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EVALUATION AND OPTIMIZATION OF WEBSITE EFFICIENCY USING GOOGLE PAGESPEED INSIGHTS

Abstract. *The article explores the specifics of determining website efficiency using the Google PageSpeed Insights tool. The main criteria for webpage efficiency are considered, including loading speed, interactivity, and stability of content display. An analysis of existing approaches to website performance evaluation is conducted, and the expediency of using Google PageSpeed Insights for their optimization is substantiated. The practical part of the study focuses on evaluating the efficiency of the website of Lesya Ukrainka Volyn National University, which allowed identifying key shortcomings and formulating recommendations for their elimination. The theoretical significance of the work lies in clarifying the concept of «website efficiency» and analyzing methods for its evaluation. The practical value of the research lies in developing recommendations for improving the performance of web resources.*

Keywords: *website efficiency or website effectiveness, Google PageSpeed Insights, optimization, loading speed or page load speed, performance, web technologies.*

INTRODUCTION, PROBLEM STATEMENT

More and more aspects of life are transitioning into the realm of web technologies, which attract people due to their accessibility, popularity, and convenience. Web technologies enable interaction across various fields with minimal effort. In today's world, it is nearly impossible to imagine the functioning of science, business, education, and everyday life without the Internet. That is why websites have become powerful tools for engaging with target audiences. As a result, a web page must be efficient. Efficiency involves minimizing the overall page load time, ensuring smooth loading, and maintaining interactivity.

It should be noted that the need to study the functioning of web technologies became relevant with the advent of the Internet. The Internet drew attention from people across different sectors, leading to numerous studies that contributed to the broad development of web technologies. People began to create and explore different principles of website operation. In particular, the fundamental theoretical principles of web page functionality, structure, and efficiency were substantiated by researcher D. Palmer. Comparative studies on measuring website efficiency were conducted by D. Lee, A. Morrison, and R. Welling. The work of S. Souders, who introduced the world to High-Performance Web Sites, is also noteworthy.

A comprehensive study of website efficiency and its tools is an important task for every website owner or developer. Thus, the practical importance of evaluating website efficiency and its impact on a site's search engine ranking determined the choice of our research topic: «Features of Website Efficiency Assessment Using Google PageSpeed Insights».

Problem Statement: The subject of this study is the evaluation and optimization of the website efficiency of Lesya Ukrainka Volyn National University.

The aim of the research is to identify the criteria for website efficiency, assess the website's performance using Google PageSpeed Insights, and develop recommendations for its optimization. Achieving this aim involves solving the following tasks:

– justify the concept of «website efficiency» and analyze the tools used for its assessment;

– substantiate the specific features of using the Google PageSpeed Insights tool for evaluating website performance;

– identify the main criteria for webpage efficiency;

– conduct an analysis and formulate recommendations for improving website efficiency.

The theoretical significance of this study lies in clarifying the concept of website efficiency, analyzing the main tools for assessing web performance, and identifying the key efficiency criteria for websites. The practical significance of the research is that it involves evaluating the efficiency of the Lesya Ukrainka Volyn National University website and developing recommendations for its optimization.

ANALYSIS OF AVAILABLE RESEARCH AND PUBLICATIONS

Today's world, it is impossible to do without an online presence aimed at expanding the client base and promoting a business, product, or service. A website has become a powerful tool for interacting with the target audience. A website is defined as a collection of webpages available on the Internet, unified by content and navigation under a single domain name [1]. Clearly, any website should be informative, visually appealing, and efficient.

Website efficiency refers to how quickly a website loads and how it is displayed during the loading process [2]. If a website performs poorly, the landing page will load slowly, leading to a low-quality user experience. Since the concept of website efficiency is complex, researchers divide it into several key components: total load time reduction, lazy loading, smoothness and interactivity, perceived performance, and performance score.

The analysis of the first component-reducing overall load time-helps understand the general strategy of minimizing file sizes, reducing the number of HTTP requests, and applying smart loading techniques.

The second component, lazy loading, means that additional resources can continue loading in the background while the user performs primary tasks. Sometimes, resources are loaded only when they are truly needed.

