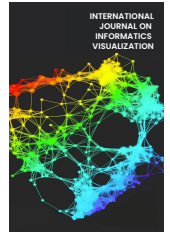




# INTERNATIONAL JOURNAL ON INFORMATICS VISUALIZATION

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## Measurement on University Websites: A Perspective of Effectiveness

Kerly Palacios-Zamora <sup>a,\*</sup>, Jorge Cordova-Moran <sup>a</sup>, Denis Mendoza-Cabrera <sup>a</sup>, Silvia Pacheco-Mendoza <sup>b</sup>

<sup>a</sup> Facultad Ciencia e Ingeniería, Universidad Estatal de Milagro, Milagro, 091050, Ecuador

<sup>b</sup> Universidad Estatal de Bolívar, Guaranda, 020150, Ecuador

Corresponding author: \*kpalaciosz@unemi.edu.ec

**Abstract**— This paper highlights the importance of evaluating the performance of university websites and how this can affect the reputation of universities. Different quality evaluation models are analyzed and emphasized in the context of efficiency and how factors such as response time, processing capacity, efficient use of resources, scalability, data transfer rate, concurrency capacity, and fault tolerance can positively or negatively affect websites. In addition, the importance of applying specific techniques to increase efficiency in loading speed is pointed out, such as image optimization, responsiveness on desktop and mobile devices, and content caching, among others, which allow to improve the website's efficiency. To conduct this process, a case study was applied where the university websites were selected, efficiency metrics were defined, and the data provided by the performance measurement tools that provide metrics and quantitative data for the evaluation were collected and analyzed. from the website. The results of the study revealed that there is room for improvement in page load time and page size optimization. In addition, the need to upgrade the performance of mobile devices was identified, given the increasing use of smartphones and tablets to access websites. As a final recommendation, it is advised to implement a comprehensive strategy to improve website performance. This strategy should include optimization of page load time and page size as well as user experience considerations. By achieving optimal performance, universities can offer their users a more satisfying online experience, thus strengthening their reputation and their ability to attract new users.

**Keywords**— Efficiency; performance; assessment; user experience; website.

Manuscript received 15 Oct. 2022; revised 19 Jan. 2023; accepted 21 Aug. 2023. Date of publication 30 Nov. 2023.  
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### I. INTRODUCTION

Technological advances have allowed people to create powerful tools readily available to facilitate development and knowledge in daily activities[1]. Thus, technology is one of the most developed knowledge fields, in which information is one of the most relevant characteristics of society and becomes the most valuable resource for companies, organizations, institutions, and other industries [2]. Technology and the web are interconnected since Internet spaces are a product of technology because it has allowed significant changes in the interaction manner companies establish with their customers, reaching surprising incomes that reflect the importance of its use[3]. The Web adapts to the user's necessities, set up with the creation of basic web pages to the incorporation of interactive content and multimedia elements [4].

Websites are currently the most widely used means of communication[5]. There are approximately two billion active websites on the web and more than five billion users accessing them all over the planet [3]. During the first months

of 2023, the average number of Internet users in the world will be 64.4% [6]. The INEC (*Instituto Nacional de Estadística y Censos*) from Ecuador gathers data about the use and Access to Internet, computers, and cellphones through the Dirección de Tecnologías de la Información y las Comunicaciones, which facilitates the analysis, formulation, and policy development. Studies carried out by the INEC show that, in 2022, approximately 60% of the Ecuadorian population had access to the Internet, which suggests that using the Internet is global.

Nowadays, with the Internet coming forth, [7] People can access many appealing websites, which has allowed companies to worry about improving issues related to visualization, accessibility, ease of use, visibility, positioning, and quality of the information published on their websites to provide better service since these elements are closely related to the reputation of the institution, it is necessary to develop a strategy to achieve greater online visibility [8]. Ecuador currently has 62 universities and polytechnic schools (34 public and 28 private); 55 of those establishments were evaluated according to the latest assessment practices,

established in 2019. Only 52 institutions received five-year accreditation status. The evaluation process for accreditation purposes of Universities and Polytechnic schools was carried out by the CACES (*Consejo de Aseguramiento de la Calidad de la Educación Superior*).

In the consciousness of a competitive environment where universities strive to attract the best quality students, a stout online presence is essential. Local and international students use these websites for information on academic programs, entry and level requirements, scholarships, opportunities, study benefits, and available resources they can access [9]. Consequently, a well-designed university website that provides a smooth, fast, and efficient user experience can significantly influence the decision-making [10].

Higher education institutions focus on analyzing and evaluating the quality of their websites according to the benefits available [11]. Institutional websites offer an extensive variety of online activities and services, including teaching and research repositories, administrative, student management, faculty, and administrative services [12]. Besides, these websites may be connected to one or more administrative or academic systems, for example, libraries or specific information or products of a faculty, as well as online hubs associated with external events [13].

To provide users with the best possible online browsing experience; websites should display promptly and follow standards and recommendations when developing them to ensure good quality [12]. In addition, the website must adapt to the latest Web innovations; such as compatibility with any device [14]. A website that does not meet these basic requirements is not considered high quality and does not provide a good user experience [15].

Performance efficiency on websites is vital in providing the best user experience [16]. Website visitors expect sites to display quickly, be navigation friendly, and deliver relevant information efficiently [17]. Deficient website performance can impact negatively the user experience, institutional reputation, and the ability to attract and uphold students, faculty staff, and researchers [18].

For these reasons, it is essential to attain tools and develop skills and techniques to measure and evaluate the efficiency of websites [19]. This facilitates the identification of necessitating improvement areas on the websites, thereby striving towards enhanced speed, efficiency, and the delivery of a superior user experience [17]. Additionally, to stay updated with best practices in web design and adapt to technological advances [20].

Traditional performance metrics measure page load times and server response capacity; for this reason, there are specialized methods to measure website performance, and one of the best-known methods is Webometrics, a discipline that focuses on measuring and analyzing the online traffic and popularity of academic institutions [21].

Webometrics recognizes the importance of universities' online presence and how it affects the university's reputation, reach of audience, and impact [22]. Assessing the performance of university websites using a Webometrics approach enables a broader understanding of their location in the digital environment and their impact on the academic community and society in general [23].

To correctly assess the influence of university websites and the online visibility of universities, Webometrics applies a variety of specific parameters and indicators [11]. These benchmarks include, among other things, the number of external links pointing to a university's website, its social media impact [24]. By considering these parameters, academic institutions can enhance their comprehension of their online positioning, identify areas that may benefit from upgrades, and develop strategies to enhance their online reputation and presence [25].

The likelihood of users bouncing (leaving the website) rises by 32% when the page display load time lasts from 1 to 3 seconds and by 106% when the page loading time escalates from 1 to 6 seconds. as mentioned in a study conducted by Google, which revealed that the longer display loading takes can correlate with reduced engagement. To ensure a successful user experience and maintain user engagement and satisfaction, it is essential to evaluate the website's display loading speed and efficiency [26].

