

The object of research considered in this paper is the design mindset process in the development of a prototype of electronic service for assessing the environmental impact of the planned activities of business entities. The problems of applying the design mindset approach to the process of automating environmental impact assessment have been investigated. As a result of the application of the design mindset in combination with the stakeholder approach, a logical-structural scheme and architecture of the electronic service interface for different categories of users have been developed. The peculiarities of the prototype of the electronic service of environmental impact assessment (EIA ES) are to provide a common understanding of the requirements and results obtained, and convenient access to the execution of calculations. Distinctive features for the implementation of calculations in EIA ES are the quantitative obtaining of the values of indicators, which are represented by a report in the form of qualitative parameters through the use of a new algorithm. This allows business entities to perform calculations of indicators using online access at the stage of preparing the report.

The developed interface design and functionality of the EIA prototype were evaluated by the expert method on a 10-point scale when making calculations for a real project. The effectiveness of the electronic service has been confirmed by the consistency of expert opinions in line with the concordation method. The estimated concordation coefficient was 0.83 and was checked for adequacy according to the Pearson criterion (20.75), which confirmed the reliability of the calculations at a significance level of 0.05.

The scope of application may be environmental impact assessment of transport construction objects and gas stations. The conditions for practical use are the availability of access to the Internet and the availability of sufficient user qualifications for performing calculations

**Keywords:** design mindset, environmental impact assessment, stakeholders, prototype, electronic service, interface

# APPLYING A DESIGN MINDSET TO DEVELOP A PROTOTYPE OF AN ELECTRONIC SERVICE FOR ASSESSING THE IMPACT ON THE ENVIRONMENT

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## 1. Introduction

The process of reconstruction of the economy of each country predetermines the rapid development of the pro-

duction sector, which, in turn, contributes to the strengthening of anthropogenic impact on the environment. Natural resources are raw materials for many production processes, their use is growing exponentially with the increasing ca-

capacity and intensity of production. At the same time, there is an increase in the volume of waste, emissions of harmful substances into the atmosphere, discharges into water bodies; soils are polluted, and biodiversity decreases. The processes of industrial activity not only negatively affect the environment but also lead to irreversible changes [1]. Therefore, along with strict environmental control in the implementation of economic activities, international legislation provides for an environmental impact assessment (EIA) at the planning stage of production activities. A complex and lengthy evaluation procedure is a laborious multiparametric problem of analytical and mathematical modeling. It requires constant attention, participation, and control by the customer of the contractor, and constructive interaction with stakeholders – the public, government agencies, and local governments.

That is why at the present stage it is relevant to study the problems of automating the process of environmental impact assessment through the development of an electronic service. Such an IT product must meet the requirements of users for the quantitative assessment of the environmental impact of the planned activities of a business entity according to clearly established indicators and the method of their evaluation. In turn, such electronic services should have a comfortable interface that will make it possible to quickly and conveniently work with the system. Solving this problem requires the use of non-standard creative approaches to develop a software product, one of which is a design mindset.

The results of such studies are necessary for practice because such electronic services, based on the design mindset approach, have an ergonomic appearance and are focused on the end user.

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## 2. Literature review and problem statement

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Traditional methods of designing electronic services, in particular, for example, the method of orderly search [2], do not meet modern requirements for the development of IT products. The disadvantage of conventional methods, which are largely focused on mathematics, is the narrow scope of their application. In particular, the method of ordered search [2] turned out to be possible for use only when solving clearly formulated problems with unchanged initial data. The modern world, like modern design, lives and operates under conditions of a high degree of uncertainty, which pre-determines higher demands on the flexibility of methods. In addition, going the conventional way, it is difficult to achieve the originality of the solution [3]. Experts in other fields argue about the use of design mindset-based methods and techniques in various non-standard, dead-end, multitasking, and uncertain situations. Therefore, it is increasingly necessary to separate design as a profession and design mindset as a special project technology, to which the authors of [4] attribute not only high efficiency but also large horizons.

In study [5], design is defined as the process of transforming existing conditions into desirable ones. Thus, a design mindset can be defined as a process always focused on creating a better future and finding new solutions to complex problems in various fields [6]. However, the design mindset-based methods and models described in works [2–6] were not applied to IT products in the environmental industry.

Among the latest significant studies on the analysis of basic design mindset-based research methods and models,

it is necessary to highlight [7, 8]. These papers are based on the Systematic Literature Review approach, which revealed the possibilities of applying integrated models to innovations in various applied fields. The models specified in [7, 8] have better flexibility to change consumer needs than conventional ones. However, they do not provide a clear answer to the question of how best to take these changes into consideration.

Work [9] focuses on the study of the use of a design mindset in the management of academic resources at higher education institutions. Interesting is the experience of using the methodology of a flexible design mindset to meet the needs of the end user in the prototyping phase. The main disadvantage of the cited study is that it has not passed sufficient practical testing.

Works [10, 11] report the analysis of design mindset-based methods and models and give recommendations for practical use. In particular, papers [10, 11] describe in more detail the application of the design mindset to certain areas, such as social projects and commercial activities. However, based on the results of research, it was revealed that IT products should be evaluated in terms of feasibility, scope, and accuracy of prototyping.

Thus, our review of scientific papers [7–11] revealed insufficient attention of researchers to the application of a design mindset in combination with a stakeholder approach.

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## 3. The aim and objectives of the study

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The aim of this study is to define an approach to the application of a design mindset in the development of a prototype electronic service for environmental impact assessment of the planned activities of business entities. This will make it possible to build an ergonomic interface for the electronic service, focused on the end user.

