

DETECTION OF ACCESSIBILITY AND QUALITY OF WEBSITES OF THE LEADING UNIVERSITIES OF THE WORLD

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ABSTRACT

Accessibility level of websites of leading educational institutions' websites has been determined through analysing compliance with the levels of accessibility under WCAG 2.1; the results obtained enable to develop hierarchical model of accessibility evaluation taking into account criteria and sub-criteria factors. Qualitative formation of the electronic system of education in fundamental and technical disciplines shall enable to provide students, regardless of health defects, with high-quality education, ensuring development of European countries in the sphere of science in accordance with international standards.

High quality of the websites of the following educational institutions has been detected: 3% for the University of Michigan Ann Arbor and 6% for the University of Cambridge, for other educational institutions it is in range from 13% to 38% (for 40 scanned pages). The website of U701 University for 100 scanned pages is characterized by minimum of 9% accessibility, 2% compatibility and 31% compliance with web standards. Massachusetts Institute of Technology has 35 pages with the problem of accessibility. National Technical University "Ihor Sikorskyi Kyiv Polytechnic Institute" has 22 pages with accessibility problem. Low accessibility level has been detected at Lviv Polytechnic National University; it has 80 pages of the website with problems for users, including those with disabilities. The proposed hierarchical model of evaluation of quality of websites by criteria and sub-criteria factors shall form accessible websites to users, improve access to them regardless of functional disorders, reducing the duration and effort to search for information.

Keywords: WCAG 2.1, AA level, SortSite, website, W3C, hierarchical model

1. INTRODUCTION

Implementation and ensuring accessibility of websites, regardless of the country of development, is an important academic and practical task of many organizations of any form of ownership, including : educational institutions, healthcare institutions,

retail chains, etc. Moreover, web pages should be accessible not only anywhere in the universe, but also to any user, even those with disabilities. According to data of World Health Organization (WHO), 6 to 10 of every 100 people live with some limitation or even lack of certain abilities due to various disabilities in comparison to a healthy

person [1]. According to data of World Wide Web Consortium (W3C), the main difficulties are related to slow connection to the Internet, partial mismatch between accessibility of web environments and platforms for equal use by users [2].

The main purpose of academic websites is to provide future students with opportunity to learn information of the institution, the courses offered, the curriculum of each course, admission requirements, consulting services, library services, employment opportunities, news updates etc. These services shall help leading universities improve service delivery and increase student participation, as well as improve the decision-making process as to which university to apply to. Ensuring accessibility of websites shall help universities to improve providing the information, improve potential participation of students in their use, the decision-making process in the course of choosing the university for admission.

Aspects of society need the accessibility of information technology, especially: people with special needs, regardless of the level of technology development of countries and digital society strategies do not have complete access to electronic information. Ensuring high-quality accessibility of websites, including leading universities for all users, especially categories with disabilities, is a matter of time nowadays. The main thing for many countries of the world is following: to overcome the problem of accessibility of information resources created by educational institutions in capacity of institutions responsible for development of websites, storage and large-scale transmission of socially important information. Ensuring high-quality accessibility of websites forms a scientific and practical task that requires the use of modern algorithms, taking into account scientific and methodological bases, level of development of information technology and user needs. So that, there is a need for research and development aimed at identifying innovative ways to increase accessibility of various websites, including leading educational institutions with maximum compliance with international standards. One of ways to ensure quality of accessibility of websites is to analyse the existing sites of leading universities in accordance with international levels of accessibility, with subsequent search for innovative ways to ensure accessibility of information resources. The creation of universal models and algorithms for evaluating the websites of leading educational institutions shall enable to actually obtain a set of systematized solutions based on taking into account of sub-

criteria, criteria and impact on the final quality of web content.

In the work [3], the results of analysis of the quality of websites based on the example of educational institutions by group of experts who noted low quality of providing information to users, especially in the framework of unprecedented changes in the education system. The reasons for this may be the low level of compliance of websites with international standards and rapid development of the COVID-19 pandemic, leaving the issues of providing a new 'e-learning' education system not fully covered. Websites are characterised by great interest to the segments of population in various fields, including education, as our daily lives are based on electronic technologies and communications on social networks. Ensuring of new education system in a pandemic requires analysing the accessibility and quality of websites for users, regardless of opportunities and disabilities. In the works [4, 5], it is noted that the load of all websites, regardless of ownership, increases. This emphasized the need to ensure full access to any information, according to the needs of the users. The use by educational institutions of virtual communication between the teacher and the audience through various platforms (for example, LMS) does not enable to make completely the following: provide, ensure and control the quality of provision and assimilation of information. Moreover, sharp transition from face-to-face presentation of scientific and practical skills from teacher to student with subsequent teaching in electronic form has required a rapid increase in the accessibility of websites and the Internet in general. The variant to overcome these difficulties may be as follows: to create a variety of algorithms for determining quality of websites, but the information technologies are developing much faster than the latter. This provides grounds to assert expediency of conducting practical research in the situation of nowadays for formation of universal methods for evaluating quality of web content, taking into account the main criteria and sub-criteria in order to ensure a quality level of information.