The efficacy of a university website includes the ability to expose high-quality and relevant content quickly and efficiently [27]. An effective website improves navigation patterns, makes it easier to find relevant information, and ensures accessibility for all users, including those with disabilities. In addition, non-relevant results can harm the image and reputation of an institution, affecting the attraction and retention of students and academic staff [28].

Higher education institutions can maximize the performance of their websites by giving users a faster and more efficient experience, also improving their online recognition by setting appropriate tools and techniques into use [29]. As a result, performance should be taken into account when designing any website to guarantee that tasks can be carried out expeditiously and accurately, enabling the proper functioning of the website even during periods of high visitors' traffic [30].

Performance testing can be defined as a software testing technique that is used to assess the current performance of a website. These tests are designed to measure the website's response to different visitor loads and traffic patterns, as well as to identify performance issues that might impact users' experience, process efficiency, access to online resources, and customer communication. A negative website perception can significantly influence an institution's reputation and user satisfaction [31].

Website performance is a crucial element in user satisfaction and the capacity of higher education institutions to attract and retain students. Online users expect websites to load without delay, provide them with the information they need promptly and easily, and offer smooth navigation on all electronic devices. If a site is slow, difficult to navigate, or has technical errors, users may abandon it and redirect to more accessible and efficient options [26].

To conduct this research paper, the measurement of the performance of university websites is investigated: from an efficiency perspective, it is analyzed how to measure and improve essential aspects of performance such as page load time, image optimization, file recognition, mobile responsiveness, and cache storing. The enactment of these techniques and technological tools can significantly increase

the speed and efficiency of the university website, thus improving the online user experience.

## II. MATERIALS AND METHODS

The quality of a website is essential to guarantee users a positive experience and the achievement of their goals. Assessing and evaluating a website can be challenging due to its complexity [32]. This occurs due to the fact that many services are attached to the home page of the website. The main activities and services offered by universities are described on their websites. Different assessment models, tools, or techniques can be used to evaluate the quality of a website, depending on the parameters and objectives meant to be measured and appraised. Since determining the quality level is the goal of any assessment process and the starting point of improvement process, it is crucial to understand how assessment and quality are related [12].

Assessment consists of measuring the worth of a thing and grasping it as a quality that satisfies various needs, evaluating the value of a product, service, or institution [33]. Quality is the set of properties and characteristics of a service or product that allow it to satisfy the stated needs of the product [34]. It is imperative to employ a structured and objective methodology when assessing the quality of a website. In pursuit of this, diverse models are implemented to furnish precise criteria and metrics for measuring and scrutinizing numerous facets of applications or websites. These models enable a comprehensive and systematic evaluation, thereby facilitating the identification of areas that necessitate improvement and the implementation of effective strategies to enhance the quality and efficiency of website.

As people's reliance on websites and apps increases, it is imperative to ensure they uphold high-quality benchmarks and meet user's expectations. With the aim of attaining this, several approaches and methodologies have been designed to assess the quality of websites and applications. Considering this scenario, in Table 1 it shows the four approaches that were selected and that stand out as references in the quality assessment, which are: The Portal Quality Model (PQM), The ISO/IEC 25010 standards, The Quality Evaluation Method (QEM) and the Web Quality Model (WQM) [35]. These standards provide a structured framework to identify and measure different aspects of quality that allow assessing the functionality, usability, efficiency, reliability, security, and maintainability of websites and applications [36].

TABLE I  
QUALITY ASSESSMENT STANDARDS CHARACTERISTICS

| PQM            | ISO/IEC 25010                              | Web QEM         | WQM                                   |
|----------------|--|-----------------|---------------------------------------|
| Responsiveness | Performance<br>Efficiency<br>Compatibility | Efficiency      | Efficiency                            |
| Empathy        | Usability                                  | Usability       | Usability                             |
| Reliability    | Reliability                                | Trustworthiness | Faithfulness                          |
| Assurance      | Security                                   |                 |                                       |
|                | Maintainability                            |                 | Maintainability                       |
|                | Portability                                |                 | Portability                           |
| Data Quality   | Data Quality                               |                 | Content<br>Navigation<br>Presentation |

In the context of assessing the quality of websites and applications, one of the most important features to consider is

efficiency. It is the ability to maximize resource utilization and meet performance expectation. Promoting design and development efficiency is critical to delivering an effortless user experience and incrementing the utilization of technological resources [37]. Efficiency is an important characteristic to assess the quality of websites and applications. In the following graphic Table 2 the sub characteristics that the efficiency characteristic possesses are shown according to each of the standards that were analyzed for the quality assessment on the websites:

TABLE II  
QUALITY ASSESSMENT STANDARDS CHARACTERISTICS

| PQM                        | ISO/IEC 25010                  | Web QEM           | WQM                   |
|----------------------------|--------------------------------|-------------------|-----------------------|
| <b>Responsive capacity</b> | <b>Performance Efficiency</b>  | <b>Efficiency</b> | <b>Efficiency</b>     |
| Scalability                | Temporary Behavior             | Performance       | Temporary Behavior    |
| Speed                      | Resources Utilization capacity | Accessibility     | Resources Utilization |

### A. Standards to Measure the Efficacy of Higher Education Institutional Websites.

To offer the optimal user experience and ensure dependable performance, it is crucial for university websites to operate efficiently. Efficiency refers to the capacity to utilize resources effectively and promptly. The following are several factors that influence the efficacy of a university website.

1) *Responsiveness*: It concerns to the duration it takes for a website to load and respond to user requests. A swift response time is crucial in maintaining user engagement and preventing loss of interest. Responsiveness can be enhanced through techniques such as code optimization, utilization of high-performance servers, and implementation of cache storing mechanisms.

2) *Processability*: Processing capacity: It is the competence of a site to handle a given workload. A university website may have a large number of simultaneous requests, for example: access to content, student enlistment, admission, among others. It is important that the website is designed to handle these requests efficiently without compromising performance. This includes the use of powerful servers, proper configuration, and scalability technologies.

3) *Efficient resource utilization*: To guarantee efficiency, it is imperative to employ website resources such as memory, bandwidth, and storage capacity in an optimal manner. Enhancing the utilization of resources aids in enhancing website performance and preventing blockage. This can be accomplished by consistently monitoring and adjusting resources, implementing data compression techniques, and employing efficient algorithms.

4) *Scalability capacity*: is the ability of a website to handle increased workloads. University websites may experience traffic peaks during registration periods, exams, etc. It is necessary that the website can scale horizontally or vertically to handle this increase in web traffic without negatively affecting performance. This is attained through the implementation of scalable technologies such as cloud computing and load balancing.

5) *Data transfer rate*: refers to the maximum amount of data that can be sent and received between the server and the user at any given time. University websites host several resources like multimedia files and academic papers that users need to access. To ensure prompt and efficient delivery of these resources, high data rates are necessary. Optimization can be achieved by employing compression techniques and effective file transfer methods, in addition to utilizing a server with a sufficient bandwidth.

