fluctuations in groundwater levels (as a percentage of existing). Unit of measure percent, pending on the *x*-axis. The model view is shown in Fig. 7.

8. Aggressiveness of underground water (on the horizon)

The nature of the dependence of the environment quality on the aggressiveness of underground water is similar to the dependence on the total mineralization (Fig. 8). As an argument, we use the aggressiveness of underground water in relation to concrete, which is measured in g/l and recorded as COD. The minimum value of the function argument corresponds to the natural total mineralization. Maximum-the largest COD mineralization.

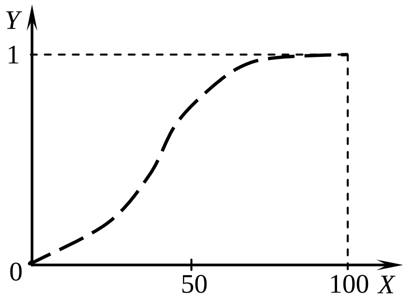

Fig. 7. Model describing the groundwater regime (by horizon)

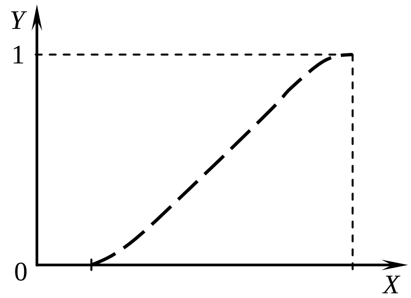

Fig. 8. Model describing the aggressiveness of underground water (along the horizons)

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9. Chemical composition of underground water (by horizon)

It makes sense to evaluate the environment quality by several criteria based on such significant and sensitive characteristics of the environment as water quality. For example, it is possible to assess the environment quality by water contamination with biogenic elements for the existing situation ("zero" option) and for the projected one.

It is also possible to assess the environment quality and the content of any toxic pollutant in the water, for example, heavy metal.

One can also evaluate the quality of water by its total mineralization. The model will look like this (Fig. 8).

Thus, the integral indicator of the environment condition according to the "water quality" will be equal to the average arithmetic quality of the environment, determined by several criteria.

10. Conditions for underground water protection (by horizon)

The quality of environment by this component is evaluated depending on changes in the category of underground water protection (*C*) calculated using the Goldberg method. The change in safety category is measured in points and is located on the axis 0*X*. The model looks like below (Fig. 9).

11. Air quality

Air quality is, of course, a very important indicator of the environment condition, and although this indicator is not directly related to this project, it is not very useful to assess the air quality by the concentration of pollutants that predominate in the exhaust of construction machinery. Pollution shows the exhaust of construction and other equipment. Units of measurement: g/m^3, recorded in the form of COD. The minimum value of the function argument corresponds to the natural environment condition (without contamination). The maximum is the highest COD concentration of the pollutant. In this case, the model shall appear as below (Fig. 10).

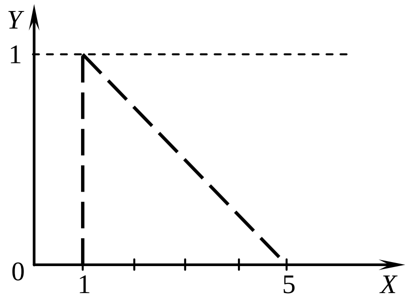

Fig. 9. Model describing the conditions of underground water protection (by horizon)

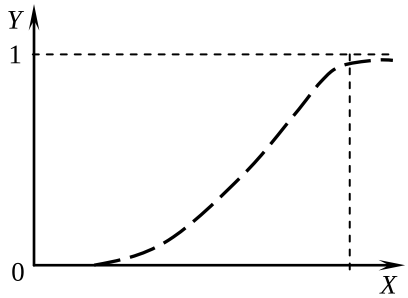

Fig. 10. Model describing the air quality

12. Activity of karst-suffosion processes (KSP)

The quality of the environment response by this component is assessed depending on the change in the construction area's proximity to the zone of surface manifestations of karst (KSP) in accordance with the "map of engineering-geological zoning for the activity of karst-suffusion processes". The KSP is expressed in points, its values are found on the 0*X* axis. The model looks like below (Fig. 11).

