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FUZZY LOGIC MODEL OF USABILITY OF WEBSITES OF HIGHER EDUCATION INSTITUTIONS IN THE CONTEXT OF DIGITALIZATION OF EDUCATIONAL SERVICES

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The purpose of the study is to substantiate a fuzzy logic model for the usability of websites of higher education institutions in the context of digitalization of educational services based on the previous results of the stakeholder survey in accordance with the selected criteria: loading speed, convenience, efficiency, relevance, accessibility, interactivity, cross-browser compatibility, lack of forced content, attractive design, satisfaction. The research methodology is based on the results of the previous scoring of personal data and fuzzy logical conclusions of stakeholders regarding the convenience of using the websites of higher education institutions. As a result, a model of fuzzy logical inference was substantiated and implemented in the Fuzzy Logic Toolbox MatLab environment according to the Mamdani algorithm based on 180 constructed rules. As a result of a study of eight institutions of higher education, the degree of usability of their sites was determined and a quantitative assessment of usability was obtained. The scope of application of the modeling results concerns the possibilities of providing a more accurate understanding of the directions for making further management decisions regarding improving the usability of the

site in order to provide quality educational services within the boundaries of the existing online interaction of higher education institutions and their stakeholders. In practice, the use of the developed model is an effective tool for ensuring the quality of educational services in the context of active digitalization of the functioning of higher education institutions.

Keywords: *fuzzy logic model, Mamdani fuzzy inference system, website usability, higher education institutions, quality assurance of education, digitalization*

JEL Classification: C51, I21, L86

Introduction

In the modern world, the promotion of educational services occurs mainly in the vastness of the global Internet. Today, each institution of higher education has its own website, which is its calling card both nationally, internationally and educational society. It is the site that allows the institution of higher education to demonstrate the activity of actions, the results of events, foster informal communication and exchange of experience, keep in touch with all stakeholders, ensure the learning process, demonstrate competitive advantages, and so on. Social research has confirmed that official websites are the main source of information for applicants when they choose their future specialty and educational institution.

In addition, in the context of a pandemic and quarantine restrictions, the activities of the predominant number of socio-economic processes have moved from the offline environment to the online environment. And only those subjects, whose information content and structure of sites meet the requirements of the present and the interests of stakeholders, quickly adapted to the new operating conditions. Institutions of higher education are no exception, the limited resources and information transparency of which hindered the development of their online image. The activation of distance learning in the context of reforming the education system in Ukraine has revealed the consequences of the informational limitations of the online functioning of higher education institutions. First of all, it is the important role of the convenience of using the websites of higher education institutions. Convenience of using characterized mainly subjectively in terms of qualitative and technical indicators or parameters, therefore it is difficult to quantify.

Related works

The importance of the website and its usability is difficult to overestimate for the activities of a higher education institution, and this has long been proven by specialists [1]. The theory and practice of researching the usability of websites has been developing for more than two decades [2, 3]. However, the very concept of usability remains quite subjective [4], meaning and interpretation significantly depend on the group of researchers, their awareness, age [5], preferences, culture, and so on. The subjectivity of the definition of the essence of this concept affects the substantiation of the criteria by which it is assessed, therefore, today specialists have identified a wide list of features, criteria, and parameters of site usability [6, 7].

At the same time, the choice of research methodology remained a difficult issue. Quite popular are test and sociological research, expert and rating analysis of web content, cognitive methods, methods of verbal study of the protocol, main components, critical discourse, regression and others [7-13]. In addition, some researches are devoted to the use of AWUSA [14], ANFIS [15] for studying the usability of sites. With the active spread of digitalization, the importance of having a high-quality website has increased significantly; this has become sensitive in some sectors of the economy. The format of distance learning in institutions began to actively influence the quality of educational services. All subjects of education felt the burden and limitations in the provision of educational services when the emphasis of activities shifted from offline to online environment during the period of quarantine restrictions, which is described in [16, 17]. At the moment, it remains unresolved to ensure the usability of the websites of educational institutions in terms of the ambiguity of the concept, broad methodology and subjectivity of assessing the features of the provision of educational services, which in the conditions of Covid-19 significantly hinders the functioning of institutions.

Statement of the research task

The purpose of the article is to study the usability of websites of higher education institutions by means of fuzzy logical inference in the context of digitalization of educational processes.