To achieve the set aim, the following tasks have been solved:

- to describe the algorithm for quantifying environmental impact assessment indicators of the planned activity, which underlies the developed electronic service;
- to develop an interface to the prototype of the electronic service using a design mindset in combination with a stakeholder approach;
- to perform an expert assessment of the functionality and interface of the developed electronic service.

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## 4. The study materials and methods

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The object of this study is the design mindset process in the development of a prototype of electronic service for assessing the environmental impact of the planned activities of business entities.

The development of the electronic service is based on an algorithm for quantifying environmental impact assessment indicators of the planned activity. This algorithm is based on the use of the Leopold matrix, followed by a study of the influence of indicators using the Harrington function. The basic hypothesis of the study assumes that when applying the design mindset approach to prototyping an IT product, the best way is to use a stakeholder approach. The main assumption of the study is to take into consideration the opinions of groups of independent external stakeholders in the

development of the functionality and interface of an electronic service. This makes it possible at the stage of testing the developed prototype to take into consideration the needs of interested parties, which reduces the number of negative feedbacks from users at the stage of demo testing of the electronic service. The developed demo version of the prototype of the electronic service for environmental impact assessment of EIA was tested by five experts – professionals in the field of environmental impact assessment. The adequacy of the results of applying the design mindset approach in the development of a prototype electronic service is assessed by the consistency between the opinions of experts using the concordation method, followed by verification according to the Pearson criterion.

**5. Results of the development of a prototype electronic service for environmental impact assessment**

**5.1. Algorithm to quantitatively determine the environmental impact assessment indicators of the planned activity**

The algorithm for quantifying environmental impact assessment indicators (EIA) of the planned activities is based on a combined approach. The Leopold matrix [12] was used with the subsequent study of the influence of indicators using the Harrington function [13, 14].

The Leopold matrix is built in the form of a table that contains horizontally a list of processes that have an impact on the environment at different stages of the life cycle of planned activities. Vertically, the matrix contains criteria and indicators of environmental impact, which are the corresponding characteristics of the environment. The formed cells of the matrix (Table 1) determine the estimate, which, in turn, reflects the intensity of the impact (amplitude) and is a measure of the significance of changes in the ecosystem (importance).

Table 1

Leopold matrix (template)

The <i>i</i> -th criterion indicator, <i>i</i> ∈ [1; <i>n</i> ]	The <i>j</i> -th component of the <i>k</i> -th process, <i>j</i> ∈ [1; <i>m</i> ]				Σ <i>w</i> <sub><i>i</i></sub>	<i>I</i> <sub><i>i</i></sub>	<i>Y</i> <sub><i>i</i></sub>
	1	2	<i>j</i>	<i>m</i>			
1	<i>w</i> <sub>11</sub>	<i>w</i> <sub>12</sub>	<i>w</i> <sub>1<i>j</i></sub>	<i>w</i> <sub>1<i>m</i></sub>	...	...	...
2	<i>w</i> <sub>21</sub>	<i>w</i> <sub>22</sub>	<i>w</i> <sub>2<i>j</i></sub>	<i>w</i> <sub>2<i>m</i></sub>	...	...	...
<i>i</i>	<i>w</i> <sub><i>i</i>1</sub>	<i>w</i> <sub><i>i</i>2</sub>	<i>w</i> <sub><i>i</i><i>j</i></sub>	<i>w</i> <sub><i>i</i><i>m</i></sub>	...	...	...
<i>n</i>	<i>w</i> <sub><i>n</i>1</sub>	<i>w</i> <sub><i>n</i>2</sub>	<i>w</i> <sub><i>n</i><i>j</i></sub>	<i>w</i> <sub><i>n</i><i>m</i></sub>	...	...	...
Σ <i>w</i> <sub><i>j</i></sub>	...	...	...	...	Σ <i>w</i> <sub><i>i</i><i>j</i></sub>	...	...
<i>I</i> <sub><i>j</i></sub>	...	...	...	...	...	...	...
<i>Y</i> <sub><i>j</i></sub>	...	...	...	...	...	...	...

Note: *w* – assessment of the intensity of impact for each criterion of processes; *n* – the number of indicators of the criterion; *m* – the number of indicators for assessing the state of the object of study; *I* – the total strength of the impact of the planned activities on the environment; *Y* – an integral indicator of environmental impact assessment

The algorithm for quantifying environmental impact assessment indicators of the planned activity is implemented as follows:

– Step 1. An assessment of the intensity of impact for each criterion of processes (*w*<sub>*i*</sub>) that have an impact on the environment is carried out. To do this, determine the final point score (*K*<sub>*b*</sub>) of each criterion by the formula:

$$K_b = \sum_{i=1}^n (P_i + L_i + A_i + M_i + F_i + T_i + N_i) \cdot Z_i, \tag{1}$$

where *P*<sub>*i*</sub> is the assessment of the danger of the impact of the *i*-th indicator of the criterion;

*L*<sub>*i*</sub> is the assessment of the fulfillment of legislative and regulatory requirements for the *i*-th indicator of the criterion;

*A*<sub>*i*</sub> is the assessment of public opinion on the *i*-th indicator of the criterion;

*M*<sub>*i*</sub> is the assessment of the scale of influence of the *i*-th indicator of the criterion;

*F*<sub>*i*</sub> is the assessment of financial costs to overcome the consequences of the impact of the *i*-th indicator of the criterion;

*T*<sub>*i*</sub> is the time or duration of exposure to the *i*-th indicator of the criterion;

*N*<sub>*i*</sub> is the use of new innovative technologies;

*Z*<sub>*i*</sub> is the assessment of the ability to control the *i*-th indicator of the criterion;

$$P_i, L_i, A_i, M_i, F_i, T_i, N_i, Z_i \in [0, 1, 2, 3].$$

Next, according to the resulting final point estimates, the intensity of the impact for each criterion of the processes is determined according to Table 2.