In the work [6], the researches are presented aimed at determination of the accessibility of university websites, in particular in Turkey, with the subsequent identification of the main shortcomings, among which the most common shortcoming is about access to the Internet, which essentially complicates the further use of websites. So that, most universities were not ready for such a drastic transformation in methods of teaching,

emphasizing the feasibility of research in this area in order to ensure the highest quality access to information resources of higher education institutions.

The need to ensure quality of website accessibility provides grounds to assert the feasibility of research to determine the accessibility and quality of websites according to the standard Web Content Accessibility Guidelines (WCAG) 2.1 [11], established by the W3C. Essential attention should be paid to the component of the analysis of criteria and sub-criteria in the framework of formation of universal algorithms and models that combine scientific and practical solutions to the problem of ensuring high-quality accessibility of websites. Analysing and implementing innovative models in order to ensure quality of websites shall provide full access of the users to various areas, including education. It should be noted that the use of accessible websites with professional and social multimedia in educational institutions is an act of social justice, which increases the prospect of independence of users with the feeling of a full-fledged person. So, using the WCAG 2.1 standard will allow to determine the level of quality of accessibility of websites of higher education institutions in accordance with the requirements of the W3C. At the same time, leaving unresolved the issue of forming a sound scientific and practical methodology taking into account the influence of criterion and sub-criteria factors that have a significant impact on the final quality of sites. This, in turn, determines the feasibility of research to identify the availability of websites of higher education institutions and the formation of universal algorithms, models for quality assurance and compliance with international standards.

The purpose of the study is to determine accessibility of websites on the example of websites of higher education institutions, by analysing web pages in accordance with international requirements and standards for WCAG 2.1 under AA level of accessibility. Development of the hierarchical model of criteria and sub-criteria evaluation of website quality shall provide the algorithm for creating high-quality websites for all users, regardless of limited properties.

In order to achieve this goal, the following was tasked:

– to analyse the overall quality of websites of higher education institutions according to WCAG 2.1 on the level of accessibility of AA and the

program SortSite Professional (Edinburgh, United Kingdom);

– to analyse web pages for accessibility, browser compatibility, compliance with web standards, and give an example of error map visualization;

– to develop the hierarchical model of criterion and sub-criteria evaluation of websites quality in order to ensure formation of qualitative-accessible website.

The hypothesis of scientific and practical research is that the preconditions are to determine the level of accessibility of the websites of leading educational institutions through analysis according to WCAG 2.1, with the subsequent implementation of the results obtained in a hierarchical model for assessing the quality of websites by criteria, sub-criteria factors. This will improve the accessibility of sites to users, regardless of functional impairments, reducing the duration and efforts to search for information.

2. MATERIALS AND METHODS

The WAI (Web Accessibility Initiative) within the World Wide Web Consortium (W3C) is constantly improving the document entitled "Website accessibility Guidelines". One of the documents, Web Content Accessibility Guidelines (WCAG), is a set of accessibility standards guaranteeing full provision of users with disabilities with a quality level of content accessibility [11]. WCAG is implemented by grouping recommendations according to the following principles: perception, manageability, clarity and reliability, which generally makes accessibility of web content for the user, even with disabilities.

The purpose of these guidelines is to promote and make the access to the Internet accessible for people with various chronic disabilities of with disabilities emerged during life. Application of the guidelines is directly related to the source code of the web page, therefore these principles should be considered during the website development phase. These four principles are divided into twenty-nine guidelines. According to each guideline, the series of performance criteria designed to facilitate WCAG 2.1 compliance testing shall be checked.

Each recommendation has its own level (A, AA, AAA), which determines accessibility of the interface (table. 1). The larger A, the better: $A < AA < AAA$. It is said that the interface complies with WCAG 2.1 AA if all A and AA recommendations are implemented. Achieving a

Table 1: Levels of compliance with WCAG performance criteria 2.1

Accessibility level	Symbol	Description
Low accessibility	A	Designed websites shall meet this level of success criteria. Since auxiliary technology may not provide read and control of the page or view. As a result, one or more groups of people with disabilities shall be unable to access the information on the website. Achieving this level is a basic requirement for web pages to ensure accessibility.
Average level of accessibility	AA	Designed websites shall meet this level of success criteria. This level of accessibility should provide access to the state-owned websites of European countries. Adherence to the AA level shall enable to remove important barriers to accessing web pages.
High level of accessibility	AAA	Developed websites may meet this level of success criteria. Adherence to this level shall improve access to web pages and usually requires adherence to parts of websites and web applications serving a specialized audience.

high level of compliance is desirable, but not always possible.

The latest version of WCAG 2.1, published on 5 June 2018, contains a combination of the requirements of previous versions, including WCAG 1.0 and 2.0, since each updated version adds new recommendations to the existing one. The previous version of WCAG 2.0 has been adopted as the ISO standard (ISO/IEK 40500: 2012) [12], and WCAG 2.1 has been adopted as the European standard for accessibility of information and communication technologies (ICT) EN 301-549 [13]. EN 301 549 applies to all digital technologies, including websites, software, electronic devices and mobile applications. If there are any problems that prevent people with disabilities from accessing ICT, a government organization can be held liable for violating EN 301 549 [14].