The third component, smoothness and interactivity, refers to the use of practices that ensure a seamless experience, such as using CSS animations

instead of JavaScript and minimizing re-rendering of the user interface caused by changes in the DOM.

The fourth component, perceived performance, is about how fast the website feels to the user, which can have a greater impact on user engagement than the actual speed of the page. Even if an operation takes time, the user can stay engaged by showing a loading spinner or helpful tips while they wait.

The fifth component, the performance score, involves identifying actual and expected application speed, applying optimizations where possible, and continuously monitoring performance to ensure that improvements remain effective over time [3].

As previously mentioned, website efficiency can be measured and evaluated using specific tools. It is appropriate to examine some of these tools in more detail.

Lighthouse is a free, open-source tool for testing website performance (fig. 1).

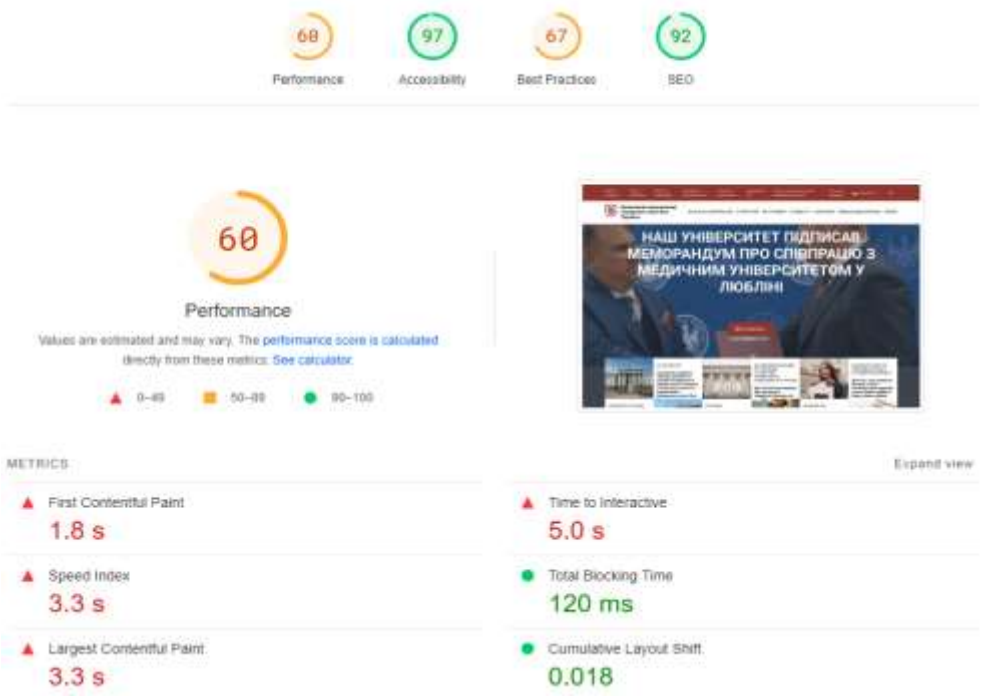

Figure 1 – General View of the Generated Lighthouse Report

It can provide personalized recommendations for optimizing website performance, accessibility, and search engine optimization. You can work with Lighthouse in Chrome DevTools, from the command line, as a Chrome extension, or as a Node.js module. All you need to do is enter the URL into Lighthouse, and it will run a series of audits based on lab data, then generate a report showing how well the web page performed and how it can be improved [4].

WebPageTest (WPT) is another open-source tool that can be used to measure website performance (fig. 2), check Core Web Vitals, generate a Lighthouse report,

compare the performance of one or more pages, dive into detailed statistics, and test functionality on a real device.