Table 2

Determining the intensity of the impact of the planned activities on the environment

Final evaluation of the criterion ( <i>K</i> <sub><i>b</i></sub> ), point	Degree/intensity of impact	
	Impact value, <i>w</i> <sub><i>i</i></sub>	Impact category
3–13	0	missing
14–24	1	weak
25–35	2	average
36–46	3	strong
47–57	4	very strong
58–63	5	critical

– Step 2. The significance of all influences (*γ*) for each criterion of processes in the matrix (Table 1) is determined by the formula:

$$\gamma = \frac{100}{R}, \tag{2}$$

where *R* is the number of significant cells in the matrix (in which *w* ≠ 0).

– Step 3. The total strength of the impact of the planned activities on the environment is calculated (*I*<sub>*i*</sub>):

$$I_i = \gamma \cdot \sum_{j=1}^m w_{ij}. \tag{3}$$

Similarly, the force of influence is determined horizontally *I*<sub>*j*</sub>. The obtained values are summed up horizontally and vertically in the matrix. Thus, the most intense actions are determined and objects that are the most sensitive and are most affected by the processes of the planned activity are identified.

The overall impact of the planned activities on the environment (*I*<sub>*ij*</sub>), in this case, is found by:

$$I_{ij} = \frac{\sum_{i=1}^n \sum_{j=1}^m w_{ij} \cdot \gamma}{S}, \tag{4}$$

where *S* is the total number of cells in the matrix.

– Step 4. The ratio of the obtained value to the maximum  $I_{max}$ , expressed as a percentage, determines ( $Y_i$ ), the level of the local impact of the planned activity process on the environment or the level of danger to the environmental component:

$$Y_i = \frac{I_i}{I_{max}}. \tag{5}$$

– Step 5. The integral indicator of EIA is determined by the generalized Harrington desirability function [12]:

$$D = \sqrt[m]{\prod_{i=2}^m d_i}, \tag{6}$$

where  $D$  is the generalized desirability  $D \in [0; 1]$ ;

$m$  – the number of indicators for assessing the state of the object of study;

$d_i$  – partial desirability;

$\prod_{i=2}^m$  is a function of the product  $d_i$  for all  $i$  from 2 to  $m$ .

The value of the indicators of the standard Harrington desirability scale is given in Table 3.

Table 3

Harrington standard desirability scale

Conclusion	Scale
Very good	1.0–0.81
Fine	0.80–0.64
Satisfactorily	0.63–0.38
Badly	0.37–0.21
Very bad	0.20–0

– Step 6. The integral EIA indicator ( $Y$ ) is calculated by the formula:

$$Y = \sqrt[m]{\prod_{i=2}^m Y_i}, \tag{7}$$

where  $Y_i$  is the level of the local impact of the planned activity process on the environment;

$m$  – the number of local indicators of environmental impact.

– Step 7. A conclusion is formed on the result of EIA based on transformed quantitative values of the integral indicator into a qualitative assessment based on the gradation of the intensity of the impact force.

This algorithm forms the mathematical basis of the developed electronic service, the interface of which will provide support for decision-making for quantitative assessment of the environmental impact of the planned activities of a business entity [14].

### 5. 2. Applying a design mindset approach to the development of an electronic service interface

The design mindset procedure in the modern world is an effective tool for the development of IT products. The effectiveness of the design mindset method is in the speed of implementation and mundaneness. Speed is achieved through prototyping and testing hypotheses in the initial stages of work. This significantly reduces the time for implementing solutions and further work on errors. Mundaneness is achieved due to the maximum possible objectivity of the developed solutions. This approach makes it possible to clearly plan the project, speed up prototyping, testing, and work on errors.

The application of the design mindset approach has made it possible to develop an interface for the electronic environmental impact assessment service ECEIA (Electronic Cal-

culator for Environmental Impact Assessment). This software product fully meets the requirements of all its users.

The development of the electronic service ECEIA by the design mindset method involved analytical research, the study of the issue of its necessity and relevance. For this purpose, the method of questioning based on the stakeholder approach was applied. The target audience in the study was business entities planning activities subject to environmental impact assessment. In addition, project organizations and construction companies, representatives of the interested public and government officials took part in the survey. The main problems faced by the respondents in their activities on environmental impact assessment were the lack of a unified assessment methodology, subjectivism in the assessment, and the inability to quantify EIA indicators. In turn, about 40 % of respondents saw a solution to these problems in the development of an electronic service. Regarding the main expectations from the development of an electronic service, 46 % of respondents identified the possibility of quick processing of information. And about 70 % of respondents believe that the service will be useful in preparing reports on EIA.

When establishing the level of need to introduce an electronic service for screening environmental impact assessment, the largest share of stakeholders chose the “need” and “very necessary” assessments. Based on the analysis of the obtained data during the survey, a logical-block diagram (Fig. 1) and a visual model (Fig. 2) of the prototype of the ECEIA electronic service were developed.