The AAA level is not recommended to be selected as a general policy in web site development, because it is impossible to meet all AAA success criteria for specific content, according to W3C's Understanding Conformance [15].

The research used an automatic evaluation tool: SortSite (Edinburgh, United Kingdom); (PowerMapper Software [16]). SortSite enables you to check any website for accessibility, broken links, HTML and CSS standards, usability, search engine optimization, and browser compatibility. The advantage of the software is to check the

accessibility not only of the home page of the website, but also of the website as a whole.

The hierarchy analysis method (Analytic Hierarchy Process – AHP) has been used as a basis of scientific and practical methodology for determining the quality of web content according to the main criteria and sub-criteria [17]. AHP involves decomposing the problem into simple components and processing the judgements of the decision-maker; it combines the procedures of synthesizing many expert statements, obtaining prioritizing criteria, sub-criteria, and finding alternative solutions.

3. RESULTS AND DISCUSSION

Research on determining accessibility and quality of websites of leading higher education institutions is aimed directly at identifying in a particular country of the world without comparison with other countries. This is related to the following factors:

- quality of the implemented various regulations aimed at ensuring the accessibility of websites of higher education institutions and compliance with the international level;
- different levels of development of the information and digital system of each country in the world, which in turn complicates the comparative analysis between countries on the

quality of accessibility of websites of higher education institutions;

– analysis of ways to increase the accessibility of information to all users, regardless of human disabilities, ensuring the quality of knowledge directly to their nation in compliance with international standards.

The research is aimed at analysing the accessibility of websites of leading higher education institutions, especially in the context of a pandemic and transition to distance learning, which in turn shall ensure the quality of education at the international level. For reasonable sound study of sites to determine the accessibility and quality of websites of higher education institutions, a sample

from the world ranking of QS World University Rankings 2021 was selected [18]. The ranking of universities is based on evaluation of institutions by indicators: reputation in the academic environment, citation of scientific publications, the ratio of teachers and students, attitude of employers to university graduates, percentage of foreign students [19]. The sample under QS World University Rankings® 2021 was formed for research in order to reflect the state of accessibility and quality of websites of higher education institutions in the world (table 2, fig. 1) and compliance with international standards. The evaluation has been carried out since 10 December 2020 till 30 December 2020.

Table 2: Pilot sample of the world's leading higher education institutions according to QS World University Rankings 2021

Rating 2021	Name of University	Country
U1	<u>Massachusetts Institute of Technology (MIT)</u>	United States
U2	<u>Stanford University</u>	United States
U3	<u>Harvard University</u>	United States
U4	<u>California Institute of Technology (Caltech)</u>	United States
U5	<u>University of Oxford</u>	United Kingdom
U6	<u>ETH Zurich - Swiss Federal Institute of Technology</u>	Switzerland
U7	<u>University of Cambridge</u>	United Kingdom
U8	<u>Imperial College</u>	United Kingdom
U9	<u>University of Chicago</u>	United States
U10	<u>UCL - London's Global University</u>	United Kingdom
U11	<u>National University of Singapore (NUS)</u>	Singapore
U12	<u>Princeton University</u>	United States
U13	<u>Nanyang Technological University, Singapore (NTU)</u>	Singapore
U14	<u>EPFL</u>	Switzerland
U15	<u>Tsinghua University</u>	China (Mainland)
U16	<u>University of Pennsylvania</u>	United States
U17	<u>Yale University</u>	United States
U18	<u>Cornell University</u>	United States
U19	<u>Columbia University</u>	United States
U20	<u>The University of Edinburgh</u>	United Kingdom
U21	<u>University of Michigan-Ann Arbor</u>	United States
U22	<u>The University of Hong Kong</u>	SAR Hong Kong
U23	<u>Peking University</u>	China (Mainland)
U24	<u>The University of Tokyo</u>	Japan
...
U447	<u>V. N. Karazin Kharkiv National University</u>	Ukraine
U601	<u>Taras Shevchenko National University of Kyiv</u>	Ukraine
U651	<u>National Technical University "Kharkiv Polytechnic Institute"</u>	Ukraine
U701	<u>National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"</u>	Ukraine
U701*	<u>Sumy State University</u>	Ukraine
U801	<u>Lviv Polytechnic National University</u>	Ukraine