13. Activity of slope processes

The ratio of forces holding and shifting in a given section (*F*) can be considered as an argument. The forces *F* are shown on the abscissa axis. When $F>1$ the slope is stable. The model appears as below shown (Fig. 12).

14. Availability of green spaces

The territory quality by this component is determined by the ratio of green area to total land area before and after construction of structures (GA). This parameter is calculated as a percentage, shown as an argument. The model looks like below (Fig. 13).

15. Recreational value of the territory

The quality of environment situations by this component, as in the previous one, is estimated by the ratio of the area of territory occupied by construction to the area of recreation-valuable territory. Calculated as a percentage, shown as an argument. The model looks like this (Fig. 14).

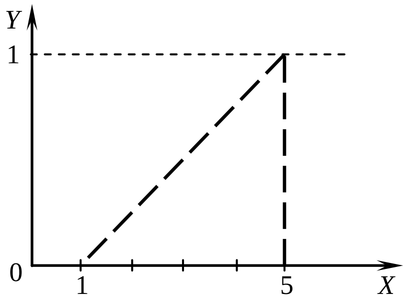

Fig. 11. A model describing the activity of karst-suffusion processes (KSP)

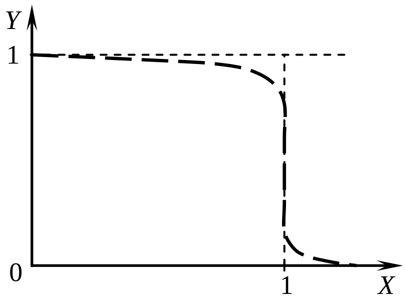

Fig. 12. A model describing the activity of slope processes

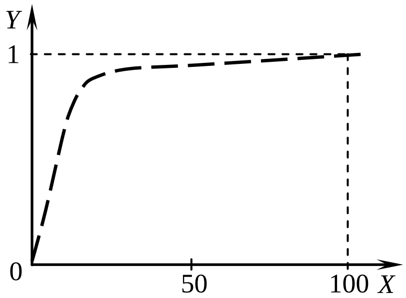

Fig. 13. A model describing the presence of green spaces

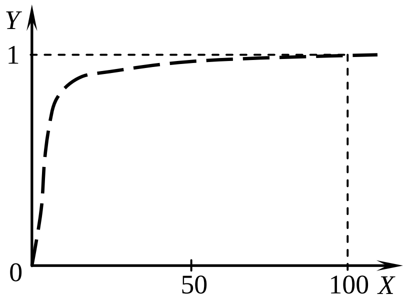

Fig. 14. A model describing the recreational value of a territory

16. Availability of protected areas (parks and forest parks, architectural monuments, urban-planning complexes and ensembles)

The quality of environment by this component is assessed by the ratio of the protected areas surface (parks and forest parks, architectural monuments, urban complexes and ensembles), occupied by construction, to the total protected areas surface (*S*). Similarly, as in previous cases, the percentage shown as an argument is calculated. The model view is shown in Fig. 15.

17. Landscape aesthetics

The environment quality by this component is evaluated depending on the change in the territory's landscape class (natural (1), agricultural (2), urbanized (3), industrial (4) and damaged land (5)). Assessment units here are classes, which values are found in the 0*X* axis. The model looks like this (Fig. 16).