Thus, the applied design mindset method has made it possible, based on the results of a survey of stakeholders, to develop a prototype of electronic service for environmental impact assessment. That has allowed us to offer a modern, unique graphical design of the EIA ES interface without the use of common templates for all typical pages, interface elements, and text markup.

When implementing the graphical user interface, the requirements and recommendations for the placement of windows, tips, the appointment of control and function keys, etc. are taken into consideration. The interface provides the possibility of reverse user actions and various modifications for data recovery. Means of obtaining reference data on the possibilities of the electronic service of EIA are provided, and the possibility of receiving context-dependent prompts on the screen for the performance of operations and functions is provided. Navigation elements are executed in a user-friendly form (Fig. 2).

The general structure of the EIA electronic service includes two main blocks:

1. Block to start the work and enter general information (Fig. 3), which provides:

- entering information related to user identification;
- the creation of projects and representation of the necessary data for selection from the built databases on objects of two categories (transport construction and gas stations);
- counter of appeals to the program.

2. The result presentation block includes:

- quantitative assessment of the impact on each element of the environment;
- quantitative assessment of the impact of planned activities on the environment;
- proposals for making management decisions of the project;
- preservation of the obtained results;
- correction, deletion, updating, copying of stored information;
- presentation of analytical reports on the results of work.

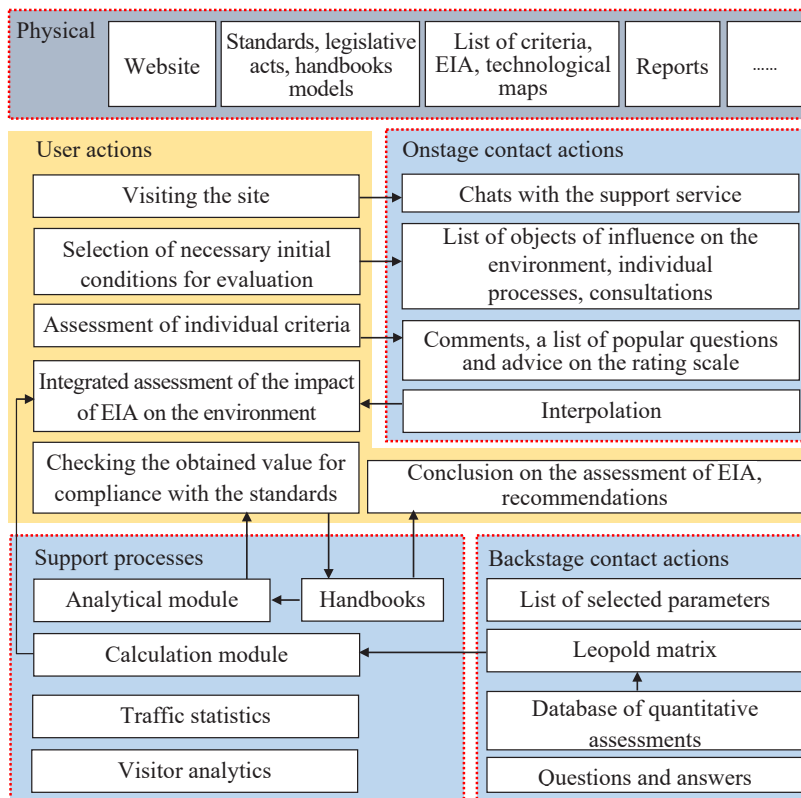


Fig. 1. Logical-block diagram of the prototype of the Electronic Service for Environmental Impact Assessment

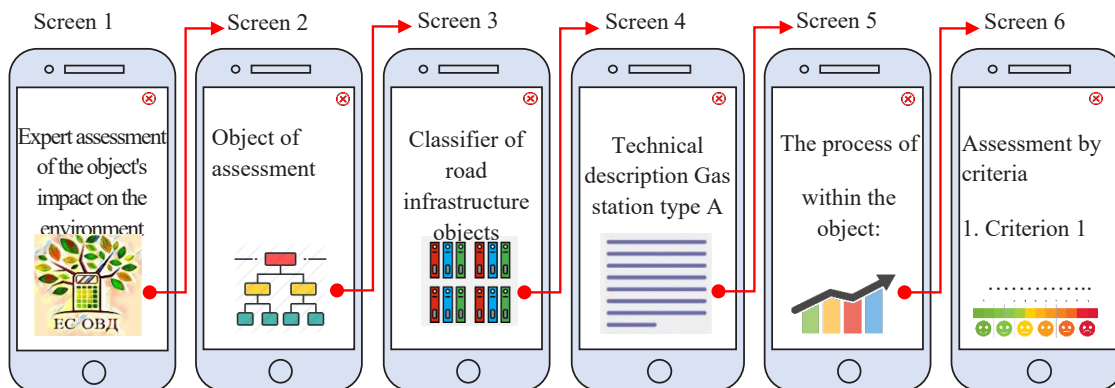


Fig. 2. Visual model of the prototype of the Electronic service for environmental impact assessment

The database “Criteria for environmental impact assessment” includes the following types of criteria:

- the quality of the surface layer of atmospheric air;
- resource-saving, energy saving;
- the quality of the aquatic environment;
- waste management;
- the quality of land resources;
- the quality of the geological environment;
- physical factors influencing the environment;
- biodiversity;
- social environment;
- man-made environment.

The algorithm that determines the order of work with databases, built on the basis of the design mindset approach, is shown in Fig. 4.