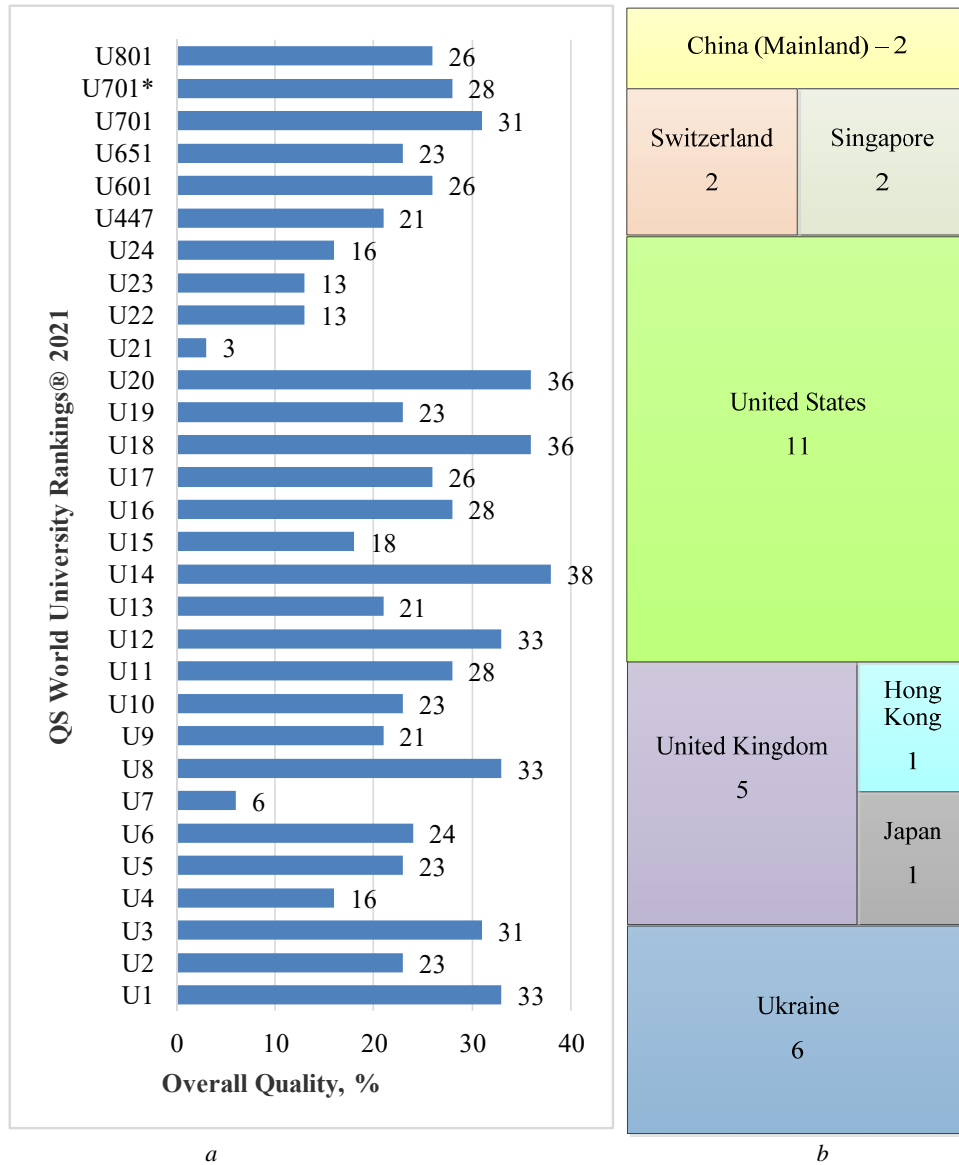


Fig. 1. The Results Of The Analysis Of Higher Education Institutions Of The World: A – Overall Quality Of The Accessibility Of Websites; B – Number Of Analysed Universities In The Sample By Country

The proposed sample of global higher education institutions is based on a study of the state of accessibility of websites with different levels of information and digital development in order to reflect the generalized worldwide condition state of this problem. At the same time, the obtained results shall ensure formation of generalized recommendations for ensuring accessibility of websites of institutions in any country and with the compliance of provision of information in accordance with international standards. The primary task was to determine the overall quality (%) of websites of higher education institutions listed in table 2 (fig. 1) in the course of analysing 40 pages of websites.

In fig. 1, the data of the overall quality of accessibility of websites of higher education institutions and the number of analysed universities in the sample by country, regardless of geographical location, are shown. In doing so, displaying a high percentage of overall site quality indicates more errors in making websites accessible. In particular, the following are of high quality: University of Michigan Ann Arbor (U21 is 3%) and Cambridge University (U7 if 6%). In other higher education institutions, the overall quality of websites is in the range of 13% to 38%; it confirms feasibility of analytical researches and search of recommendations for websites quality assurance in accordance with international standards.

Analysis of each website according to the recommendations of WCAG 2.1 based on AA level of accessibility has been carried out using SortSite Professional for accessibility. The resulting analysis generated a report based on a browser page, enabling users to report specific issues related to accessibility of higher education websites. The pages of each of the websites of higher education institutions were analysed from the following points of view:

1) accessibility on the Internet (Accessibility) – in the course of evaluating accessibility of websites, a check was made on: compliance with the WAI-ARIA standard 1.1. Accessibility Initiative – Accessible Rich Internet Applications is a technical specification published by the World Wide Web Consortium (W3C) that defines the way how to increase the accessibility of web pages, including dynamic content and user interface components developed using Ajax, HTML, JavaScript, etc. [15].