6) *Concurrency capacity*: describes the website's capability to handle multiple user requests simultaneously. A university website often experiences a high influx of users accessing it concurrently, making it crucial for the website to effectively manage these simultaneous requests. This involves implementing techniques such as threading, load balancing, and effective concurrency management in the website's code. These measures ensure that the website can scale and handle the increased workload without compromising performance or user experience.

7) *Fault tolerance*: refers to the ability of a website to perform consistently and uninterrupted despite possible failures. University websites can face setbacks such as programming errors, network problems, and server failures. Several strategies can be implemented, such as data backup and recovery, monitoring and alerting, load balancing and distribution, and failover tests. The institutional website efficacy relies in a fast response time, processing power, efficient use of resources, sufficient scalability capacity, high data transfer rate, effective concurrency, and stable fault tolerance.

These factors contribute to a positive user experience and ensure reliable website performance. In Table 3 The standards to take into account while assessing how efficient a university website is, are presented:

TABLE III  
UNIVERSITY WEB SITE EFFICIENCY SUB CHARACTERISTICS

| Standards                     | Mark examples  |
|-------------------------------|--|
| Response time                 | Page load time.<br>Server response time.<br>Transaction processing time.         |
| Processability                | Concurrent processing capacity.<br>Processing capacity of large volumes of data. |
| Efficient resource management | Memory usage.<br>CPU usage.<br>Bandwidth usage.                                  |
| Scalability capacity          | Vertical scalability   |
| Data transfer rate            | Horizontal scalability<br>Server-client data transfer                            |
| Concurrency capacity          | Concurrency levels.<br>Lock control.   |
| Fault tolerance               | Fault tolerance.<br>Failover.  |

It is important to highlight that these examples were assessed based on the significance of this work, as efficiency can be evaluated and measured differently depending on the specific needs and requirements of the website or application.

### B. Technological Tools to Measure Efficiency on University Websites

There are various tools available that aid in measuring the efficiency of websites, providing administrators with accurate

data-backed information to make informed decisions and enhance the user experience. Some commonly utilized tools include

1) *Google PageSpeed Insights*: This tool is useful for measuring and evaluating website performance. It offers comprehensive metrics, recommendations for improving efficiency, and provides performance metrics for mobile and desktop platforms [38].

2) *GTmetrix*: This tool enables to assess website efficiency through speed tests and offers in-depth analysis of various metrics. Furthermore, it generates a report encompassing page load time, page size, and other pertinent data. It also provides recommendations to enhance performance, such as optimizing code, reducing image size, or enabling compression [39].

3) *WebPageTest*: This tool allows to perform speed and performance tests and provides detailed information on load times, server response times, page sizes, and other correlated metrics. In addition, it offers a breakdown of HTTP requests and allows to simulate different connection speeds. [40].

Generally, these tools mentioned are just a few examples among many available popular and functional alternatives. However, selecting the most suitable tool depends on specific needs and preferences. It is advisable to test multiple tools and evaluate which one aligns best with website efficiency requirements and objectives.

### C. Assessing the Efficiency of University Websites Process

The protocol for measuring and assessing website performance encompasses a range of techniques and tools, along with the careful selection and analysis of relevant data. It is crucial to ensure the accuracy and reliability of the collected data.

In this paper, a meticulously planned and methodical approach is put forth for evaluating the efficiency of university websites. The evaluation process is subdivided into multiple phases, each serving a distinct purpose in analyzing and measuring performance. The following sections outline the phases employed in this study:

1) *University Web site selection*: All university websites or a representative sample are designated for evaluation. The selection process takes into view the diversity of academic institutions, considering factors such as their relevance, online presence, availability, and accessibility.

2) *Efficiency metrics definition*: Indicators are identified to measure the efficiency of the university website. These metrics encompass various aspects such as page load time, server response time, content download speed, file size, compression, and more.

3) *Selection of technological tools for efficiency measurement*: Appropriate measurement technology tools are selected for accurate data collection on website performance. Some commonly used tools include Google PageSpeed Insights, GTmetrix, and WebPageTest. Each Instrument offers different characteristics and performance metrics, so it is vital to pick the most suitable tools for the specific project objectives.

4) *Data collection*: To collect information about the performance of the websites, tests were conducted using the selected tools. These tests involved recording and measuring the relevant performance metrics. To guarantee data consistency and accuracy, multiple samples were taken; a more comprehensive and reliable assessment of website performance can be obtained by conducting tests and collecting data from different samples.

5) *Data Analysis*: In order to derive meaningful conclusions, the collected data undergoes rigorous statistical analysis. The results from various websites are compared to identify performance patterns and trends. This action enables the evaluation of websites based on their strengths and weaknesses. By conducting a thorough analysis of the data, valuable insights can be obtained, aiding in the assessment and improvement of website performance.

6) *Results Analysis*: The analysis findings will be decoded to gain insights into the overall performance of university websites and to provide specific recommendations for enhancing their effectiveness and speed. These suggestions may entail optimizing the website's code and structure, minimizing the number of HTTP requests, compressing images and files, implementing static content caching, and prioritizing critical content.

After conducting data analysis, a more profound comprehension of the performance of university websites can be attained. The interpretation of these results yields valuable insights that can be utilized in the implementation of performance improvement techniques. In this regard, it is advisable to consider the following techniques to optimize website efficiency.

#### D. Improve Performance Techniques

Improving the performance of a university website is a continuous process that involves implementing various techniques. Here are some effective techniques to enhance website efficiency:

1) *Website coding and structure*: Significant performance improvements can be achieved by utilizing clean code, eliminating duplication, and removing unnecessary coding. Additionally, ensuring a logical and well-organized website structure enhances user navigation and reduces the number of clicks needed to access information. It is equally important to properly utilize header tags (h1, h2, h3, and so on) to indicate content organization and convey meaning, thereby highlighting the hierarchical structure of HTML.

2) *Pictures and files Compression*: Reducing resource consumption and enhancing website performance are crucial. Image compression is a vital technique to reduce the file size of images without compromising quality. Tools like TinyPNG and ImageOptim can be used for this purpose. Similarly, CSS, JavaScript, and HTML files can be compressed using programs such as GZIP to decrease their size. Compression occurs on the server and is then decompressed in the user's browser, resulting in reduced transfer time and faster page loading speed.

3) *Static content cache*: refers to storing website resources such as JavaScript, CSS, and images that are not

frequently updated. By stockpiling these resources in the user's browser cache, they can be retrieved quickly without repeated downloads, resulting in faster page loading time. The amount of time in which these resources are cached can be set through cache headers on the server. Additionally, implementing a file versioning policy ensures that the browser fetches the latest version of the resource instead of relying on the cached version. This can be achieved by appending a version number or a unique hash to the file name each time it is updated.

4) *Prioritization of critical content*: The objective is to provide users with swift access to the necessary information, enabling prompt loading of the initial page. This can be achieved through the implementation of asynchronous loading techniques for non-essential resources and the utilization of prefetch methods. Asynchronous loading of non-essential resources ensures unhindered loading of the primary page content, expediting rendering and user interaction. Conversely, prefetching enables the browser to proactively reload the resources required for subsequent pages in the background, thereby enhancing web browsing speed.