The interface provides a quick change in the structure of the EIA ES sections if necessary and editing the information content of the sections. It also provides for automatic visual-

ization of the obtained results of environmental impact assessment, collection, and processing of complete statistics of visits through the connection of Google Analytics tool (USA).

The software component, which provides integration with other systems, provides for the possibility of connecting an arbitrary number of external users. This is done by configuring access rights to information and determining other parameters necessary to establish communication with an external information system.

Logging into the service involves authentication and verification of users via HTTPS protocols, which ensures the confidentiality of information through its strong encryption. The main groups of users are given in Table 4.

Fig. 5, 6 show the start page of the prototype “Electronic service EIA ES” and the user registration window.

Input – output of data, reception of commands and display of the results of their execution are carried out in interactive/dialog mode (Fig. 7).

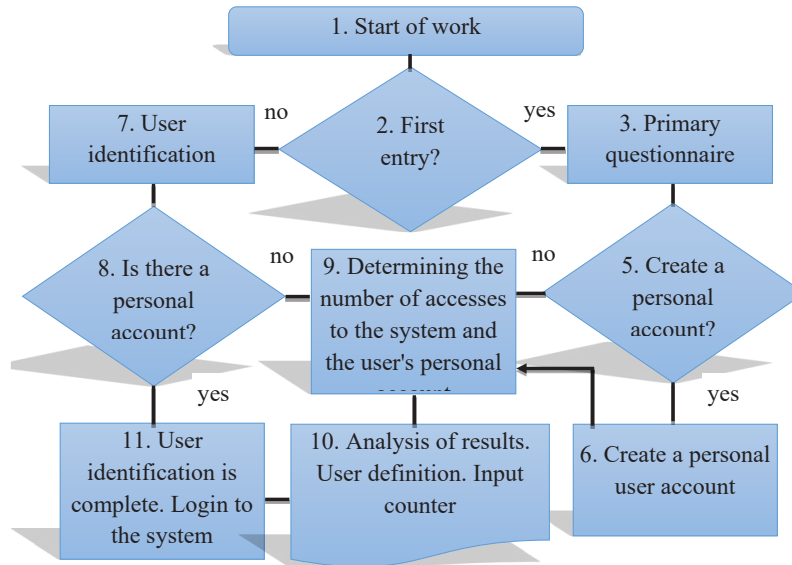


Fig. 3. Algorithm of block 1 "Getting started"

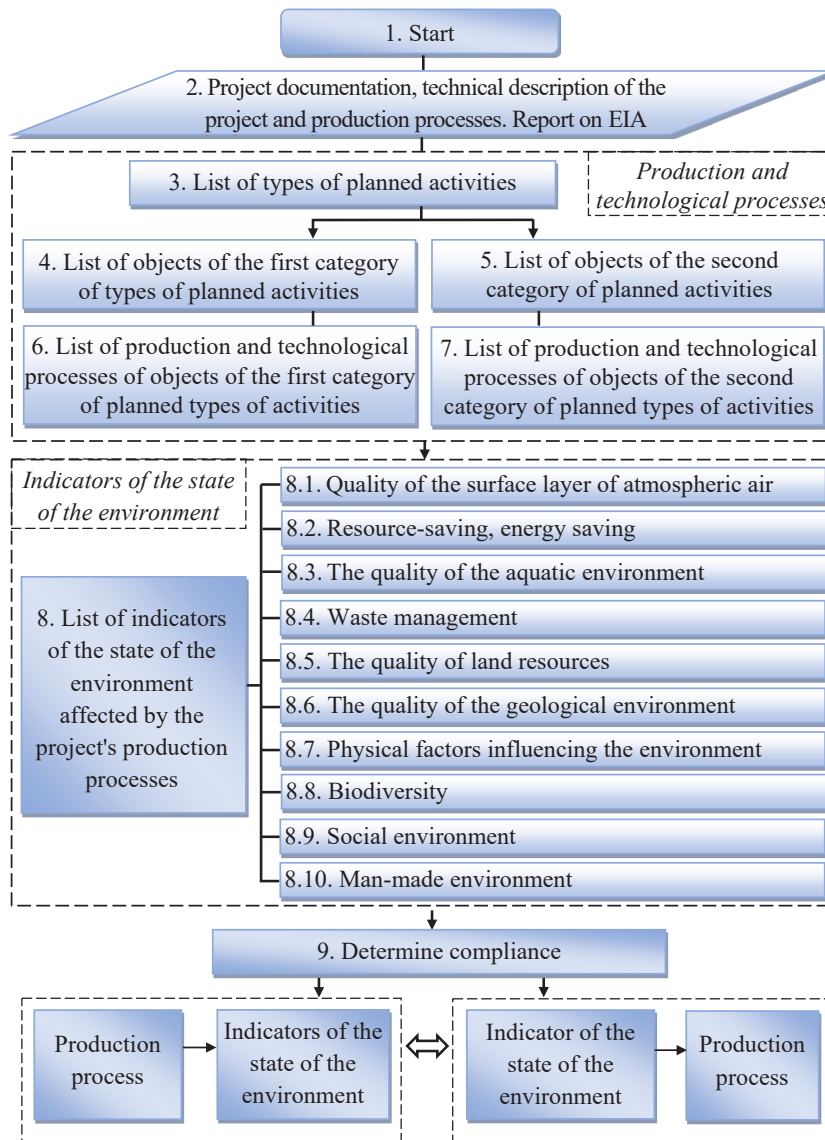


Fig. 4. Algorithm for selecting data for calculation from the database of the Electronic Service for environmental impact assessment