2) Browser Compatibility (Compatibility) – is used to check accessibility of HTML formats, scripts and images that are not operable in regular

browsers. Analysis web pages that show browser behaviour or cause browser errors: browser compatibility Android (USA), Chrome (USA), Edge (USA), Internet Explorer (USA) (check from version 11), Firefox (USA), Opera (Norway), Safari (USA), iPhone (USA) / iPad (USA) (check from version 6).

3) Web Standards: aimed at check of HTML/XHTML syntax and correct use of CSS tables according to W3C standards. SortSite automated tool check web page layout in HTML, XHTML etc. According to W3C [16], "Check of web-documents is an important step that shall significantly help to improve and ensure quality, saving time and money." The result of the layout check shall be summed by number of errors and warnings on the web page. Moreover, this tool evaluates web page style sheets for compliance with open W3C standards and CSS specifications. It can also detect the situation when CSS carries certain risks in terms of usability, pointing out errors or misuse of CSS.

4) Invalid links (Search) – checks for broken links and spelling errors, violations of search engine rules and pages that do not reflect practical tips for search engine optimization.

5) Navigation (Usability) – check for compliance with the Usability.gov rules [17] to reflect common navigation problems on web pages for users.

The example of the analysis is the webpage of the National Technical University of Ukraine "Ihor Sikorskyi Kyiv Polytechnic Institute" using the automatic evaluation tool SortSite Professional; it is shown in Fig. 2.

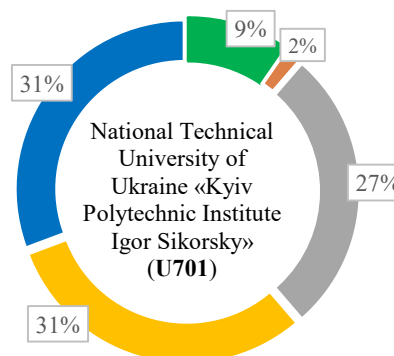


Fig. 2. Analysis Of The Webpage Of The National Technical University Of Ukraine "Ihor Sikorskyi Kyiv Polytechnic Institute" (U701%): – Accessibility; – Compatibility; – Search; – Web Standards; – Navigation (Subject To Conversion Of Each Share By 100%)

The research website of the higher education institution (U701) is characterized by a minimum accessibility: 9%, navigation 31%, search 27%, compatibility 2% and compliance with web standards 31%. Detailed results for determining the accessibility of other selected world institutions of higher education according to QS World University Rankings 2021 are given in table. 3. The results given in table 3 obtained with SortSite Professional automatic evaluation tool shall enable you to determine the web accessibility of the sites of leading higher education institutions and other web resources.

The results given in table 3 obtained with SortSite Professional automatic evaluation tool shall enable you to determine the web accessibility of the sites of leading higher education institutions and other web resources.

Research has found that Usability.gov 10:11 is violated on most scanned websites with a link to one word or several lines. A one-word text link does not provide enough information about the destination, and a link from a group of words is not read quickly, especially if it moves to the next lines. Moreover, violation in the implementation of Usability.gov 14:3 W3C based on the total number of cases has been observed. Because large images slow down loading speed of web pages, which should not exceed 5 seconds. Users are usually frustrated by the slow speed of websites download. Moreover, if omitting the width or height attributes, then “img” shall cause jumping the text on the page while loading the image; in so doing, download speed, websites quality and the perception of the information by the user shall be reduced.

Table 3: Analysis Of The Accessibility Of Sortsite Professional Websites Of Higher Education Institutions

Higher educational institution	Accessibility, %	Compatibility, %	Search, %	Web standards, %	Naviga-tion, %	Overall quality, %
U1	36	2	33	35	34	36
U14	45	45	44	45	45	45
U447	55	54	54	54	54	55
U601	40	2	36	36	36	40
U651	75	17	75	75	75	75
U701	23	4	65	73	73	73
U701*	68	67	67	67	67	68
U801	81	5	81	81	81	81

The checked websites of higher education institutions had errors of accessibility level A for WCAG 2.1 A F68, namely the use of embedded frames without alternative textual information. PDF/UA – Matterhorn Protocol 1.02 issues have been raised in more than half of the sites and are related to the lack of a link on the PDF page to download Acrobat Reader. Common problems with file name signatures and PDF files (WCAG 2.1 A F65) with no alternative text, which occurred on 70% of the websites analysed, are also worrisome

The analysed web pages had problems concerning WCAG 2.1 A F91 standard: “Row and column headers must be identified for data tables.” Inclusion of information about rows and columns is extremely important in order to make tables accessible to users relying on text readers, providing them with the context for the table data. It was also the lack of information about names or an empty button, which enables screen readers to

define what the control is doing, making it difficult for people with disabilities to perceive the information.

