Principal Component Analysis Applied To The Heuristic Evaluation Of The Quality Of Websites Of Universities

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Abstract

In the present research endeavor, the assessment of the quality of websites belonging to Ecuadorian universities is posited. To facilitate this assessment, a heuristic tool has been formulated, drawing upon contributions from various authors, Given the absence of a singular methodology within this research domain for appraising the quality of these digital platforms. This involves the analysis of content derived from official websites, applying an evaluation form composed of 55 indicators that verify the existence and functionality of digital resources. As an additional contribution, the information has been processed using Principal Component Analysis to identify components capable of explaining the variability in the data, Furthermore, HJ-Biplot graphs have been utilized to pinpoint multivariate covariation structures among the quality indicators employed. The scrutiny extended to the official websites of all 62 accredited universities in Ecuador. Notably, the analysis revealed that 6 components contribute to over 53% of the variability in the data. This outcome has facilitated the identification of the most pertinent indicators crucial for evaluating the quality of the examined websites. Similarly, the results of this study highlight that well-conceived web design is characterized by being intuitive, accessible, and functional, with special attention to communication and interaction with the university community

Introduction

The internet stands as the most extensively utilized communication platform worldwide, with approximately two-thirds of the global population employing the web as a primary means of communication. [1], This h[1]as compelled universities to enhance and maintain a proper digital presence since their websites have become a representation of their image and commitment to accessibility and the dissemination of knowledge [2], [3][4], transforming websites into authentic and accessible digital platforms is essential to effectively inform, persuade, and, to a certain extent reflect the educational quality of the institution. [5], [6]. For this reason, it is considered very important for universities to maintain an accessible, usable website with relevant information that meets the needs of their audience.[7], [8].

In this context, Numerous researchers and professionals have delved into diverse aspects pertaining to the quality, usability, and effectiveness of these websites. [9]. For instance, Macakoğlu, Peker, and Medeni identified common patterns and problematic areas concerning user experience and navigability on university websites in Europe, North America, and Oceania. Their research specifically centered on the experience of

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prospective students, regardless of whether they had special needs, aiming to discern the accessibility levels of these websites.[10].

Similarly, Akgül found that numerous Turkish universities boast visually appealing websites with substantial informative content, yet they exhibit shortcomings in terms of accessibility for students with disabilities. The deficiency arises from the fact that accessibility has not been regarded as a fundamental criterion in the development of these platforms. Consequently, this not only limits students' access to educational resources but also contributes to the creation of a digital divide [11].

Besides, Wahyuningrum et al. discerned alterations in search patterns and information consumption by scrutinizing the interactions, behaviors, and information consumption of users on the University of Timor Leste's website. They underscored the pivotal role of this platform in guaranteeing educational continuity, particularly in the context of the challenges posed by the COVID-19 pandemic [12].

It is also relevant to mention that, Saleh et al. conducted a successful identification of a broad spectrum of criteria and methodologies for evaluating website quality via a systematic literature review. Consequently, they underscored the imperative to establish a unified framework for the assessment of website quality, aiming to ensure consistency and facilitate comparisons in future research endeavors [13].

Conversely, Hai and Nguyen conducted an assessment of the quality of Vietnamese university websites by analyzing student perceptions and employing web quality metrics. Their findings indicated that a well-designed, intuitive, and functional website can notably enhance the university's image and reputation. They further demonstrated a high correlation between website quality, the level of trust, and student satisfaction [14].

Finally, Rashida et al. developed a structured tool to assess the qualities of university websites with a holistic approach that addresses both technical and functional aspects. This methodology considers site effectiveness, user experience, and content coherence. The result is a versatile tool that provides institutions with a deep understanding of their digital platforms, identifying potential areas for improvement [15].

The presented information underscores the responsibility of universities to uphold and enhance the quality of their websites. Moreover, it highlights the imperative to establish and validate tools, techniques, and methodologies for assessing website quality. This is crucial not only for identifying existing issues but also for implementing effective improvement plans.

Materials and Methods

A tool to assess the website's quality

Through the literature review, it was determined that there is no standard model for evaluating the quality of websites. Studies [16], [17], [18], [19], detail and validate various methods for website evaluation, utilizing evaluation forms, Through parameters and indicators organized into specific factors or criteria, they assess the quality of a website. The present evaluation proposal is based on the "Articulated System of Web Platform Analysis." [16] and the "Web Quality Index" [17].