Table 4

Main user groups

User group	Access
Unauthorized users	<ul style="list-style-type: none"> <li>– review of the electronic service, the possibility of determining the impact on the environment without saving data by cadastral number;</li> <li>– familiarization with the regulatory framework for environmental impact assessment, on the basis of which the work of the electronic service is based;                             <ul style="list-style-type: none"> <li>– viewing text pages of the electronic service;</li> </ul> </li> <li>– downloading information on environmental impact assessment criteria and assessment method *.pdf and/or *.json;                             <ul style="list-style-type: none"> <li>– using the feedback form</li> </ul> </li> </ul>
Authorized users	<p>Authorized users are divided into «Users» of the system and «Legal entities». The powers of the latter include:</p> <ul style="list-style-type: none"> <li>– the possibility of adding/uploading information after its verification and approval by the administrator;</li> <li>– saving the results of environmental impact assessment and their further analysis.</li> </ul> <p>Also, all authorized users have access to information and functions that are available to non-authorized users</p>
Administrator of the electronic service	<p>Service part:</p> <ul style="list-style-type: none"> <li>– filling the electronic service with text information;</li> <li>– uploading data on environmental impact criteria and production and technological processes that exert this impact;                             <ul style="list-style-type: none"> <li>– confirmation of registration of authorized users;</li> <li>– viewing information about authorized users;</li> </ul> </li> <li>– review of information on an environmental impact assessment;                             <ul style="list-style-type: none"> <li>– management of page content and information exchange with third-party databases;                                     <ul style="list-style-type: none"> <li>– ensuring timely backup of files;</li> </ul> </li> <li>– setting user rights and creating new users;</li> </ul> </li> <li>– verification of data packets from authorized users and their publication;                             <ul style="list-style-type: none"> <li>– viewing the history of data transfer (data packets);</li> <li>– statistics of visits to the electronic service</li> </ul> </li> </ul>

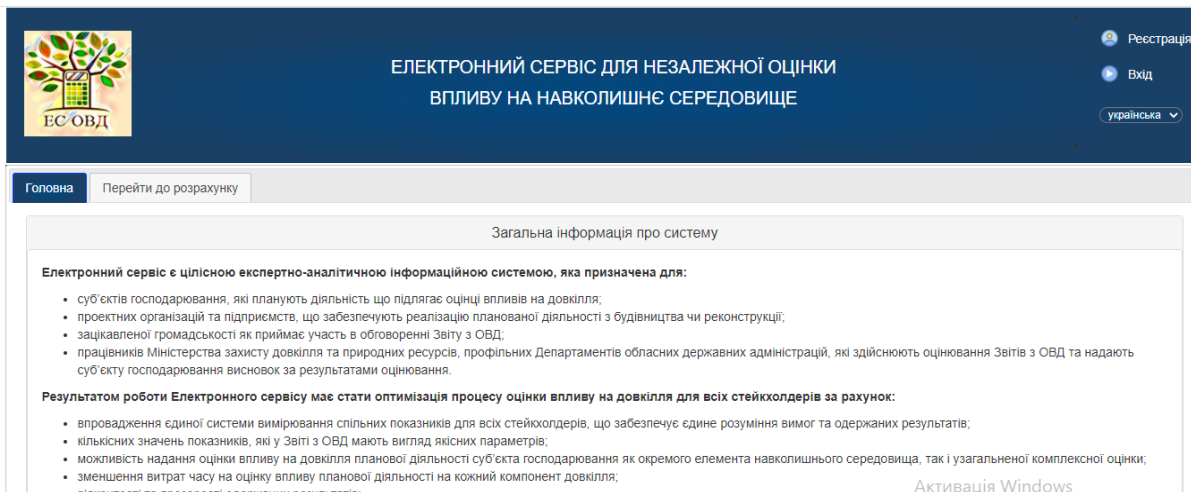


Fig. 5. Start page of the Electronic service for environmental impact assessment

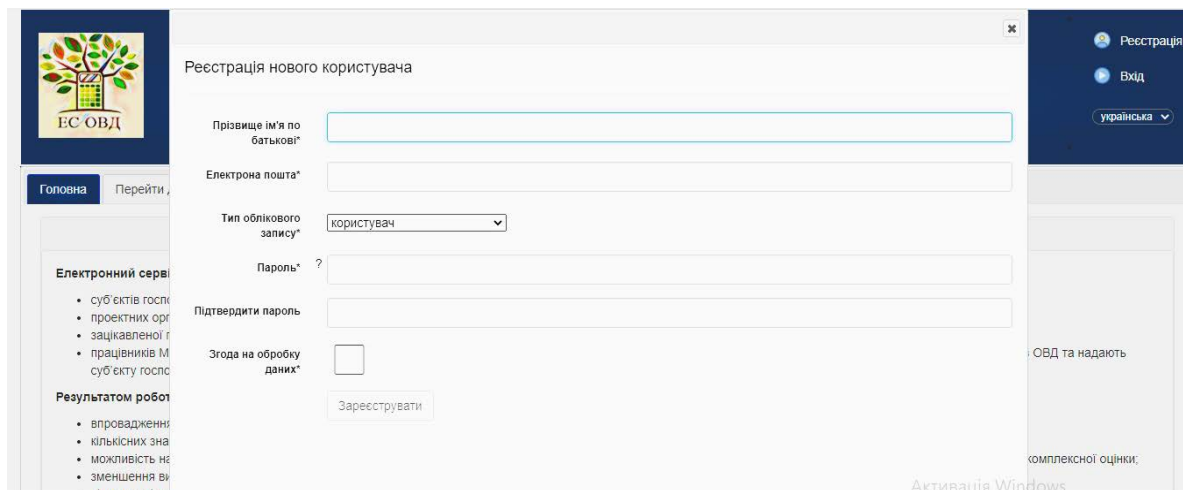


Fig. 6. Window for registration of a new user of the Electronic service for environmental impact assessment