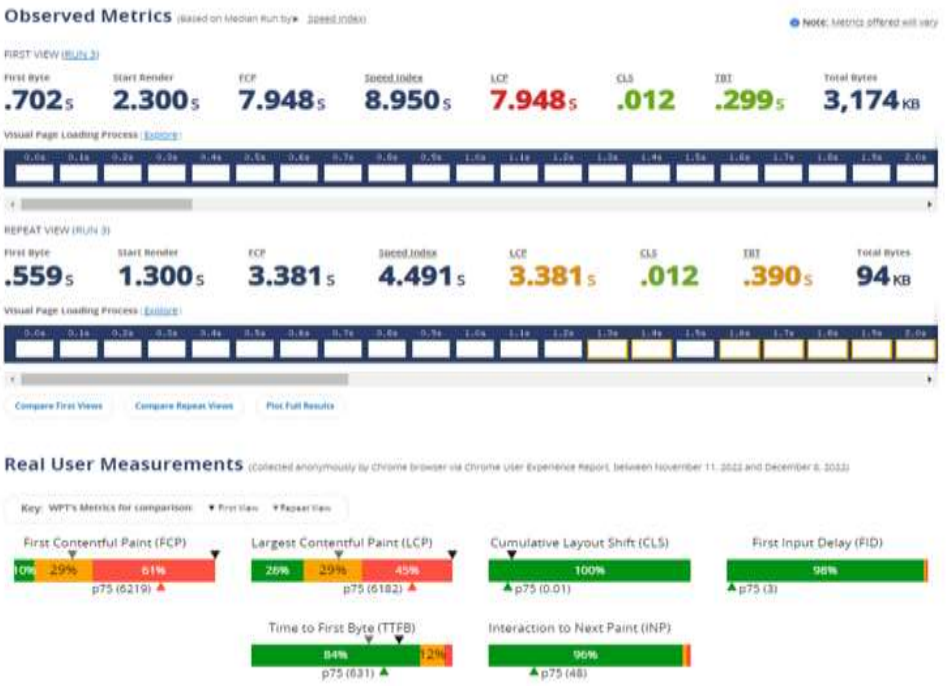

Figure 2 – General View of the Generated WebPageTest Report

Its system uses its own testing environment, Lighthouse [5] and Core Web Vitals, and runs tests using a URL. It generates a report that highlights key issues and offers recommendations for improving the website. Additionally, WebPageTest (WPT) can compare the performance of multiple pages and display average results [6].

GTmetrix is a reliable tool used to obtain a detailed report and assess website performance (fig. 3). Its main advantages include the ability to view the total page load time, identify major issues that need to be resolved, and detect resources that place the highest load on the server.

For example, GTmetrix can identify that the main issue to address on a website is avoiding excessive network loads. It can provide a complete list of URLs on the page that need fixing [7].

PageSpeed Insights (PSI) is a free tool that helps find and fix problems slowing down a website. It can recommend compressing images to reduce file load times, reducing the amount of unused JavaScript code, showing which scripts impact page load times, and much more. Currently, PSI holds a leading position among performance evaluation tools because it uses real user data from Google in its reports and incorporates the Lighthouse tool in its system, which generates a separate report for a more detailed analysis [8].