In order to analyse the web pages of higher education institutions (table 2) by criterion of accessibility, a maximum of 100 pages of each of the websites were scanned for accessibility, compatibility and compliance with web standards from the website (fig. 3). The validation included HTML content, dynamically generated pages (ASP, ASPX, and PHP), images (PNG, GIF, and JPEG), links to third-party websites, and various other related resources (CSS, JavaScript, PDF, Flash, RSS-channels, etc.).

The results obtained indicate that almost 70% of websites had more than 50 pages with accessibility issues (Fig. 3). The Massachusetts Institute of Technology (U1) and the Federal Polytechnic School of Lausanne (U14) have the fewest pages: 35 and 44 (both of 100) pages with accessibility

issues, respectively. National Technical University “Ihor Sikorskyi Kyiv Polytechnic Institute” (U701) has 22 pages out of 100 with the problem of accessibility. For Lviv Polytechnic National University (U801), the low level was detected with 80 (of 100) pages of a website with problems for users, including those with disabilities.

Analysis of the results of table. 3 and fig. 3 note that the most common accessibility problem of all surveyed websites was WCAG 2.1 A F89. This violation means that each element must contain the text or attribute "a", "img", "alt". In fact, this

indicates that individual images, graphics, and other embedded structural elements should be accessible, typically by providing a textual description of the element.

Quality assurance on the example of researched websites requires innovative solutions for implementation of modern scientific and practical methods of determining the accessibility of websites based on models, enabling to evaluate the interaction between the main criteria and sub-criteria. In turn, it shall reduce the operational time

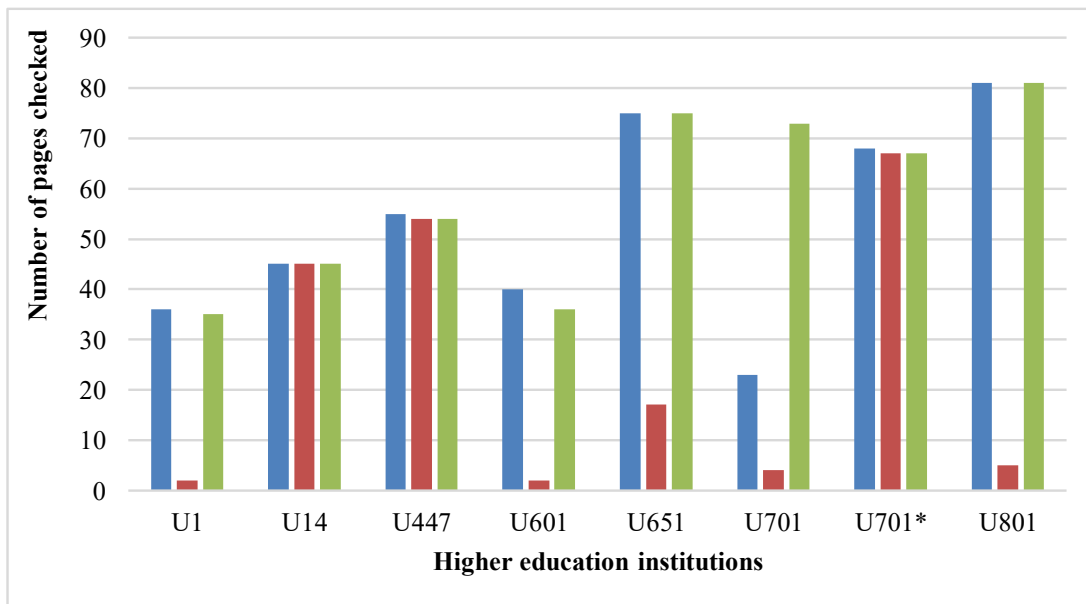


Fig. 3. Analysis Of Web Pages Of Higher Educational Institutions Regarding ■ – Accessibility; ■ – Compatibility; ■ – Web Standard

when developing and testing websites by developers in terms of ensuring international standards, taking into account the preferences of users.

Analysis of overall quality of websites under AA accessibility level of accessibility parameters, browser compatibility, compliance with web standards and consideration of the literature review, enabled to form the main criteria and sub-criteria for evaluating websites. The latter are the basis for formation of academic and practical hierarchical model for evaluating quality of websites on the example of higher education institutions and are based on the results taking into account the needs of users (fig. 4).

Highest level of the hierarchical structure is responsible for quality of the overall development of websites (the main goal), the average level is based on generalized criteria, each of which has its own sub-criteria, forming an evaluation model of website quality.

The analysis of the hierarchical model of criterion and sub-criteria evaluation of website quality was tested on the example of three educational institutions, located at the basis of hierarchical levels and had from maximum to minimum values of accessibility. Selected websites were compared for each sub-criterion and interaction with the criterion, forming the overall level of quality of each site, which creates an analytical and scientific-practical tool for evaluating the quality of websites. In doing so, advantage of

each website of the institution is evaluated by calculating a pairwise evaluation by experts for each sub-criterion (dotted line, Fig. 4), which is part of main criteria of the developed hierarchical model. The solid lines in the model are linking the websites of the institutions with the criteria, noting that the evaluation is carried out taking into account all sub-criteria, so institution A is related to all sub-criteria in the form of dotted lines (Fig. 4). The analysis of the hierarchical model of criterion and sub-criteria evaluation of the quality of the website

was tested on the example of three educational institutions, located at the basis of hierarchical levels and had the results of accessibility from maximum to minimum values.