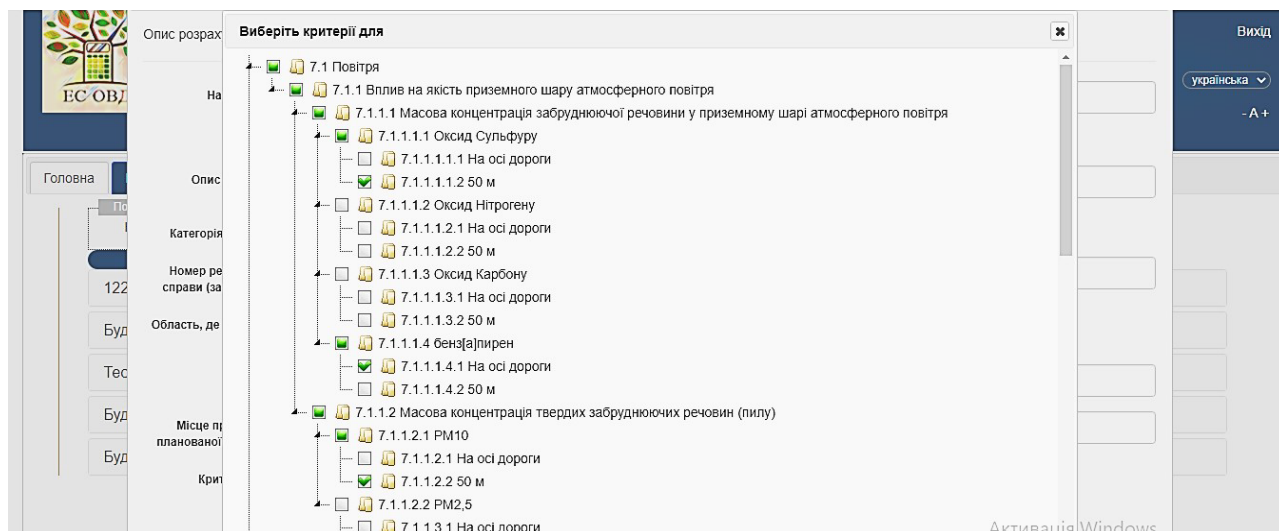


Fig. 7. Criteria selection window for entering indicators

The most important principles in the design and implementation of the EIA software product were modularity based on modular programming, interoperability (technical and semantic), openness, integrity, and data security. The interaction of the electronic service with the external environment is based on open protocols, and existing standards that define the unified structure and content of data in the field of environmental impact assessment.

**5. 3. Expert evaluation of the functionality and interface of the developed electronic service**

To determine the effectiveness of the EIA ES, an expert assessment of the functionality and interface of the developed electronic service was carried out. Five leading experts in the field of environmental impact assessment of the planned activities were involved in the assessment. The experts assessed the EIA indicators for a real project for the reconstruction of a section of a public road with a length of 5.1 km under a manual mode and with the help of service from [14]. At the same time, respondents were asked to evaluate the following indicators of the effectiveness of the EIA electronic service on a 10-point scale:

- speed of information processing;
- availability, convenience, and interface design;
- reliability of the calculation of criteria;
- full automation of calculations;
- the possibility of remote access;
- option to save results for further work (monitoring).

The results of the survey of experts were statistically processed by the method of concordance, which shows the consistency between expert opinions:

$$W = \frac{S_{kv}}{\frac{1}{12} e^2 \times (p^3 - p) - e \times \frac{1}{12} \sum (b_i^3 - b_i)}, \tag{8}$$

where  $W$  is the concordance coefficient,  $W \in (0;1,0)$ ;

$e$  is the number of experts;

$p$  is the number of service performance indicators evaluated by experts;

$b_i$  is the number of indicators, the assessment of which is repeated in a series for the  $i$ -th expert;

$S_{kv}$  is the sum of the squares of deviations:

$$S_{kv} = \sum_{i=1}^p \left( \sum_{j=1}^e G_{ij} - G_{mid} \right)^2, \tag{9}$$

where  $G_{mid}$  is the arithmetic average value of the service performance indicator.

According to the results of the survey, a consolidated matrix of ranks  $M(G_{ij})$  was compiled (Table 5).

The next step is to reform the matrix  $M'(G_{ij})$  to further determine the concordation coefficient (Table 6).