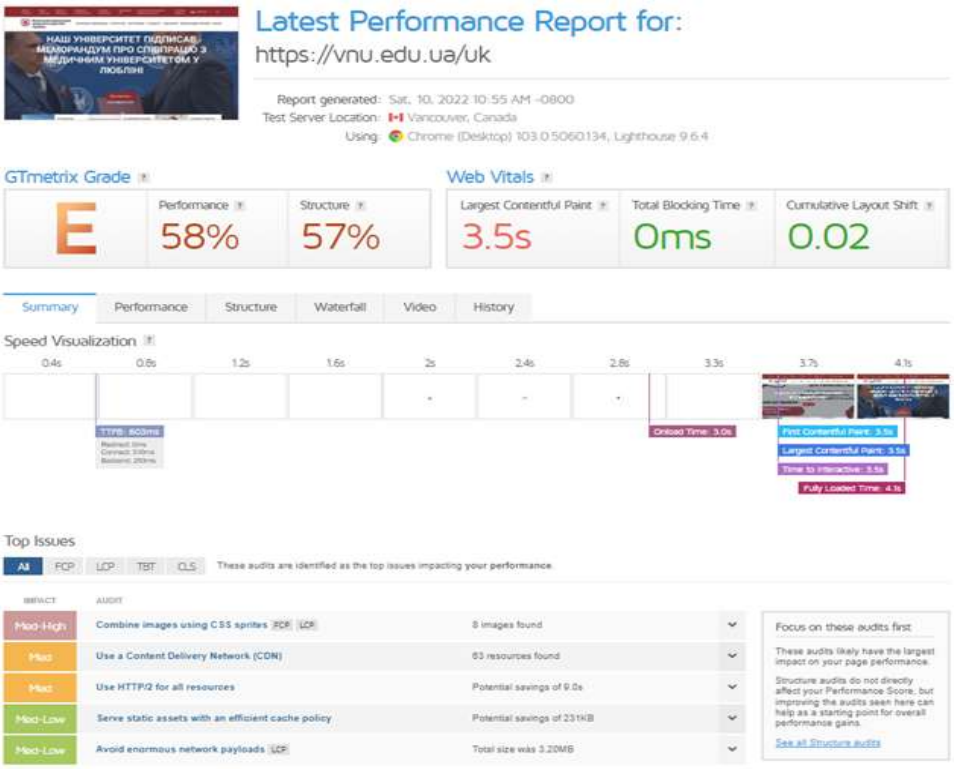

Figure 3 – General View of the Generated GTmetrix Report

PURPOSE OF THE ARTICLE

Based on the above, we can conclude that PageSpeed Insights is one of the most popular tools for assessing website performance. Additionally, it is worth noting that the metrics provided by this service strongly correlate with a site's ranking in Google's search results. Therefore, we consider it appropriate to conduct a more detailed analysis of this tool and its performance evaluation system in the following subsection.

MAIN ARTICLE

Google PageSpeed Insights Tool. The leading tool PageSpeed Insights (PSI) uses various measurement technologies, including the Lighthouse tool, which collects and analyzes lab data combined with real-world data from the Chrome User Experience Report (CrUX) [9]. The result is a score summarizing website performance and a set of optimization recommendations.

PSI allows switching between desktop and mobile versions of the report, which is useful for optimizing user experience on different devices. It is important to note that the metrics and scores may differ between these versions: a desktop site may be more optimized than its mobile version or vice versa. Therefore, analyzing webpages should be done separately for each platform [10].

The PSI architecture relies on the CrUX dataset, which gathers real user experience metrics from Chrome users during their browsing activity. This data is

publicly available through various tools and is used by Google to form page quality assessments. However, not all websites are included in CrUX: sites must be publicly accessible and have sufficient traffic to generate statistically significant data [11].

The PSI report provides real-user experience measurements over the previous 28-day period for key metrics such as [12]:

– Largest Contentful Paint (LCP) – the time to load the largest visible content block;
– First Contentful Paint (FCP) – the time to first content rendering;
– First Input Delay (FID) – the delay in the first user interaction;
– Cumulative Layout Shift (CLS) – total layout shift;
– Interaction to Next Paint (INP) – time to respond to the next interaction;
– Time to First Byte (TTFB) – waiting time for the first byte.

Additionally, PSI invokes the Lighthouse tool, which generates a supplementary report based on controlled lab tests, including metrics such as:

– Time to Interactive (TTI) – time until the page becomes fully interactive;
– Total Blocking Time (TBT) – total time blocking user interactions;
– Speed Index (SI) – speed index of content rendering.

Note that some metrics are duplicated: some are derived from real CrUX data, others from Lighthouse lab tests. For example, First Contentful Paint (FCP) appears in both reports but is calculated differently, although measuring the same parameter – the time to first content rendering [13].

In addition to Core Web Vitals, PSI includes experimental metrics such as Interaction to Next Paint (INP) and Time to First Byte (TTFB).

Thus, PageSpeed Insights is a powerful web performance testing tool that combines real user data from Google and lab data from Lighthouse, providing detailed optimization recommendations.