In this particular case study, a comprehensive evaluation of the efficiency of all websites belonging to Ecuadorian universities and polytechnic schools was undertaken. To measure the performance of these websites, a methodical and structured approach was adopted, taking into account specific efficiency metrics. The evaluation process of the university websites' efficiency encompassed several distinct phases, as outlined in the Materials and Methods section. These phases encompassed the selection of university websites, the establishment of efficiency metrics, the selection of measurement tools, as well as the collection and analysis of data. The ensuing sections present a detailed description of the phases employed in the evaluation process.

#### E. University Website Selection

To conduct this research, a selection was made of all the universities and polytechnic schools in Ecuador that are listed in *CACES* and have a website. The availability of public data on the performance of their websites was also considered. The chosen websites encompass universities located in various provinces of Ecuador, including Pichincha, Guayas, Azuay, among others, and are listed in Appendix A: List of Higher Education Institutions in Ecuador.

#### F. Efficiency Metrics Definition

Website efficiency encompasses factors such as fast response time, sufficient processing capacity, efficient resource utilization, scalability, high data transfer rate, and concurrency. These aspects contribute to optimal performance, a seamless user experience, and uninterrupted website availability. The chosen efficiency metrics for this study are outlined below:

- Response timing
- Processing capacity
- Effective use of resources
- Scalability capacity
- Concurrency capacity

### G. Selection of Technological tools for Efficiency Measurement

For the measurement of university websites, the following recommended tools were selected, as each tool offers different features and performance metrics:

#### 1) *WebPageTest*

- **Visual Page Loading Process:** A loading process visualization provides a visual representation of how a web page loads and displays its elements on the user's screen. It allows for the identification and analysis of the timing of various elements during the loading process. The data is typically presented in seconds, indicating the time it takes for each element to load and appear on the screen. (s).
- **Page Weight:** it refers to the total size of a web page, including all the resources that are downloaded when a user visits it, such as HTML, CSS, JavaScript, images, and other media files. The weight load of a web page has an impact on its loading speed, as larger pages take longer to download the necessary files. The data is typically measured in kilobytes (KB) and provides an indication of the amount of data that needs to be transferred from the server to the user's computer.
- **DNS Lookup:** Before loading a Web page, the user's browser needs to perform a DNS (Domain Name System) lookup to translate the page's domain name into an IP address understandable for the server. The DNS lookup process involves querying a DNS server to retrieve the IP address associated with the requested domain. The time it takes for the DNS lookup to complete can vary depending on factors such as the DNS server configuration, network conditions, and the user's geographic location. The duration of DNS lookup is measured typically in milliseconds (ms).
- **SSL Negotiation:** Negotiation refers to a security protocol that establishes an encrypted connection between the browser and the web server. It involves the exchange of information about encryption and keys. The negotiation process can impact upload speed, particularly if it takes longer to establish a secure connection. The duration of the negotiation is measured in milliseconds (ms).

#### 2) *GTmetrix*

- **GTmetrix Grade:** is an overall score assigned to a web page's performance based on multiple factors evaluated by GTmetrix. These factors include load time, page size, image optimization, file compression, and more. The GTmetrix Grade provides a general evaluation of the website's performance and is represented by letters (A, B, etc.)
- **Performance:** it provides a detailed assessment of the website's performance. It includes metrics such as total load time, time to first byte (TTFB), time to interaction (TTI), and total DOM load time. These metrics are represented in percentage (%)
- **Structure:** focuses on the framework and composition of web pages. It evaluates the total size of the page, the number of HTTP requests, the weight of CSS and JavaScript files, the use of GZIP compression, and

other optimizations related to the Web page's design. The data for evaluation is given in percentage (%)

- **Fully Loaded Time:** indicates the total time required to fully load a web page, including all resources such as images, CSS, JavaScript, and subsequent load activities like AJAX requests or ad loading. The data for this metric is given in seconds (s).

#### 3) *PageSpeed Insights*

- **Core Web Metrics Assessment:** analyzes key metrics related to the performance and optimization of a web page. It provides an assessment that includes factors such as; load time, image optimization, resource usage, and other relevant elements. Evaluating these metrics helps understand the current state of website.
- **Performance:** refers to the speed and efficiency with which web pages are loaded and displayed to users. In addition to allowing, to measure the loading time of site, identify what is slowing it down, and get recommendations for improvement (last 28 days).
- **Speed Index:** indicates the average time it takes for the visible content to appear on the screen during loading. The lower the speed index, the faster the content will be displayed to the user. A low-speed index promotes a faster and more satisfactory user experience. The data is given in seconds (s).

### H. Data Collection

Tests and measurements were executed utilizing the designated technological tools and metrics. In order to gather data pertaining to the performance of university websites, the address of each website was inputted into the measurement tools. These tests facilitated the acquisition of comprehensive information regarding load time, server performance, page size, and other pertinent metrics essential for assessing the efficiency of university websites.

#### I. Data Analysis:

In this study, a meticulous examination of the measured variables was conducted, employing descriptive statistical techniques. Measures such as means, standard deviations, as well as relevant parameters such as minimum and maximum values, were calculated. The obtained results unveiled a substantial variability in the means and standard deviations of the evaluated variables, signifying noteworthy distinctions in the collected data.

For the analysis and evaluation of the data, the statistical software Jasp, version 0.17.2, was employed. This tool enabled accurate and efficient descriptive statistical analysis. Its utilization facilitated the extraction of pertinent information concerning the characteristics of the variables, allowing for a comprehensive understanding of data variability within the study's context. The implementation of Jasp software provided a dependable platform to delve deeper into the results and draw meaningful conclusions based on the statistical analysis.

#### J. Results Interpretation

The interpretation of the results derived from the data analysis yields valuable insights into the study's findings. The trends and relationships observed among the evaluated variables were thoroughly examined, facilitating a

comprehensive understanding of the prominent patterns and characteristics. It is important to emphasize that a detailed and comprehensive analysis of the results is presented in the subsequent section, "Results." This section delves into the relevant aspects in greater detail, providing a more comprehensive perspective on the obtained data.

### III. RESULTS AND DISCUSSION

The study implemented the Efficiency Evaluation Process for university websites, as depicted in Figure 1. The data collected during the evaluation were obtained from specialized performance measurement tools. Prominent and extensively utilized tools such as WebPageTest, GTmetrix, and PageSpeed Insights were employed. The subsequent overview provides a summary of the evaluation process that was employed:



Fig. 1 Assessing the Efficiency of University Websites Process

This case study was conducted by applying the assessment. In this paper, a statistical analysis is presented to provide an efficiency perspective in measuring the performance of these websites. Here are some important facts to consider:

#### A. Page Load Speed on Desktop - WebPageTest

Fig. 2 illustrates the page load speeds in the desktop environment of the top 10 universities with the fastest web page loads. The chart is based on data collected using the

WebPageTest tool and showcases various metrics associated with page load performance. These metrics include the visual load process, page weight measured in kilobytes (kb), DNS lookup time, and SSL negotiation time.