The formed hierarchical model of evaluation of websites with statistical analysis is the effective academic and practical method of evaluating the quality of various websites in the formation, helping both practitioners and academic scientists in developing algorithms for evaluating sites.

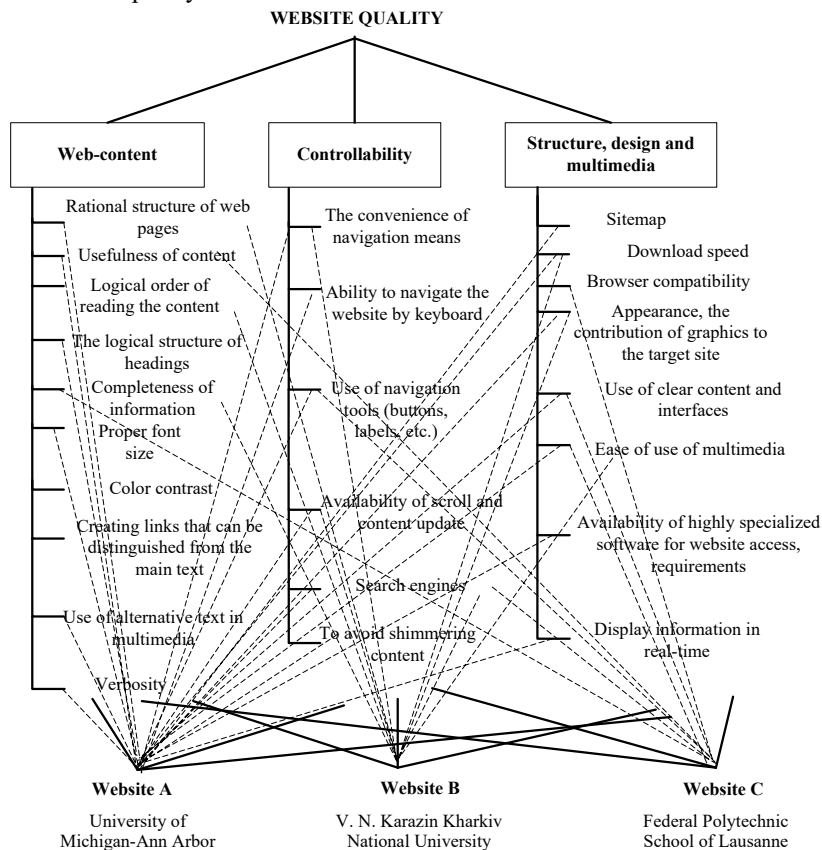


Fig. 4. Academic And Practical Hierarchical Model Of Evaluating The Quality Of Websites On The Example Of Higher Education Institutions

In the course of the research, a sample of QS World University Rankings 2021 was formed in order to reflect the status of accessibility and quality of websites of higher education institutions in the world (Table 2). The following institutions have high accessibility of websites: University of Michigan Ann Arbor (U21 – 3%) and the University of Cambridge (U7 – 6%). In other higher education institutions, the overall quality of websites is in the range of 13% to 38%; it confirms feasibility of analytical researches and search of recommendations for websites quality assurance in accordance with international standards. Analytical and practical results of research on the accessibility

of websites of higher education institutions (table 2) for users with disabilities when using WCAG 2.1 on the level of accessibility of AA (table 3). Each website with accessibility level set by WCAG 2.1 has problems with level A accessibility. Experimental web page of the National Technical University of Ukraine “Ihor Sikorskyi Kyiv Polytechnic Institute” (U701) is characterized by minimal accessibility at the level of 9%, its navigation level 31% and its compatibility level is 2% (Fig. 2).

The results of accessibility of world institutions of higher education according to QS World

University Rankings 2021 (table 3) have accessibility issues. WCAG 2.1 A F89 indicating a violation of the presence of each text element or attribute “a”, “img”, “alt”. At the scanned Usability.gov 10:11 and 14:3 W3C websites, the inadequate content and the large-images content was detected. This leads to difficulties concerning instantly opening web pages and information on it, thereby disappointing users with disabilities. Problems with file name signatures and PDF files (WCAG 2.1 A F65) were identified, due to the lack of alternative text on 70% of the analysed websites (table 3). Moreover, the analysed web pages had problems with the WCAG 2.1 A F91 standard: “Row and column headers must be identified for data tables”.

The formation of a new “e-learning” education system, especially in the context of the COVID-19 pandemic, will provide students with a quality education. During the research, the authors formed a sample according to the QS World University Rankings 2021 in order to reflect the availability and quality of web content of higher education institutions in the world (Table 2). The University of Michigan-N-Arbor (U21 – 3%) and the University of Cambridge (U7 – 6%) have high quality web content accessibility. In other higher education institutions, the overall quality of web content ranges from 13...38%, which confirms the feasibility of research on the analysis and search for recommendations on ensuring the quality of web content in accordance with international standards. The obtained analytical and practical results of studies of the accessibility of web content of higher educational institutions (Table 2) for users with disabilities using WCAG 2.1 according to the AA accessibility level (Table 3).