Results

In the context of the existing competition for the main stakeholders of the educational process (potential applicants), the requirements for the content of the websites of higher education institutions, work efficiency, the use of modern services and platforms in order to improve navigation, design, interactivity and visibility in the Internet are becoming more demanding [18, 19]. The concept of "usability" is responsible for the convenience and ease of use of the site.

In accordance with the International Standard ISO 9241-11 [20], usability is characterized as the measure or the degree to which a certain object or subject is used productively, effectively, with pleasure in achieving a certain goal. The founder and one of the leading usability consultants is the Danish researcher Nielsen J. In his numerous publications, he considers usability as a qualitative characteristic that determines how easy the user interface is to use [2, 3]. Therefore, the main task of usability is to protect the rights of users and fight for simplicity. Thus, on the one hand, usability is a method of quality control and assurance, and on the other hand, it is a system of concepts that should ensure the power of a person over what he has created [2, 3].

Aziz N., Kamaludin A., Sulaiman N. [18] consider usability to be the main factor that determines the success of a website. In their understanding, usability encompasses not only the user interface, its ease of use, but also the informational meaning, the functionality of the website. The core of the concept of usability is human interaction with a standard software product, and therefore, it has three main components: the users themselves, the achievement of goals by users, and the use of the software product. Usability determines how easily a user without special training can interact with the information system of a website. Thus, the goal of usability is to have a product that is easy to understand, easy to learn, efficient to use, and enjoyable to use.

The paper [21] analyzes various published definitions of usability. The authors revealed that the most common attributes of usability in the 37 studied definitions are efficiency, effectiveness, flexibility, learning ability, memorability and satisfaction.

A distinctive feature of the websites of higher education institutions is that they have a non-profit orientation, are

communicative, informative, aimed at the most effective presentation and positioning of the institution in the information space among all groups of stakeholders. Hornbæk K. characterizes the usability of a website of a higher education institution as a combination of software and technical characteristics, design and navigation [22]. At the same time, the site design is responsible for the association of users with the institution of higher education, navigation displays the structure of information presentation for the user, software and technical characteristics are responsible for the functionality and viability of the site. Together, these parameters determine the quality of the user's experience in a particular online environment.

In the context of increasing competition in the market of educational services, educational institutions, together with the information content of the site, should also take care of the convenience of working with it. The usability of the website of an institution of higher education is considered in the context of providing a convenient structure, navigation, search, and correct operation of links. The authors emphasize that the websites of higher education institutions do not have a commercial focus, while methods of improving usability, as for commercial institutions, should be based on behavioral analysis and consumer surveys.

Consider the criteria, the fulfillment of which will ensure a high level of usability of any website.

Nielsen J. identifies five quantitative components of usability [2, 3]:

1) the ability to learn (the component is responsible for the ease of completing tasks by users who first met an unfamiliar interface);

2) efficiency (the component is responsible for the speed at which the task is completed by users after getting acquainted with the design of the site);

3) memorability (the component determines how easy it is for the user to restore the skills of working with the site after a certain period of time);

4) errors (the component is responsible for the number of errors that the user makes during the achievement of the goal, how easily the user can correct these errors);

5) satisfaction (how pleasant the user is to use the site).

Wang J., Senecal S. [23] believe that three dimensions are sufficient to assess the usability of a website:

1) ease of navigation (responsible for the level of effort required to complete specific tasks);

2) speed (the loading time of the home page should not be harmful to the evaluation of the website);

3) interactivity (characterizes the level of communication capabilities of the site).

Aziz N., Kamaludin A. and Sulaiman N. [18] proposed a usability model, the criteria of which are efficiency, productivity, learning ability, satisfaction, and accessibility.

Separate works are devoted to the study of usability criteria for the websites of higher education institutions. So, the authors of the research [24] point to the need to take into account usability criteria when developing an educational portal, studying consumer behavior and the impact on the image of an educational institution. At the same time, when conducting a usability analysis, one should take into account such criteria as the easiest site menu for the user, easy search for information, connections between sections, the ability to return to the main page of the site, that is, the overall convenience and comfort of working with the website is assessed.

The authors of the research [1] emphasize the need for periodic internal monitoring of the website by the educational institution in order to identify its compliance with the objectives of the institution of higher education and modern requirements put forward by stakeholders. One of the requirements is adherence to the usability approach, which includes the site menu as easy as possible for the visitor, easy search for information for all stakeholder groups, the ability to return to the home page, the presence of a calendar and an archive of information.