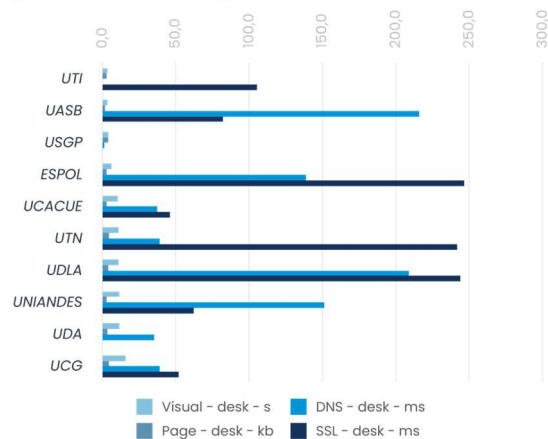


Fig. 2 Top 10 universities with the best efficiency in terms of website performance - Desktop - WebPageTest

#### B. Page Load Speed on Mobile Devices - WebPageTest

Fig. 3 illustrates the mobile page load speeds of the top 10 universities with the fastest web page loads. The chart is based on data collected using the WebPageTest tool and displays various metrics that are relevant to page load performance. These metrics include the visual load process, page weight in kilobytes (kb), DNS lookup time, and SSL negotiation time. The chart provides valuable insights into the efficiency of these universities' web pages and allows for comparisons based on these key performance metrics.

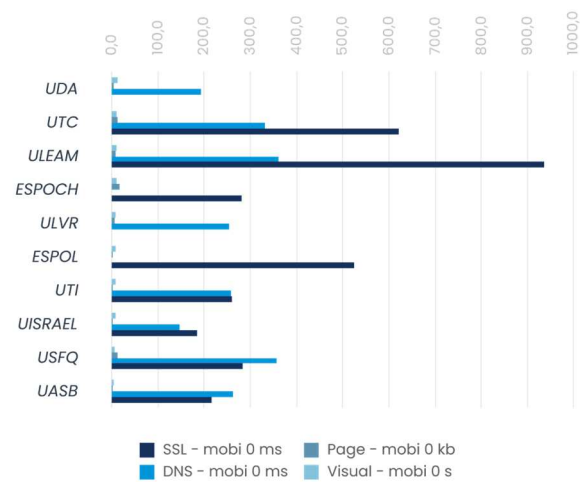


Fig. 3 Top 10 Universities with the best efficiency in terms of website performance - Mobile - WebPageTest

#### C. Performance Per Page Load on Desktop - GTmetrix

Performance per page load in the desktop environment is analyzed using the GTmetrix tool. Fig. 4 represents the 10 universities and polytechnics with the highest efficiency in terms of performance, as assessed through metrics such as GTmetrix Grade, performance, structure, and full load time. The chart highlights the universities and polytechnics that demonstrate exceptional performance in these areas, providing valuable insights into their website optimization and efficiency.



Fig. 4 Top 10 Universities with the best efficiency in terms of website performance - GTmetrix

*D. Performance Exceeded by Page Load Speed on Desktop- PageSpeed Insights*

Fig. 5 represents the performance per page load in the desktop environment using the PageSpeed Insights tool. The graph displays the effectiveness of university websites that have passed the test in terms of performance metrics and Speed Index. According to the collected data, Universidad San Gregorio stands out as the only university that has successfully passed the performance test, demonstrating a satisfactory level of performance compared to other universities.

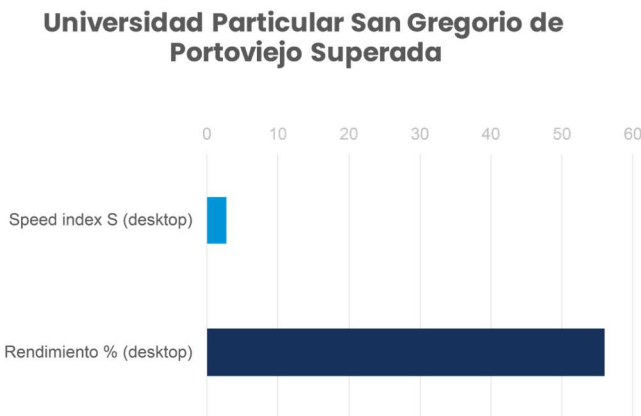


Fig. 5 University that passed the test Desktop – PageSpeed Insights

*E. Improving Performance through Page Load on Mobile Devices- PageSpeed Insights*

Fig. 6 represents the performance per page load in the mobile environment using the Page Speed Insights tool. It showcases the performance of the universities that successfully passed the test, highlighting their performance metrics and Speed Index. The data collected provides valuable insights into the efficiency and speed of the mobile versions of these university websites.

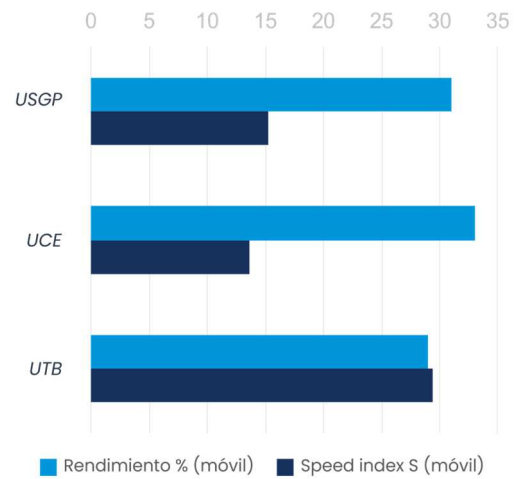


Fig. 6 University that passed the test in Mobile devices – PageSpeed Insights

*F. Slower Page Loading Speed on Desktop - WebPageTest*

Fig. 7 illustrates the lowest page load speeds in the desktop environment of the 10 universities with the slowest web page loads. The chart is generated based on data collected using the WebPageTest tool and showcases various metrics related to page load performance, including the visual load process, page weight in kilobytes (kb), DNS lookup time, and negotiation of SSL. This data provides insights into the areas that may require optimization to improve the overall performance of these university websites.