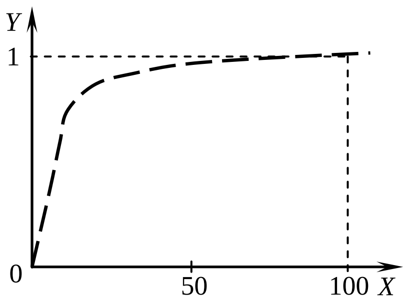

Fig. 15. A model describing the presence of protected areas

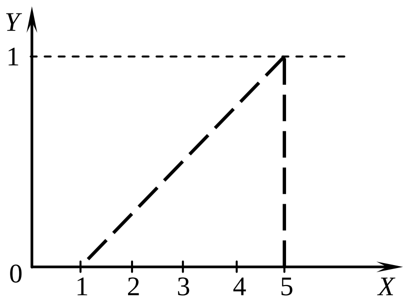

Fig. 16. A model describing the landscape's aesthetics

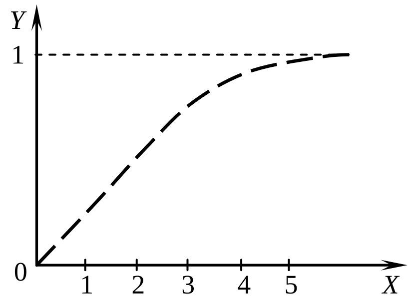

Fig. 17. A model describing social amenities

18. Social amenities

The environment quality by this component is assessed by the number of inconveniences associated with the construction of structures. The model looks like below shown (Fig. 17).

This list is not limited to the list of environmental characteristics. In specific conditions, the necessary lines can be added to it. For example, when laying a water pipeline, it is important to note and enter in the EIA the characteristic “improvement of housing and population living conditions” or “comfort of living”. When constructing a sewer, it is reasonable to introduce a characteristic that determines the sanitary and hygienic conditions of living of the population.

On the other hand, the listed set of environmental impact characteristics is not strictly mandatory, but should be compiled individually for each project, depending on the specific construction conditions, design decisions, etc.

To ensure the uniformity of measurements, the possibility of their comparison and comparison, when assessing the impact on the environment, units of measurement of environmental characteristics should be used, provided for by current regulatory and technical documents and State Standards.

Calculation of influence coefficients

All the impact characteristics described below are taken into account as coefficients when calculating the quality index.

In assessing the potential impact that relates to the construction and operation stages of the proposed project, it is necessary to analyze the potential impact in terms of:

– exposure (impact nature);

– turnovers;

– directions;

– cumulative and synergistic effects.

Exposure (characteristic of influence)

Each process that leads to an impact onto environment must be described in terms of the limits, intensity, and duration of the impact.

The criterion for the limits of influence includes the geographical area (whether the area of influence is a limited area, located near or inside the proposed object, or it is much wider) and the number of influence objects (characteristics of the environment that will be affected by this type of impact).

The impact intensity characterizes the degree of change in the environment component: strong, weak.

The action duration may be equal to, for example, the construction period, the duration of operation of the structure, or it may be longer if the remaining contamination is very persistent. It is also necessary to indicate the effect of periodic, continuous or it is due to an environment situation.

The reversibility of the impact

Some effects are not reversible or poorly reversible. An impact or change is significant when the ability to weaken or reverse it is limited. Natural forces, direct cleaning operations, and other measures provided for in the design solution can help the process of weakening or turnover.

Direction of influence

Direct influence is inherent in the characteristics of the production project, that is, the process itself, accidents, construction. Indirect impact becomes significant in different places after time has passed or in other elements of an environment. Indirect impacts include, for example, vegetation degradation due to long-term water loss.

Cumulative and synergistic effects

The assessment process should take into account the cumulative impact of all these indicators, along with the impact of each separately. This is very important, because the impact of individual indicators can be insignificant, and the cumulative one is much larger.

The reason is that the impact of individual pollutants may change as they accumulate over time.

Special attention should be paid to the synergistic effect, since the reaction to two or more indicators that affect simultaneously is stronger than a simple summation of the effects.

See Table 5 below, the ranges of influence coefficient values are given, which are taken into account later for each component when calculating the quality index.