Parnenko V. in the paper [25] examines the criteria for meeting usability standards of technical institutions of higher education. We take into account such groups of criteria as the convenience of the interface (readability of fonts, highlighting of links, rational distribution of space, correct display of video materials), the business logic of the site structure (determination of the user's location, the presence of an “entry point” and “return button”, ease of registration), evaluation of information (correctness and ease of navigation), evaluation of the main page (content of the main page of the site). It is

these criteria, in the opinion of the author of the article, that determine the quality of the user's work with a particular website.

At the same time, it is advisable to take into account precisely the group of stakeholders, from the point of view of which the site is assessed. In the previous research [26], according to the specified criteria, a questionnaire was developed and a survey was conducted of 1170 stakeholders of higher education institutions – students and applicants, the overwhelming majority of whom (about 70%) choose an institution for training using the website. The above made it possible to begin to form statistics of the initial data, even taking into account their subjectivity.

Due to the fact that the criteria for the concept of usability are characterized by a subjective component, they do not lend themselves to precise mathematical interpretation, are rather vague and vaguely defined. Therefore, to substantiate the quantitative value of usability, it is advisable to use the methodology of fuzzy mathematics, the use of which for modeling various processes is given, for example, in [27].

According to the interviewed stakeholders, the criteria that form the level of usability of the websites of higher education institutions and will be the input parameters of the fuzzy logic model include: x_1 – loading speed; x_2 – convenience; x_3 – efficiency, x_4 – relevance; x_5 – accessibility; x_6 – interactivity; x_7 – cross-browser compatibility; x_8 – lack of forced content; x_9 – attractive design; x_{10} – satisfaction.

As input parameters of the model, the ratio of the scores obtained for each usability criterion to the maximum possible number of points for a separate criterion is used. The results of preliminary calculations are given in [26]. Thus, the normalized indicators of the criteria for each of the sites of higher education institutions were obtained (Table 1).

Output parameter of the model is the indicator of the website usability I_{us}.

The terms of the specified input and output linguistic variables are defined as fuzzy sets [27]:

$$T_i = \{(x, \mu_{Ti}(x)) : x \in X, \mu_{Ti}(x) \in [0;1]\}, \quad (1)$$

where $\mu_{Ti}(x)$ – membership function of corresponding fuzzy set. A symmetric Gaussian form of the membership function was chosen

for both input and output variables, which is due to the flexibility and simplicity of the function, since it is set only by two parameters:

$$\mu_{Ti}(x) = e^{-\frac{(x-b)^2}{2c^2}}, \quad (2)$$

where b – function maximum coordinate and $\mu(b) = 1$; c – standard deviation (concentration factor of symmetric Gaussian membership function).

Table 1

NORMALIZED INDICES OF THE INPUT PARAMETERS OF THE FUZZY LOGIC MODEL

Criterion	NTUU "Igor Sikorsky Kyiv Polytechnic Institute"	Taras Shevchenko National University of Kyiv	Sumy State University	Lviv Polytechnic National University	V.N. Karazin Kharkiv National University	Interregional Academy of Personnel Management	Kharkiv University	Academy of Advocacy of Ukraine
Loading speed	0,797	0,882	0,713	0,709	0,835	0,682	0,675	0,851
Convenience	0,795	0,548	0,780	0,575	0,372	0,584	0,578	0,630
Efficiency	0,852	0,769	0,785	0,840	0,504	0,805	0,781	0,510
Relevance	0,681	0,621	0,707	0,793	0,459	0,769	0,721	0,503
Accessibility	0,756	0,697	0,769	0,756	0,6	0,791	0,774	0,475
Interactivity	0,800	0,571	0,802	0,826	0,756	0,848	0,535	0,620
Cross-browser compatibility	0,875	0,595	0,906	0,880	0,526	0,915	0,889	0,595
Lack of forced content	0,872	0,897	0,897	0,889	0,889	0,906	0,863	0,889
Attractive design	0,808	0,545	0,761	0,838	0,499	0,818	0,607	0,543
Satisfaction	0,837	0,600	0,828	0,846	0,344	0,759	0,767	0,369

The model was implemented in the Fuzzy Logic Toolbox MatLab environment according to the Mamdani algorithm, in which the output variable is determined by the base of rules of the type

$$\text{IF } (x_1 \text{ IS } X_1^{(i)} \text{ AND } x_2 \text{ IS } X_2^{(i)} \text{ AND } \ldots \text{ AND } x_n \text{ IS } X_n^{(i)}) \text{ THEN } I_{us} = Y_k^{(i)},\ i = 1, \ldots, I, \quad (3)$$

where $X_1^{(i)}$, $X_2^{(i)}$,…, $X_n^{(i)}$, $Y_k^{(i)}$ – values from a term set that correspond to the i^{th} rule.