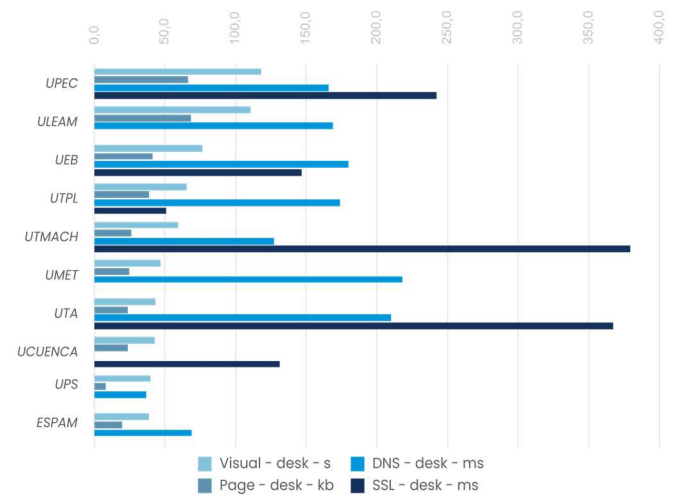


Fig. 7 10 Universities with the least efficiency - Desktop -WebPageTest

*G. Slower Page Loading Speed on Mobile Devices - WebPageTest*

Fig. 8 presents the slowest page load speeds in the mobile environment of the 10 universities with the slowest web page loads. The chart is based on data collected using the WebPageTest tool and shows different metrics related to page load performance, such as visual load process, page weight in kilobytes (kb), DNS lookup, and negotiation of SSL.



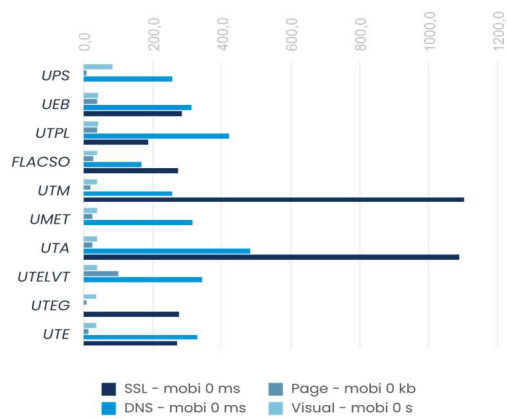


Fig. 8 10 Universities with the least efficiency - Mobile -WebPageTest

H. Did not Outperform Per Page Load on Desktop-PageSpeed Insights

Fig. 9 represents the lowest performance of the websites of the 10 universities that failed the test and also had the lowest performance per page load in the desktop environment using the PageSpeed Insights tool. The graph showcases the performance metrics and Speed Index of these universities, highlighting their poor pe performance.

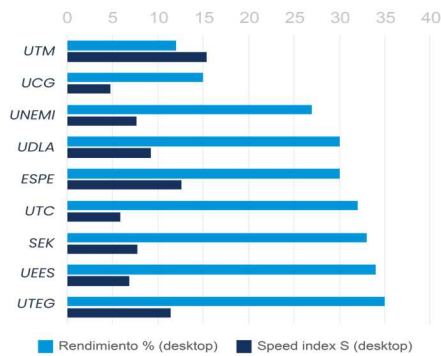


Fig. 9 Universities that did not outperform per page load on Desktop – PageSpeed Insights

I. Universities that did not Outperform Per Page Load on Mobile Devices – PageSpeed Insights

Fig. 10 conveys the lowest performance of the websites of the 10 universities that did not pass the test and also had the lowest per page load performance in the mobile environment using the PageSpeed Insights tool. The graph showcases these institutions' performance metrics and Speed Index o.

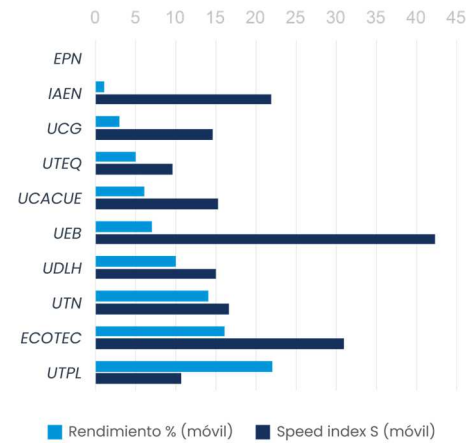


Fig. 10 Universities that did not outperform per page load on Mobile devices – PageSpeed Insights

J. Performance and Speed Statistics of University Websites

In the study, the characteristics of the measured variables were assessed via descriptive statistical analysis, wherein the means, standard deviations, and other pertinent measures such as minimum and maximum values were examined. The outcomes presented in Table 4 illustrate a variability in the means and standard deviations of the variables. Specifically, a moderate dispersion of data was observed around the mean for the variables "Visual desk s," "Visual - mobi - s," and "Fully Loaded Time." These results indicate that there exists notable variation within these variables, implying potential disparities or inconsistencies in their respective measurements.

TABLE II  
UNIVERSITY WEB SITE EFFICIENCY SUB CHARACTERISTICS

|                    |         | Tools                       | Type | Valid | Absent | Mean       | SD         | Shapiro-Wilk | Shapiro-Wilk p-value | Minimum | Maximum    |
|--------------------|---------|-----------------------------|------|-------|--------|------------|------------|--------------|----------------------|---------|------------|
| WebPageTest        | desktop | Visual Page Loading Process | s    | 55    | 0      | 25.820     | 23.009     | 0.735        | < .001               | 3.100   | 118.000    |
|                    |         | Page Weight                 | kb   | 55    | 0      | 11.884.661 | 13.534.545 | 0.696        | < .001               | 10.020  | 67.384.000 |
|                    |         | DNS Lookup                  | ms   | 55    | 0      | 107.091    | 98.252     | 0.896        | < .001               | 0.000   | 356.000    |
|                    | mobile  | SSL Negotiation             | ms   | 55    | 0      | 158.073    | 273.244    | 0.458        | < .001               | 0.000   | 1.966.000  |
|                    |         | Visual Page Loading Process | s    | 55    | 0      | 22.715     | 12.695     | 0.862        | < .001               | 4.400   | 81.500     |
|                    |         | Page Weigh                  | kb   | 55    | 0      | 10.661.615 | 15.557.070 | 0.617        | < .001               | 1.130   | 99.574.000 |
| GTmetrix           | desktop | DNS Lookup                  | ms   | 55    | 0      | 202.655    | 165.442    | 0.886        | < .001               | 0.000   | 656.000    |
|                    |         | SSL Negotiation             | ms   | 55    | 0      | 335.836    | 317.031    | 0.863        | < .001               | 0.000   | 1.110.000  |
|                    |         | GTmetrix Grade              | 0-6  | 55    | 0      | 4.073      | 2.364      | 0.746        | < .001               | 0.000   | 6.000      |
|                    | mobile  | Performance                 | %    | 55    | 0      | 38.182     | 26.636     | 0.942        | 0.010                | 0.000   | 98.000     |
|                    |         | Structure                   | %    | 55    | 0      | 45.164     | 26.970     | 0.906        | < .001               | 0.000   | 95.000     |
|                    |         | Fully Loaded Time           | s    | 55    | 0      | 11.291     | 13.748     | 0.733        | < .001               | 0.000   | 79.900     |
| PageSpeed Insights | desktop | Main Web Metrics Assessment | 0-1  | 55    | 0      | 0.018      | 0.135      | 0.117        | < .001               | 0.000   | 1.000      |
|                    |         | Performance                 | %    | 55    | 0      | 51.655     | 16.745     | 0.988        | 0.836                | 12.000  | 96.000     |
|                    |         | Speed index                 | s    | 55    | 0      | 5.842      | 3.124      | 0.957        | 0.049                | 0.800   | 15.400     |
|                    | mobile  | Main Web Metrics Assessment | 0-1  | 55    | 0      | 0.055      | 0.229      | 0.240        | < .001               | 0.000   | 1.000      |
|                    |         | Performance                 | %    | 55    | 0      | 30.564     | 14.445     | 0.959        | 0.057                | 0.000   | 75.000     |
|                    |         | Speed index                 | s    | 55    | 0      | 18.925     | 10.353     | 0.947        | 0.016                | 0.000   | 44.700     |