Seven key evaluation areas representing general aspects of university websites have been identified. These are: Accessibility and Services, Information, Academic Content, Multimedia, Community, Social Networks, and Communication [20]. These domains

encompass a total of 22 evaluation parameters, each designed to scrutinize distinct facets within the respective fields, evaluating functional and operational characteristics as identified in academic literature. The proposed evaluation instrument comprises 55 indicators strategically devised to assess the presence and functionality of tools unique to websites, thereby facilitating a comprehensive and meticulous appraisal of quality.

The quality of websites of Ecuadorian Univerisites.

The process of website selection for this study was executed through the utilization of information provided by the Higher Education Council (CES). Authorization was secured to access the official websites of all 62 accredited universities in Ecuador, employing the content analysis technique to verify the presence and functionality of resources unique to web platforms.

The statistical processing of the data was carried out using the Principal Component Analysis (PCA) technique, considering universities as data points and evaluation indicators as study variables. Additionally, the R language has been employed for the treatment of the collected data through specialized libraries: dolyr, openxlsx, ggplot2, corroplot, factoextra, nbclust, cluster, nortest y psych, which allowed analize and visualize the obtained results.

The initial analysis indicated that the variables possess a structure conducive to Principal Component Analysis (PCA) application, as evidenced by the satisfactory outcomes of the Kaiser-Meyer Olkin test and Bartlett's test of sphericity. Consequently, the utilization of promax rotation has been warranted, considering that the factors exhibit orthogonality to each other.

Table 1: Results of the Principal Component Analysis of the quality indicators of universities.

Comp.	Standard deviation	Proportion of Variance	Cumulative Proportion
1	14.807.213	0,11305	0,11305
2	14.158.868	0,10337	0,21642
3	136.947.700	0,09670	0,31313
4	125.478.298	0,08118	0,39431
5	124.297.935	0,07966	0,47398
6	112.808.901	0,06562	0,53960
7	0,97186	0,04870	0,58830
8	0,92257	0,04389	0,63218
9	0,89409	0,04122	0,67340
10	0,83913	0,03631	0,70971
11	0,78228	0,03155	0,74127
12	0,73166	0,02760	0,76887
13	0,67664	0,02361	0,79248
14	0,62781	0,02032	0,81280
15	0,62295	0,02001	0,83281
16	0,59815	0,01845	0,85126
17	0,55673	0,01598	0,86724
18	0,51606	0,01373	0,88097
19	0,47708	0,01174	0,89271
20	0,46164	0,01099	0,90370
21	0,45158	0,01051	0,91421

22	0,43080	0,00957	0,92378
23	0,41444	0,00886	0,93264
24	0,37643	0,00731	0,93994
25	0,35748	0,00659	0,94653
26	0,35550	0,00652	0,95305
27	0,33175	0,00567	0,95872
28	0,30968	0,00494	0,96367
29	0,29413	0,00446	0,96813
30	0,27779	0,00398	0,97211
31	0,26710	0,00368	0,97579
32	0,25019	0,00323	0,97901
33	0,23294	0,00280	0,98181
34	0,22953	0,00272	0,98453
35	0,21160	0,00231	0,98684
36	0,20023	0,00207	0,98890
37	0,18980	0,00186	0,99076
38	0,17234	0,00153	0,99229
39	0,16892	0,00147	0,99376
40	0,14997	0,00116	0,99492
41	0,13082	0,00088	0,99581
42	0,12439	0,00080	0,99660
43	0,11669	0,00070	0,99731
44	0,10913	0,00061	0,99792
45	0,09329	0,00045	0,99837
46	0,08560	0,00038	0,99875
47	0,07864	0,00032	0,99907
48	0,07057	0,00026	0,99932
49	0,06948	0,00025	0,99957
50	0,06079	0,00019	0,99976
51	0,04062	0,00009	0,99985
52	0,03637	0,00007	0,99992
53	0,03028	0,00005	0,99996

Table 1 presents the principal components alongside their corresponding eigenvalues and the percentages of explained variance. Additionally, the cumulative variance is provided to assess the overall quality of the websites. According to the Kaiser criterion, it is recommended to select components up to 6, given that their eigenvalues are greater than or equal to 1. The six components collectively account for 53.96% of the explained variance in the study data.