Performance Evaluation Criteria

PSI uses the following key criteria:

1. First Contentful Paint (FCP): measures how long it takes the browser to render the first text, image, or SVG element after navigation.
2. Time to Interactive (TTI): sndicates how long it takes for the page to become fully interactive (this metric is crucial because some sites optimize content visibility at the expense of interactivity).
3. Total Blocking Time (TBT): measures the total amount of time during which the page is unresponsive to user input (e.g., mouse clicks or keyboard presses).
4. Speed Index (SI): assesses how quickly the visible content is rendered during page load (the score is based on video capture of the loading process analyzed frame-by-frame).
5. Largest Contentful Paint (LCP): measures the time from navigation to when the largest visible element (text or image) is fully rendered.
6. Cumulative Layout Shift (CLS): calculates the total unexpected layout shifts during the page load that negatively impact user experience.
7. First Input Delay (FID): measures the delay between the user’s first interaction (click, tap) and the browser’s response to that interaction.

Experimental Metrics. As for the experimental indicators, there are two of them:

– Interaction to Next Paint (INP): measures responsiveness for all user interactions and reports a single aggregated value. A low INP indicates fast response times.

– Time to First Byte (TTFB): measures the time from request sent to the first byte received from the server, reflecting server responsiveness.

Result Evaluation. PageSpeed Insights classifies performance scores into three categories (fig. 4):

– Good – indicated by a green label, meaning high optimization level;
– Needs Improvement – yellow label, indicating issues that require fixing;
– Poor – red label, signaling serious performance problems.

Figure 4 – Example of labels in the LCP metric

PSI distributes these labels so that developers can understand the quality level of the webpage (fig. 5). For example, if 9% of users fall within the yellow LCP range, it means that 9% of all observed LCP values are between 2500 ms and 4000 ms.

Figure 5 – Example of LCP label distribution

Above each PSI metric distribution bar is the 75th Percentile. It exists to help understand where the majority of users fall on the site. In addition to the standard

distribution, PSI evaluates the Core Web Vitals – a subgroup of performance metrics designed to simplify the situation and help site owners focus on the most important criteria. The main metrics are LCP, FID, and CLS, which are collected from real user data [24]. Each represents a distinct aspect of user experience: LCP relates to loading, FID to interactivity, and CLS to visual stability. To receive a positive evaluation, all three Core Web Vitals metrics must be in the green zone. Otherwise, the assessment is not passed.

If PSI has insufficient data for FID, the site will pass the evaluation only if both LCP and CLS metrics are green. If there is not enough data for either LCP or CLS, the evaluation will be negative.

In summary, it is important to note that these metrics are a crucial component of the entire PageSpeed Insights system. They play a leading role in forming the performance evaluation criteria in the reports. PSI includes three types of metrics: the first belong to Core Web Vitals, the next to experimental metrics, and the rest to Lighthouse. The results of the evaluation criteria are indicated by marks that help determine the status of each metric.

DISCUSSION OF THE RESULTS

Performance Analysis of Lesya Ukrainka Volyn National University Website. In the previous section, we focused in detail on the performance evaluation tool PageSpeed Insights. The analysis of this tool's functionality allowed us to identify a set of performance evaluation criteria: Largest Contentful Paint, First Input Delay, Cumulative Layout Shift, First Contentful Paint, Interaction to Next Paint, Time to First Byte, Time to Interactive, Total Blocking Time, and Speed Index.

Let us now assess the performance of the Lesya Ukrainka Volyn National University website based on the above criteria (fig. 6).