The defuzzification of fuzzy sets of the output variable according to the Mamdani algorithm is determined by the centroid method [27]:

$$y_k = \frac{\int_{\min}^{\max} y \cdot \mu_k(Y_k) dy}{\int_{\min}^{\max} \mu_k(Y_k) dy}, \quad (4)$$

where y_k – defuzzified value of k^{th} fuzzy set of output variable; $\mu_k(Y_k)$ – membership function of fuzzy set Y_k of output variable I_{us}; min, max – boundaries of the universe of variable I_{us}.

Thus, the level of usability of the websites of higher education institutions according to the Mamdani fuzzy inference algorithm is determined by the formula

$$I_{us} = \frac{\sum_{k=1}^{m} y_k \mu_k(Y_k)}{\sum_{k=1}^{m} \mu_k(Y_k)}, \quad (5)$$

where m – a number of fuzzy sets (elements of term set) of the output variable I_{us}.

To implement the algorithm, the domain of definition of the terms of input variables is given. Fuzzy sets with Gaussian membership functions $T_i = \{\text{N}, \text{S}, \text{D}, \text{V}\}$, i =1, 2, 3, 4, 10, that describe low, medium, sufficient and high levels of input variables x_1, x_2, x_3, x_4, x_{10}, are shown in Fig. 1.

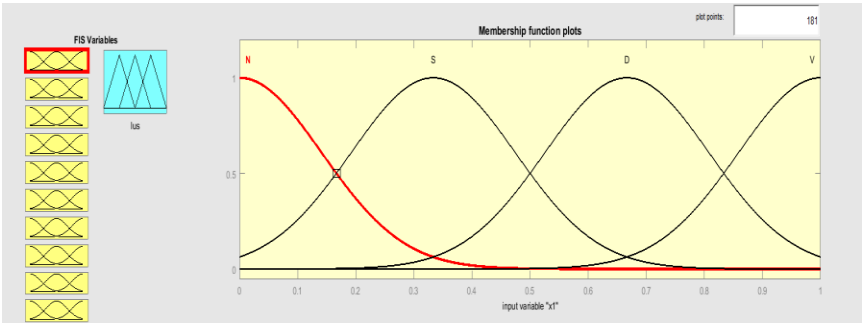

Fig. 1. Fuzzy sets with Gaussian membership functions of input variables x_i, i =1, 2, 3, 4, 10

Fuzzy sets with Gaussian membership functions $T_i = \{\mathrm{N}, \mathrm{S}, \mathrm{V}\}$, $i = \overline{5,9}$, that describe low, medium and high levels of input variables x_5, x_6, x_7, x_8, x_9, are shown in Fig. 2.

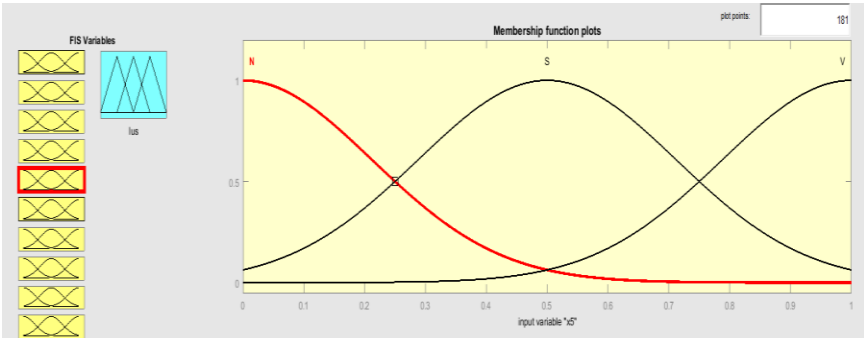

Fig. 2. Fuzzy sets with Gaussian membership functions of input variables x_i, i =5, 6, 7, 8, 9

The output linguistic variable I_{us} is the assessment of the site's usability level according to the formula (5), which is measured on the interval $[0,1]$. The linguistic output variable I_{us} is defined by the term set $T_{I_{us}} = \{\mathrm{NN}, \mathrm{N}, \mathrm{S}, \mathrm{D}, \mathrm{V}\}$, which are mean extremely low, low, medium, sufficient and high levels, respectively.