Using SortSite Professional's automatic web content assessment tool, it is possible to analyze web pages for the following parameters: web accessibility, browser compatibility, web standards compliance, broken links, navigation, usability, and compatibility. Analysis of web pages for these parameters will improve Internet content that meets international standards to ensure high-quality user access, regardless of the characteristics of life. Every website has accessibility level AA issues as defined by WCAG 2.1.

Websites had more than 50 pages with accessibility issues (Fig. 3), in particular, the Massachusetts Institute of Technology and the Federal Polytechnic School of Lausanne, have the lowest number of pages: 35 and 44 pages out of 100 with accessibility issues. National Technical

University “Thor Sikorskyi Kyiv Polytechnic Institute” has 22 pages of 100 having accessibility problem. Low accessibility was found at Lviv Polytechnic National University with 80 pages of a website out of 100 with problems for users, including those with disabilities.

The developed hierarchical model of evaluation of websites with statistical analysis is the effective scientific and practical method of evaluating the quality of various websites in the formation of sites, helping both practitioners and scientists in developing evaluation algorithms. It has been detected that Institution A is associated with all sub-criteria in the form of dashed lines, and therefore the predetermined maximum accessibility is confirmed. Websites B and C are linked to a small number of sub-criteria, generally confirming previous results from the low accessibility and quality of websites.

Research limitations include analyzing only web pages without considering other forms of information presentation, such as multimedia, PDF files, or PowerPoint presentations (USA). These shortcomings can be addressed through inclusion of accessible technology websites, expert groups, end users and automated analysis tools for analysis. The obtained data are recommended during development of websites of higher education sites to support students with disabilities, so expanding access to the institution. The results of the study clearly show that most websites of higher education institutions have many problems with convenience and accessibility.

The obtained scientific and practical research results can be used to determine the quality of accessibility of any website in the IT sphere, regardless of ownership form and location of the developer. Thus, the hypothesis is confirmed, and the proposed hierarchically model will allow to form a practical-scientific relationship between modern criteria and sub-criteria for evaluating websites in real time, the needs of our time, thereby saving significant funds. The result shall generally improve policy guidelines and general awareness of the quality of websites accessible to users, including those with disabilities.

Further research shall focus on using a multi-method approach to automated website testing software. In addition, it is necessary to analyse the security of websites during the evaluation and check for vulnerabilities in the cross-site scenario: password attacks and SQL injection, etc. This shall improve quality of access to information and

services provided by the websites to all users, including those with disabilities.

4. CONCLUSIONS

The result of scientific and practical research is a preliminary determination of the levels of accessibility of the websites of leading educational institutions through analysis according to WCAG 2.1. The following institutions have high accessibility of websites: The University of Michigan Ann Arbor (3%) and the University of Cambridge (6%), for other institutions this indicator is in the range of 13% to 38%. The website of U701 is characterized by a minimum accessibility of 9%, compatibility of 2% and compliance with web standards of 31%. Higher education websites have level A errors in WCAG 2.1 A F68, namely use of embedded frames without alternative textual information. Insufficient full content formation and the presence of large images (violations of Usability.gov 10:11 and 14:3 W3C). have been detected Problems concerning file name signatures and PDF files (WCAG 2.1 A F65) are related to the lack of alternative text (70% of the websites analysed). The analysed web pages had problems according to the WCAG 2.1 A F91 standard: "Row and column headers must be identified for data tables." Inclusion of information about rows and columns is extremely important in order to make tables accessible to users relying on text readers, providing them with the context for the table data.

When analyzing 100 crawled web pages of higher education institutions, it was found that the Massachusetts Institute of Technology and the Federal Polytechnic School of Lausanne have the fewest number of pages (35 and 44) with an accessibility problem. National Technical University "Ihor Sikorskyi Kyiv Polytechnic Institute" has 22 pages with accessibility problem. Low accessibility was found at the National University "Lviv Polytechnic" with 80 pages of problems for users. The most common problem with the accessibility of the studied websites was WCAG 2.1 A F89 – violation of the presence of text or attribute "a", "img", "alt" in each element.

The results obtained made it possible to form a hierarchical model for assessing websites by means of statistical analysis of scientific and practical methods for assessing the quality of various websites in the formation of websites. It has been detected that Institution A is associated with all sub-criteria in the form of dashed lines, and therefore the predetermined maximum accessibility is

confirmed. Websites B and C are linked to a small number of sub-criteria, generally confirming previous results from the low accessibility and quality of websites. Taking into account in the hierarchical model the criteria and sub-criteria factors affecting the final quality of web content will improve the accessibility of web sites to users, regardless of functional impairments, reducing the duration and efforts to search for information.

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