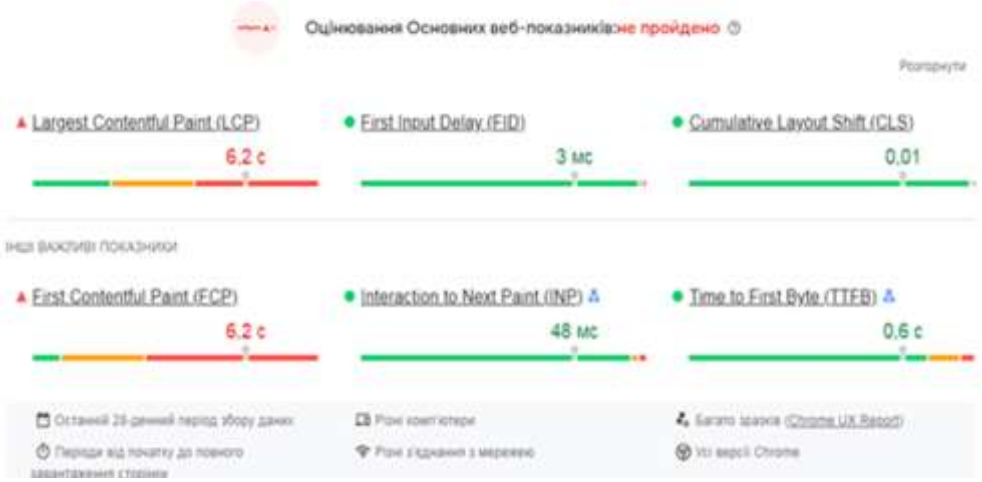

Figure 6 – General Overview of the Core Web Vitals Performance Evaluation

By visiting the main PSI page (https://pagespeed.web.dev/) and entering the URL (https://vnu.edu.ua/uk), we obtain a performance evaluation of the main and experimental webmetrics collected in CrUX over the last 28 days. It is immediately apparent that the website did not pass the evaluation of the core metrics.

Analysis of the first criterion, Largest Contentful Paint (LCP), for the website's performance evaluation allowed us to conclude that the largest element on the page loads too slowly and accordingly falls within the red zone.

Regarding the second criterion, First Input Delay (FID), its evaluation indicates that the time for the first user interaction with the content is fast.

A similar situation is observed with Cumulative Layout Shift (CLS), as it is in the green zone, which allows us to state that the site's visual stability is at a high level. Consequently, the interaction with the webpage is smooth.

Despite the fact that two core web vitals are in the green zone, the test still did not receive a positive overall assessment because the LCP metric has a stronger influence on the final score.

Analysis of the First Contentful Paint (FCP) criterion showed that the page loading occurs with delay, placing this metric in the red zone.

Regarding experimental metrics, it was found that they fall within the green zone. This means the page is capable of quickly responding to all or most user interactions and the server responds promptly to site requests.

Now let us analyze the site according to the Lighthouse report generated from data collected and analyzed in a controlled environment.

A positive aspect of the report is that the Total Blocking Time, which measures the time during which the page is unresponsive to user input, is low.

It is also worth noting that CLS is low, thus ensuring smoothness and effectiveness of the webpage. However, the Time to Interactive (TTI) metric, which reflects interactivity, is in the yellow zone. This may have negative consequences such as loss of user engagement, since sometimes the site appears ready, but when the user tries to interact with it, nothing happens due to slow interactivity (fig. 7).