On the other hand, the variables "Page desk kb" and "Page - mobi - kb" exhibited a greater dispersion of data, suggesting a wide variability in page sizes across desktop and mobile devices. Variables associated with upload speed, such as "DNS - desk - ms", "SSL - desk - ms", "DNS - mobi - ms", and "SSL - mobi - ms", displayed considerable variation in loading times and system response for both desktop and mobile devices. Furthermore, the variables "GTmetrix Grade", "Performance %", and "Structure %" that signify evaluations and scores pertaining to the performance and structure of web pages manifested some variability in the results of the assessment process. These metrics provided an overview of the performance and speed of the evaluated university websites, allowing for a comprehensive assessment of their efficiency and effectiveness.

#### IV. CONCLUSIONS

This case study aims to evaluate and analyze the performance of university websites by utilizing multiple performance measurement tools, namely WebPageTest, GTmetrix, and PageSpeed Insights. These tools provide a range of metrics and quantitative data that can be used to assess the efficiency of the websites.

Through the analysis of these metrics, valuable insights can be gained regarding key aspects of website performance, such as page load time, page size, and other relevant factors. Based on the data collected and analyzed, the following findings and recommendations can be presented:

- **Varied Performance:** The assessment of performance on college and university websites reveals significant variability across different metrics and tools. This indicates that websites exhibit varying levels of efficiency in terms of load time, page size, DNS lookup times, and SSL negotiation.
- **Performance optimization challenges:** The analysis highlights load time and page size as the primary factors impacting website performance. The results indicate that there is room for improvement in these areas among the studied university websites.

- **The importance of mobile performance:** The evaluation results comparing the desktop and mobile versions of the websites emphasize the significance of optimizing performance specifically for mobile devices. The metrics, including load times and other performance indicators, can vary between these two versions, underscoring the need to fine-tune and optimize websites to deliver an optimal mobile experience.
- **Needs for a comprehensive strategy:** Enhancing website performance requires the implementation of a comprehensive strategy that encompasses various aspects, including optimizing loading time, reducing page size, and addressing other relevant technical considerations. However, it is equally important to take into account elements such as usability, user experience, and accessibility to provide a holistic and satisfying experience for website visitors. In order to improve performance on university websites, it is crucial to apply the techniques outlined in this study's materials and methods section.

As part of future research efforts, there is a plan to conduct a comprehensive paper that encompasses case studies involving additional tests. These case studies will provide insights into the before and after scenarios of implementing various techniques and tools for measuring website performance. By comparing the results, it will be possible to highlight the effectiveness of different strategies in improving performance. Additionally, there is a focus on developing software tools that can perform real-time analysis to gather data on website performance. These tools aim to provide detailed information on key metrics such as load time and response speed.

#### APPENDIX A

##### LIST OF HIGHER EDUCATION INSTITUTIONS IN ECUADOR

This appendix lists all the higher education institutions in Ecuador that have been analyzed and evaluated in this case study. Table 5 illustrates higher education institutions' identifier, name, and category.

TABLE III  
NUMBER OF ACCREDITED UNIVERSITIES AND POLYTECHNICAL SCHOOLS

| Nº | Higher Education Institution   | Acronym | Web   | Cat. |
|----|--|---------|---|------|
| 1  | Escuela Politécnica Nacional   | EPN     | <a href="https://www.epn.edu.ec/">https://www.epn.edu.ec/</a>         | Yes  |
| 2  | Escuela Superior Politécnica Agropecuaria de Manabí "Manuel Félix López" | ESPAM   | <a href="http://www.espam.edu.ec/">http://www.espam.edu.ec/</a>       | Yes  |
| 3  | Escuela Superior Politécnica de Chimborazo                               | ESPOCH  | <a href="https://www.esepoch.edu.ec/">https://www.esepoch.edu.ec/</a> | Yes  |
| 4  | Escuela Superior Politécnica del Litoral                                 | ESPOL   | <a href="http://www.espol.edu.ec/">http://www.espol.edu.ec/</a>       | Yes  |
| 5  | Instituto de Altos Estudios Nacionales                                   | IAEN    | <a href="https://www.iaen.edu.ec/">https://www.iaen.edu.ec/</a>       | Yes  |
| 6  | Universidad Agraria del Ecuador  | UAE     | <a href="http://www.uagraria.edu.ec/">http://www.uagraria.edu.ec/</a> | Yes  |
| 7  | Universidad Central del Ecuador  | UCE     | <a href="http://www.uce.edu.ec/">http://www.uce.edu.ec/</a>           | Yes  |
| 8  | Universidad de Cuenca  | UCUENCA | <a href="https://www.ucuenca.edu.ec/">https://www.ucuenca.edu.ec/</a> | Yes  |
| 9  | Universidad de Guayaquil   | UG      | <a href="http://www.ug.edu.ec/">http://www.ug.edu.ec/</a>             | Yes  |
| 10 | Universidad de las Fuerzas Armadas "ESPE"                                | ESPE    | <a href="https://www.espe.edu.ec/">https://www.espe.edu.ec/</a>       | Yes  |
| 11 | Universidad Estatal Amazónica  | UEA     | <a href="https://www.uea.edu.ec/">https://www.uea.edu.ec/</a>         | Yes  |
| 12 | Universidad Estatal de Bolívar   | UEB     | <a href="https://www.ueb.edu.ec/">https://www.ueb.edu.ec/</a>         | Yes  |
| 13 | Universidad Estatal de Milagro   | UNEMI   | <a href="https://www.unemi.edu.ec/">https://www.unemi.edu.ec/</a>     | Yes  |
| 14 | Universidad Estatal del Sur de Manabí                                    | UNESUM  | <a href="http://unesum.edu.ec/">http://unesum.edu.ec/</a>             | Yes  |
| 15 | Universidad Estatal Península de Santa Elena                             | UPSE    | <a href="https://www.upse.edu.ec/">https://www.upse.edu.ec/</a>       | Yes  |
| 16 | Universidad Laica Eloy Alfaro de Manabí                                  | ULEAM   | <a href="https://www.uleam.edu.ec/">https://www.uleam.edu.ec/</a>     | Yes  |
| 17 | Universidad Nacional de Chimborazo                                       | UNACH   | <a href="http://www.unach.edu.ec/">http://www.unach.edu.ec/</a>       | Yes  |
| 18 | Universidad Nacional de Loja   | UNL     | <a href="https://www.unl.edu.ec/">https://www.unl.edu.ec/</a>         | Yes  |
| 19 | Universidad Politécnica Estatal del Carchi                               | UPEC    | <a href="http://www.upec.edu.ec/">http://www.upec.edu.ec/</a>         | Yes  |