Output variable I_{us} in MatLab has the form shown in the Fig. 3.

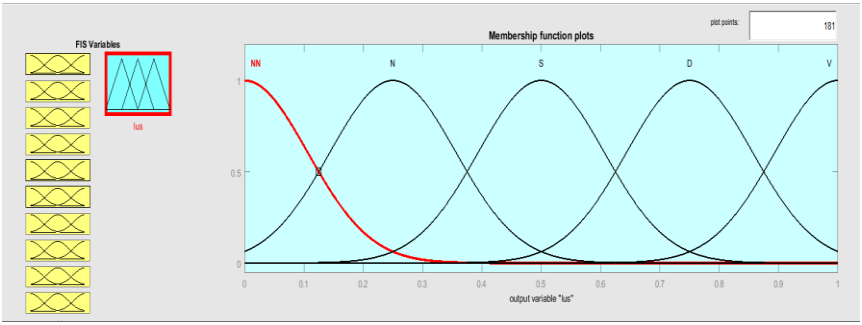

Fig. 3. Membership functions of output variable I_{us}

The Fig. 4 shows a block diagram of the Mamdani fuzzy logic inference system for assessing the level of usability of the website of a higher education institution.

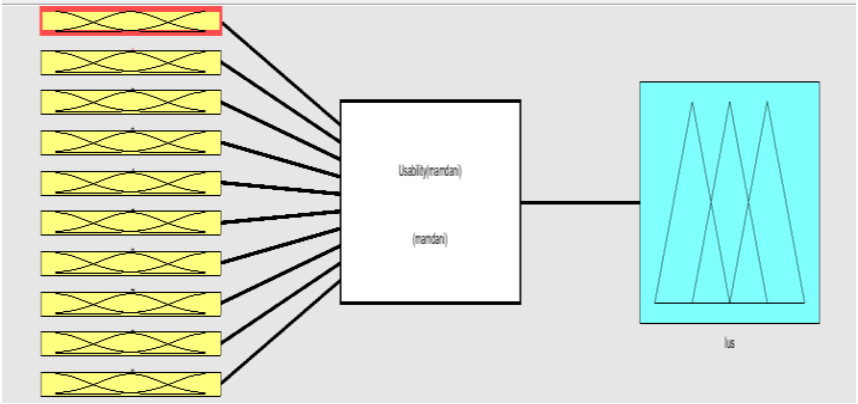

Fig. 4. Block diagram of the Mamdani fuzzy logic inference system for assessing the level of usability of the website of a higher education institution

The next stage in the construction of a fuzzy system according to the Mamdani algorithm is the formation of a base of fuzzy production rules, which contain the assessments of experts in the area under study. The total number of rules for such a base is determined by all

possible combinations of values of term sets of incoming variables. In our case, it will be a combination of four values {N, S, D, V} of five linguistic variables x_i, i = 1, 2, 3, 4, 10, and three fuzzy values {N, S, V} of five linguistic variables x_i, i =5, 6, 7, 8, 9. Thus, we have $4^5 \cdot 3^5$ =248832 rules. However, the number of production rules for inference of a fuzzy system cannot contain the full set of all existing options for fuzzy inference, otherwise the system will be deprived of flexibility, the ability to adapt to specific input data [19]. If there is no rule in the knowledge base that corresponds to the current values of the incoming variables, then the system will select a solution that is most suitable for the situation under study.

To build the rules of the knowledge base of fuzzy inference (Table 2), the terms of certain input variables x_i, $i = k_1, k_2, \ldots, k_l$, are fixed and the terms of other input variables x_j, $j = m_1, m_2, \ldots, m_r$, are varied, grouping them in accordance with one of five possible terms of the output indicator of the site usability level.