Table 5

Value of influence coefficients

Characteristics of the effect	Value of influence coefficients
Exposition	
Surface exposure	0.5…9.8
Intense exposure	1.5
Time characteristic	
Short-term exposure	0.5…1.0
Long-term exposure	1.0...3.0
Spatial characteristic	
Limited exposure	0.5…1.5
Large exposition	1.5…3.0
Turnover	
Irreversible effects	0.5…1.5
Reversible effects	1.5…3.0
Direction	
Direct impact	1.0...2.0
Indirect influence	0.5...1.
Synergy	
Cumulative impact	1.5...2.0
Synergistic effects	1.5...2.0

Resulting influence matrix

The final impact matrix looks like below shown (Table 6), where:

ω_L – frequency according to the Leopold matrix,

μ_I – evaluation based on the simulation model,

μ_K – correlation estimation,

p – specific weight of the component,

k_E – exposure coefficient,

k_O – turnover ratio,

k_N – directivity coefficient,

k_S – coefficient of synergies,

I_S – quality index.

It is filled in as follows.

First, the number of impact characteristics that affect each environmental characteristic is calculated using the Leopold matrix. It corresponds to the number of filled cells in the column opposite the environmental characteristics, divided by the total number of cells. These values are entered into the final matrix of influence in the column ω_L frequency on the Leopold matrix for each component of the environment.

After that, for each component in the column μ_I put is the value obtained from the evaluation using a simulation model.

Then, for each component, using the Liebig minimum principle, select the maximum value from the first two columns: the evaluation result using the simulation model and the frequency using the Leopold matrix. The obtained value is put to the column μ_K. The highest value is chosen due to the fact that you need to count on a more significant influence.

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Table 6

Resulting matrix of influence

Characteristics of the NS	ω_L	μ_I	μ_K	p	k_E	k_O	k_N	k_S	I_S
Contamination of soils	0.52381	0.27	0.52381	0.75	1.5	1.5	2	1.5	2.652
Presence of other negative engineering-geological phenomena (soils expansion, subsidence of soils)	0.42857	0.24	0.42857	0.75	1.5	1.5	2	1.5	2.170
Quicksands	0.33333	0.31	0.33333	0.9	1	0.5	1	1.5	0.225
Radiometric situation in the territory	0	0	0	0.75	0	0	0	0	0
Conditions of interrelation between ground and surface water (by horizon)	0.47619	0.22	0.47619	0.3	1.5	0.5	2	1.5	0.321
Ground water level (by horizon)	0.57143	0.37	0.57143	0.7	1.5	0.5	2	1.5	0.900
Ground water regime (by horizon)	0.28571	0.21	0.28571	0.45	1	0.5	2	1.5	0.193
Aggressiveness of underground water (on the horizon)	0.33333	0.34	0.34	0.7	2	0.5	2	1.5	0.714
Chemical composition of underground water (by horizon)	0.33333	0.2	0.33333	0.55	1	0.5	2	1.5	0.275
Conditions for underground water protection (by horizon)	0.19048	0.11	0.19048	0.75	2	0.5	2	1.5	0.429
Air quality	0.09524	0.1	0.1	0.85	1	0.5	0.5	1.5	0.032
Air temperature	0.04762	0.12	0.12	0.3	1	0.5	0.5	1.5	0.014
Erosion	0.04762	0.12	0.12	0.3	1	0.5	0.5	1.5	0.014
Activity of karst-suffusion processes	0.38096	0.43	0.43	0.9	1.5	0.7	1	1.5	0.610
Activity of slope processes	0.09524	0.1	0.1	0.9	2	0.7	1	1.5	0.189
Availability of green spaces	0.14286	0.21	0.21	0.55	1	0.5	0.5	1.5	0.043
Species under threat of extinction	0	0	0	0.6	0	0	0	0	0
Land animals	0.09524	0.1	0.1	0.55	0.1	0.5	0.5	1.5	0.002
Species under threat of extinction	0	0	0	0.6	0	0	0	0	0
Recreational value of the territory	0.38095	0.27	0.38095	0.6	1.5	1.5	0.5	1.5	0.386
Availability of protected areas (parks and forest parks, architectural monuments, urban-planning complexes and ensembles)	0	0	0	0.9	0	0	0	0	0
Landscape aesthetics	0	0	0	0.25	0	1	0.5	1.5	0
Social amenities	0	0	0	0.25	0	0	0	0	0
Water salinization	0.23809	0.21	0.23809	0.45	1.5	1	1	1.5	0.241
Soil salinization	0.23809	0.21	0.23809	0.45	1.5	1	1	1.5	0.241