Table 5

Consolidated matrix of ranks of expert assessments  $M(G_{ij})$

Service performance indicator	Expert				
	1	2	3	4	5
Information processing speed	8	10	9	9	8
Accessibility, usability, and interface design	7	7	8	8	9
Reliability of criteria calculation	10	10	10	10	9
Full automation of calculations	10	10	10	10	10
Possibility of remote access	10	10	10	10	10
Option to save results for further work (monitoring)	7	8	8	9	8

Table 6

Reformatted matrix of ranks of expert assessments  $M'(G_{ij})$

Service performance indicators	Expert					Sum of ranks	$S_k$	$S_{kv(i)}$
	1	2	3	4	5			
Information processing speed	3	4.5	3	2.5	1.5	14.5	-3	9
Accessibility, usability, and interface design	1.5	1	1.5	1	3.5	8.5	-9	81
Reliability of criteria calculation	5	4.5	5	5	3.5	23	5.5	30.25
Full automation of calculations	5	4.5	5	5	5.5	25	7.5	56.25
Possibility of remote access	5	4.5	5	5	5.5	25	7.5	56.25
Option to save results for further work (monitoring)	1.5	2	1.5	2.5	1.5	9	-8.5	72.25
$\Sigma$	21	21	21	21	21	105	-	305

Note:  $S_k$  – absolute deviation of the sum of ranks



Calculate the concordation coefficient using (8):

$$W = \frac{305}{\frac{1}{12} \cdot 5^2 \cdot (6^3 - 6) - 5 \cdot 14} = 0.83. \quad (10)$$

According to calculations, it is obvious that the concordation coefficient  $W \neq 0$ . Thus, we can conclude that consistency between the opinions of experts is achieved. The obtained value of the concordation coefficient  $W=0.83$  confirms the high efficiency of the developed EIA service.

With the help of the built-in function "PEARSON" in MS Excel (USA), the obtained data from the calculations of the concordation coefficient were checked for adequacy. In this case, Pearson's calculated criterion was  $\chi^2=20.75$  and was comparable to the tabular one ( $\chi^2$ ) $_T=11.0705$ , which is defined for the number of degrees of freedom  $k=p-1=6-1=5$ , with a significance level of  $\alpha=0.05$ . The calculated value of the Pearson criterion is almost twice as large as the tabular one, so it can be argued that the determined concordation coefficient ( $W=0.83$ ) is not a random value, and the results obtained are reliable.

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#### 6. Discussion of results of the application of design mindset in the development of a prototype electronic service for environmental impact assessment

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The above algorithm for quantifying the environmental impact assessment indicators of the planned activities (1) to (7) is based on the methodical approach of combining the Leopold matrix (Table 2), (1) to (5), and the assessment of integral indicators by the Harrington desirability function (6) to (7) (Table 3). This algorithm is a mathematical basis for the development of modules for calculating the electronic service for environmental impact assessment. Unlike [1], where environmental impact assessment is carried out according to qualitative indicators, this algorithm makes it possible to move on to quantitative assessment.

The expediency of applying the design mindset approach in combination with the stakeholder approach to the development of a prototype electronic service has been substantiated. In particular, the interface of the prototype of the electronic service ES EIA according to this approach was based on an analytical study of the opinions of stakeholders. About 46% of respondents consider the prototype of the electronic service useful for quick processing of information on environmental impact assessment indicators. Unlike [9–11] where a design mindset is used taking into consideration the needs of end users, our result makes it possible to flexibly and comprehensively take into consideration the opinions of stakeholders (Table 4). This approach has made it possible to develop a logical-structural scheme (Fig. 1) and a visual model (Fig. 2) of the prototype of the electronic service ES EIA, which made it possible to implement its demo version (Fig. 3–7).

The effectiveness of the EIA ES was evaluated by the expert method on a 10-point scale (Table 5). Unlike [7–9], 5 experts in the subject area of environmental impact assessment were invited to the assessment. The results of the analysis of expert questionnaires were statistically processed by the method of concordation (8), (Table 6), due to which confirmation of the high efficiency of the developed EIA service was obtained. The calculated concordation coefficient ( $W=0.83$ ) (10) showed

a high level of consistency of expert opinions, was tested for adequacy according to the Pearson criterion at a level of significance  $\alpha=0.05$ .

The limitation of the use of the EIA electronic service is that its prototype is currently focused only on transport construction facilities and gas stations. Further development of this study is to cover a wider range of areas of the national economy and the possibility of interaction of databases on objects affecting the environment. However, the disadvantage of this study is to take into consideration the opinions of all-specialized experts in the implementation of the design mindset approach.

Our research and results on the EIA ES design will form the basis of a single integrated methodological approach to making a decision on the planned activities of a business entity.

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#### 7. Conclusions

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1. The algorithm for quantifying environmental impact assessment indicators of the planned activity, which is based on the use of the Leopold matrix and the Harrington desirability function, is given. This algorithm was used in the development of calculation modules in the electronic service for environmental impact assessment EIA ES.

2. A modern interface of the prototype of the Electronic service for environmental impact assessment has been developed. For this purpose, theoretical analysis and generalization of approaches of the scientific direction of design mindset regarding the design of the architecture of computer software systems were carried out. The positions of stakeholders on the need, timeliness, and accessibility of the development of electronic service for environmental impact assessment by questioning were assessed. The results of the analysis showed the complete relevance of developing a software package based on an algorithm for quantifying environmental impact assessment indicators of the planned activities.

Taking into consideration the positions of stakeholders, a logical-structural scheme and architecture of the prototype of the electronic service have been developed, which are based on the positions of ensuring flexibility, optimization, ergonomics, and accessibility of the interface and processed data. An algorithm for selecting data from the EIA database has been constructed to perform calculations of environmental impact assessment indicators.

3. Expert evaluation of the functionality and interface of the EIA ES has been completed. For this purpose, the experts carried out interim testing of the prototype based on a real project for the reconstruction of a highway. Based on the results of expert evaluation of the performance indicators of the electronic service, it was concluded that the design mindset approach is effective. The reliability of the obtained results of the study was checked by the Pearson criterion and the consistency of expert opinions – by the statistical method of concordation.

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#### Conflict of interest

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The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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