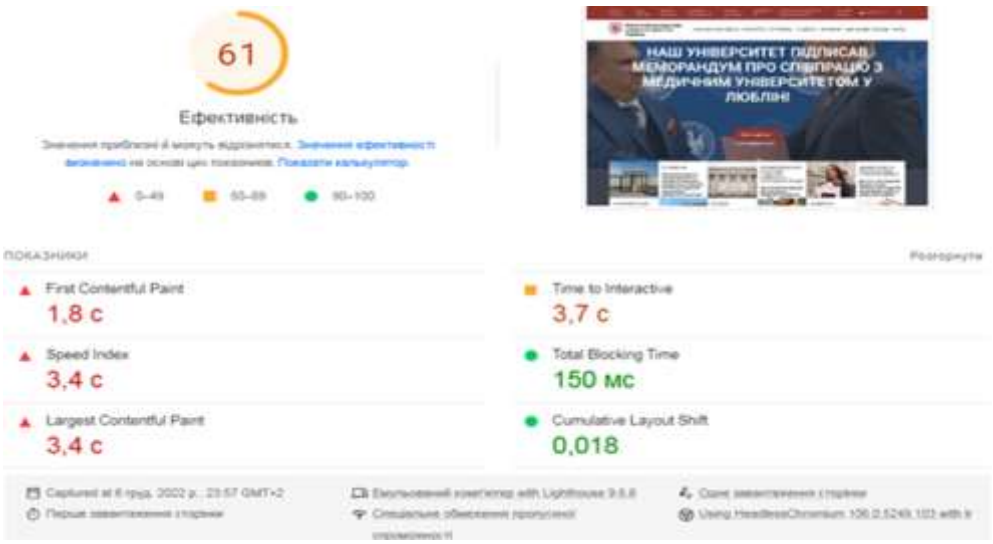

Figure 7 – General Overview of the Lighthouse Performance Assessment

We observe that the next metric is FCP (First Contentful Paint), which measures the time it takes for the first piece of content to appear on the page. In the report, it is marked in red, indicating that, for certain reasons, the website's loading time may be significantly delayed.

A similar situation is seen with the Speed Index and LCP (Largest Contentful Paint), both of which are also in the red zone. The Speed Index reflects how quickly content is visually displayed during page load. Therefore, if this metric is slow, the entire content on the site appears with delay. The LCP measures the time it takes to load the largest visible block (text or image) in the viewport relative to when the page first started loading. For optimal performance, larger elements should begin loading earlier, allowing the webpage to function faster.

From the analysis of the website, it is clear that some of the Lighthouse criteria and core web performance metrics, specifically LCP, FCP, and Speed Index, are marked red. This indicates existing issues related to efficient page loading and content rendering speed that need to be addressed.

CONCLUSIONS

It can be concluded that performance plays a crucial role in the development of websites, as it enhances user experience, usability, and overall user satisfaction.

1. It has been substantiated that performance is a complex concept characterized by multiple criteria. In practical terms, it measures how quickly a website loads and how it renders during loading, since these factors determine the success and quality of a web page. It was analyzed that due to the rapid development of web technologies, a wide range of tools such as Lighthouse, WebPageTest, GTmetrix, and Google PageSpeed Insights have emerged.

2. It has been established that PageSpeed Insights is a leading tool in its field, collecting information from various sources and performing a comprehensive analysis of overall website performance, generating reports on core web metrics as well as Lighthouse data.

3. Key website performance criteria were highlighted, including Largest Contentful Paint, First Input Delay, Cumulative Layout Shift, First Contentful Paint, Interaction to Next Paint, Time to First Byte, Time to Interactive, Total Blocking Time, and Speed Index. Several issues related to long page load times were identified, such as the use of PNG or JPG image formats, which compress poorly and therefore increase website loading duration.

4. Based on the identified criteria, an analysis of the performance of the Volyn National University named after Lesya Ukrainka website was conducted, revealing existing shortcomings. Optimization steps were proposed for the site developers to improve the overall performance of the website.

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ОЦІНКА ТА ОПТИМІЗАЦІЯ ЕФЕКТИВНОСТІ ВЕБ-САЙТІВ ЗАСОБАМИ GOOGLE PAGESPEED INSIGHTS

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Анотація: у статті досліджено особливості визначення ефективності веб-сайтів із використанням інструменту Google PageSpeed Insights. Розглянуто основні критерії ефективності веб-сторінок, зокрема швидкість завантаження, інтерактивність та стабільність відображення контенту. Проведено аналіз існуючих підходів до оцінки продуктивності веб-сайтів та обґрунтовано доцільність використання Google PageSpeed Insights для їх оптимізації. Практична частина дослідження спрямована на оцінку ефективності веб-сайту Волинського національного університету імені Лесі Українки, що дозволило виявити ключові недоліки та сформувати рекомендації щодо їх усунення. Теоретична значимість роботи полягає в уточненні поняття «ефективність веб-сайту» та аналізі методів її оцінки. Практична цінність дослідження полягає у розробці рекомендацій щодо покращення продуктивності веб-ресурсів.

Ключові слова: ефективність веб-сайту, Google PageSpeed Insights, оптимізація, швидкість завантаження, продуктивність, веб-технології.