In the column "component specific weight" for each component, the value corresponding to specific conditions is entered, the range of which is given in the Leopold matrix (see Table 1). To simplify the calculation and with reference to the fact that the component's specific weight shall be found in the interval from 0 to 10, we proceed to the component's specific weight calculation according to formula $p = \frac{x_{\max} + x_{\min}}{2} \cdot \frac{1}{10}$.

Then we fill in the columns of various "impact Factors" calculated for each component, based on the specific characteristics of the impact. The range of values for the impact characteristics is shown in Table 1.

The final calculation of "quality Index" is made as follows: for each component, the "Correlation score" values are multiplied by the "specific weight of the component" and by all "influence coefficients". The resulting value is entered in the "Quality Index" column.

The final environment quality index is obtained by summing the quality indices of all components. The higher the quality index being, the more the environment is negatively affected by the implementation of the proposed project and the worse its condition will be for the estimated period.

This article provides an example of calculating the environment quality index for the project "Lake reclamation near the Odessa-Sorting station of the Odessa railway". It is equal to approximately 9.649.

The quality index of the "zero" option, which is calculated for the conditions "without the projected structure", for this project is more than twice the quality index obtained when developing the documentation for the environment assessment for the project.

As variants of the projected activity, various routes for laying engineering communications, their various designs and depths of occurrence, as well as various methods of conducting construction work are considered.

To assess the environmental consequences of various planned activities variants, it is important to set construction dates and their timing for a specific season of the year. If this is not yet possible at the stage of the project feasibility study, then impacts in different seasons are considered as options.

V. *"Measures to minimize harm to the environment"*

This section should substantiate proposals for compensatory and rehabilitative measures necessary to minimize damage to emergencies, proposals for setting up environmental monitoring, conducting special additional hydrogeoecological studies.

At the same time, it is not only acceptable, but also desirable to justify such proposals for the protection, protection and rehabilitation of the environment, which will significantly reduce harm to nature and man. Such proposals are worthy of independent impact assessment along with the abovementioned ones.

Research result

The quality indices calculated in this way for different project variants can be compared with each other and with the "zero" quality index, which is calculated for the conditions "no planned structures".

The differences between the quality indices will serve as a criterion for evaluating the impact of the designed structures on the environment.

It is mandatory to evaluate the "zero" option, that is, the situation of rejection of the project. For the large cities conditions, a common practice are such cases when the "zero" option to be the least preferred, especially when the route passing through wastelands, landfills, as well as when a set of compensation and rehabilitation measures are introduced into project.

Conclusion

This article summarizes the conclusions about the degree of influence of various project options on the environment based on a comparison of the received estimates the conclusion is made about the favorability of a particular project option.

The proposals for minimizing the damage to the environment during the implementation of the proposed project are summarized in a short form.

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Олех Георгій Сергійович; Olekh Heorhii, ORCID: https://orcid.org/0000-0002-7033-8504
Колеснікова Катерина Вікторівна; Kolesnikova Kateryna, ORCID: http://orcid.org/0000-0002-9160-5982
Прокопович Ігор Валентинович; Prokopovych Ihor, ORCID: https://orcid.org/0000-0002-8059-6507
Козлов Олексій Ігорович; Kozlov Oleksii, ORCID: https://orcid.org/0000-0002-1834-6902

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