Table 2

THE COMPONENTS OF THE KNOWLEDGE BASE RULES OF THE MAMDANI FUZZY INFERENCE SYSTEM

Components of fuzzy inference production rules «IF»										«THEN»	Number of rules
x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	I_{us}	
N S D	N	N	N S	N S V	N	N S	N	N	N	NN	$3^2 \cdot 2^2 = 36$
N	N	N S D V	N	N	N	S	N S V	N S V	N	N	$4 \cdot 3^2 = 36$
D	S	S	S	S	N S V	N S V	V	S	N S D V	S	$3^2 \cdot 4 = 36$
D	N S D V	V	V	S	N S V	V	N S V	S	D	D	$4 \cdot 3^2 = 36$
S D V	V	V	V	V	V	S V	N S V	V	S V	V	$3^2 \cdot 2^2 = 36$

Thus, 180 production rules have been entered into the knowledge base of Mamdani fuzzy inference, which will make it possible to obtain a quantitative assessment of the level of usability of sites for any current values of the input variables. Fuzzy inference estimates obtained from the research results are shown in Fig. 5.

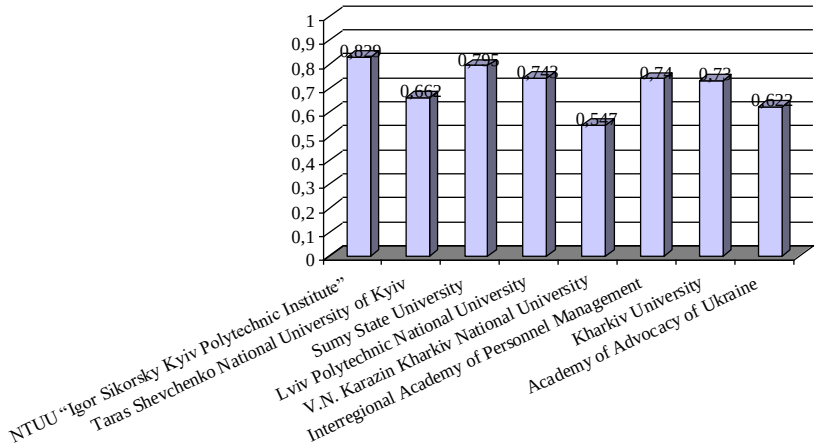

Fig. 5. Estimates of the output indicator of usability of the websites of higher education institutions I_{us}

It was revealed that website of NTUU "Igor Sikorsky Kyiv Polytechnic Institute" has a high level of usability, sites of Sumy State University, Lviv Polytechnic National University, Interregional Academy of Personnel Management, Kharkiv University, Taras Shevchenko National University of Kyiv are at a sufficient level, sites of Academy of Advocacy of Ukraine and V.N. Karazin Kharkiv National University have an average level.

Conclusions

The paper proposes an approach to assessing the usability of websites of higher education institutions using the apparatus of fuzzy logic. The input variables of the constructed model are usability criteria, the output linguistic variable is an indicator that characterizes the usability level of the websites of higher education institutions. The

form of a symmetric Gaussian membership function is chosen for both the input variables and the output one, which is due to its sufficient flexibility and ease of use. The model was implemented in the Fuzzy Logic Toolbox MatLab environment using the Mamdani algorithm. As input parameters of the model, we used the results of our earlier sociological survey of 1170 stakeholders of higher education institutions in a questionnaire format, in particular, the ratio of scores obtained for each usability criterion to the maximum possible score for one criterion.

A base of 180 fuzzy production rules has been formed, which contains a fuzzy logical inference mechanism, which allows us to draw a conclusion about the level of usability of the website of a higher education institution. The simulation results provide a more accurate understanding of the directions for making further effective management decisions regarding the ease of use of the site.

The values of the usability indicators of the websites of higher education institutions, obtained by the method of fuzzy inference and the method of taxonomic convolution of the scores of the results of the stakeholder survey, correlate with each other. It was revealed that site of NTUU "Igor Sikorsky Kyiv Polytechnic Institute" has a high level of user friendliness, sites of Sumy State University, Lviv Polytechnic National University, Interregional Academy of Personnel Management, Kharkiv University, Taras Shevchenko National University of Kyiv have a sufficient level, sites of Academy of Advocacy of Ukraine and V.N. Karazin Kharkiv National University have an average level.

The prospect for further research is the development of the monitoring system and the collection of a knowledge base regarding the usability of the websites of higher education institutions. Improvement of the research methodology by the method of constructing a model of fuzzy inference is envisaged to be done by eliminating subjectivity and generating input data in terms of scoring.

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