| Nº | Higher Education Institution                            | Acronym   | Web   | Cat. |
|----|---|-----------|---|------|
| 20 | Universidad Técnica de Ambato                           | UTA       | <a href="https://www.uta.edu.ec/">https://www.uta.edu.ec/</a>                   | Yes  |
| 21 | Universidad Técnica de Babahoyo                         | UTB       | <a href="https://www.utb.edu.ec/">https://www.utb.edu.ec/</a>                   | No   |
| 22 | Universidad Técnica de Cotopaxi                         | UTC       | <a href="http://www.utc.edu.ec/">http://www.utc.edu.ec/</a>                     | Yes  |
| 23 | Universidad Técnica de Machala                          | UTMACH    | <a href="https://utmachala.edu.ec/">https://utmachala.edu.ec/</a>               | Yes  |
| 24 | Universidad Técnica de Manabí                           | UTM       | <a href="https://www.utm.edu.ec/">https://www.utm.edu.ec/</a>                   | Yes  |
| 25 | Universidad Técnica del Norte                           | UTN       | <a href="https://www.utm.edu.ec/">https://www.utm.edu.ec/</a>                   | Yes  |
| 26 | Universidad Técnica Estatal de Quevedo                  | UTEQ      | <a href="http://www.uteq.edu.ec/">http://www.uteq.edu.ec/</a>                   | Yes  |
| 27 | Universidad Técnica Luis Vargas Torres de Esmeraldas    | UTELVT    | <a href="https://www.utelvt.edu.ec/">https://www.utelvt.edu.ec/</a>             | No   |
| 28 | Facultad Latinoamericana de Ciencias Sociales           | FLACSO    | <a href="https://www.flacso.edu.ec/">https://www.flacso.edu.ec/</a>             | Yes  |
| 29 | Universidad Andina Simón Bolívar                        | UASB      | <a href="https://www.uasb.edu.ec/">https://www.uasb.edu.ec/</a>                 | Yes  |
| 30 | Pontificia Universidad Católica del Ecuador             | PUCE      | <a href="https://www.puce.edu.ec/">https://www.puce.edu.ec/</a>                 | Yes  |
| 31 | Universidad Católica de Cuenca                          | UCACUE    | <a href="https://www.ucacue.edu.ec/">https://www.ucacue.edu.ec/</a>             | Yes  |
| 32 | Universidad Católica de Santiago de Guayaquil           | UCSG      | <a href="https://www.ucsg.edu.ec/">https://www.ucsg.edu.ec/</a>                 | Yes  |
| 33 | Universidad del Azuay                                   | UDA       | <a href="http://www.uazuay.edu.ec/">http://www.uazuay.edu.ec/</a>               | Yes  |
| 34 | Universidad Laica Vicente Rocafuerte de Guayaquil       | ULVR      | <a href="http://www.ulvr.edu.ec/">http://www.ulvr.edu.ec/</a>                   | Yes  |
| 35 | Universidad Politécnica Salesiana                       | UPS       | <a href="http://www.ups.edu.ec/">http://www.ups.edu.ec/</a>                     | Yes  |
| 36 | Universidad Técnica Particular de Loja                  | UTPL      | <a href="https://www.utpl.edu.ec/">https://www.utpl.edu.ec/</a>                 | Yes  |
| 37 | Universidad UTE   | UTE       | <a href="https://www.ute.edu.ec/">https://www.ute.edu.ec/</a>                   | Yes  |
| 38 | Universidad Particular Internacional SEK                | SEK       | <a href="https://www.uisek.edu.ec/">https://www.uisek.edu.ec/</a>               | Yes  |
| 39 | Universidad Casa Grande                                 | UCG       | <a href="https://www.casagrande.edu.ec/">https://www.casagrande.edu.ec/</a>     | Yes  |
| 40 | Universidad Particular de Especialidades Espíritu Santo | UEES      | <a href="http://www.uees.edu.ec/">http://www.uees.edu.ec/</a>                   | Yes  |
| 41 | Universidad de Especialidades Turísticas                | UDET      | <a href="https://udet.edu.ec/">https://udet.edu.ec/</a>                         | No   |
| 42 | Universidad de Las Américas                             | UDLA      | <a href="https://www.udla.edu.ec/">https://www.udla.edu.ec/</a>                 | Yes  |
| 43 | Universidad de los Hemisferios                          | UDLH      | <a href="https://www.uhemisferios.edu.ec/">https://www.uhemisferios.edu.ec/</a> | Yes  |
| 44 | Universidad de Otavalo                                  | UO        | <a href="https://www.uotavalo.edu.ec/">https://www.uotavalo.edu.ec/</a>         | Yes  |
| 45 | Universidad del Pacífico Escuela de Negocios            | UPACIFICO | <a href="https://web.upacifico.edu.ec/">https://web.upacifico.edu.ec/</a>       | Yes  |
| 46 | Universidad Iberoamericana del Ecuador                  | UNIBE     | <a href="https://www.unibe.edu.ec/">https://www.unibe.edu.ec/</a>               | Yes  |
| 47 | Universidad Internacional del Ecuador                   | UIDE      | <a href="https://www.uide.edu.ec/">https://www.uide.edu.ec/</a>                 | Yes  |
| 48 | Universidad Metropolitana                               | UMET      | <a href="http://www.umet.edu.ec/">http://www.umet.edu.ec/</a>                   | Yes  |
| 49 | Universidad Regional Autónoma de los Andes              | UNIANDES  | <a href="https://www.uniandes.edu.ec/">https://www.uniandes.edu.ec/</a>         | Yes  |
| 50 | Universidad San Francisco de Quito                      | USFQ      | <a href="https://www.usfq.edu.ec/es">https://www.usfq.edu.ec/es</a>             | Yes  |
| 51 | Universidad Particular San Gregorio de Portoviejo       | USGP      | <a href="http://www.sangregorio.edu.ec/">http://www.sangregorio.edu.ec/</a>     | Yes  |
| 52 | Universidad Tecnológica ECOTEC                          | ECOTEC    | <a href="https://www.ecotec.edu.ec/">https://www.ecotec.edu.ec/</a>             | Yes  |
| 53 | Universidad Tecnológica Empresarial de Guayaquil        | UTEG      | <a href="https://www.uteg.edu.ec/">https://www.uteg.edu.ec/</a>                 | Yes  |
| 54 | Universidad Indoamérica                                 | UTI       | <a href="https://indoamerica.edu.ec/">https://indoamerica.edu.ec/</a>           | Yes  |
| 55 | Universidad Tecnológica Israel                          | UISRAEL   | <a href="http://www.uisrael.edu.ec/">http://www.uisrael.edu.ec/</a>             | Yes  |

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