Figure 1 provides a clearer visualization of the eigenvalues associated with each component.
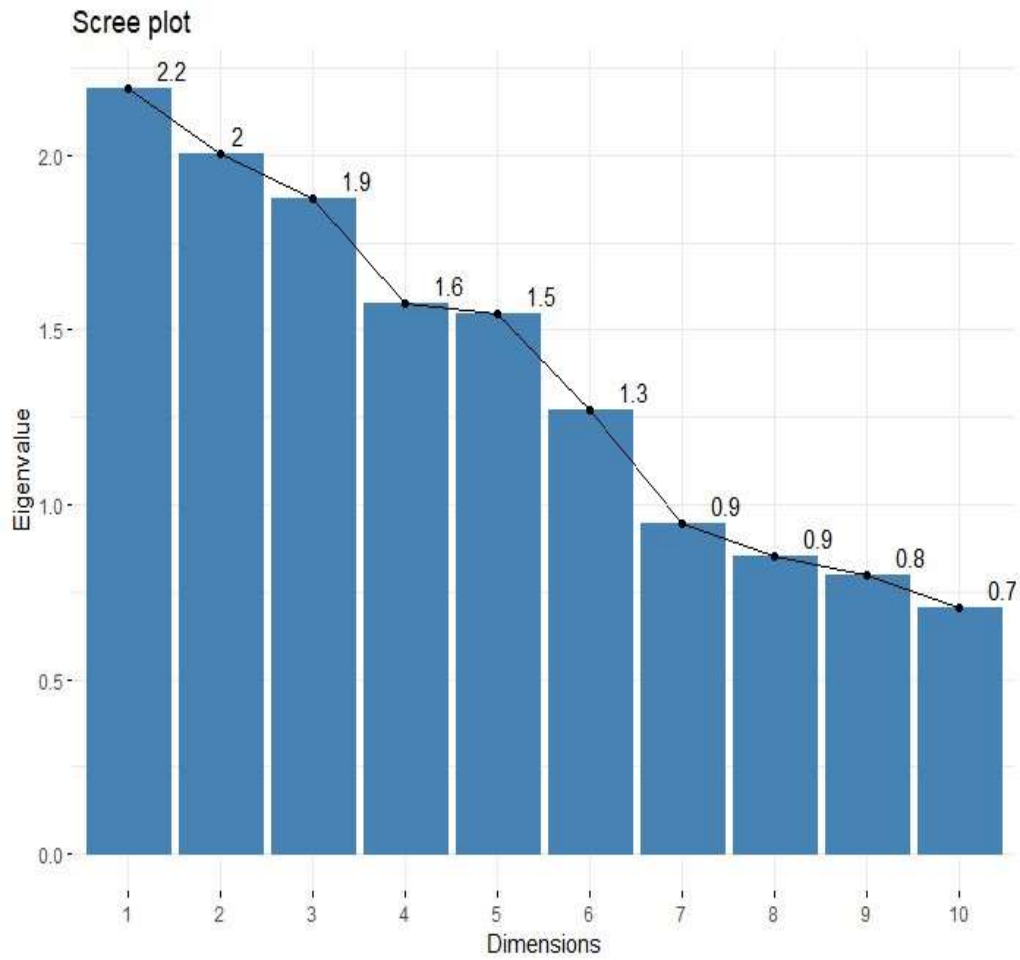
Scree plot

Figure 1: Eigenvalues of the components in the evaluation of the quality indicators.

Table 2 describes the indicators that exhibit the most significant contributions to the identified components. The codes assigned to these indicators delineate the field, parameter, and indicator number they represent.

Table 2: Contribution of Indicators to the Main Components.

Cod.	Quality Indicator	Components					
		1	2	3	4	5	6
2.1.1	User registration tool	0.551					
2.1.3	Registration Parameters	0.572					
3.3.5	Routes or Specialties		0.287				
3.3.8	Contact		0.283				
5.1.1	Option to Share Contents		0.415				
1.2.1	Tool to Adjust Font Size			0.273			
1.2.2	Visual adaptation tool			0.292			

Code	Indicator			
7.3.2	Directory Format	0.439		
3.3.2	Cost		0.285	
4.2.1	Virtual Tour		0.310	
4.2.2	Virtual Tour Options		0.371	
7.3.1	Electronic Directory		0.326	
7.2.2	Official Email Support			0.658
1.1.1	Language Change for Portal Content			0.475
1.1.2	Site Languages			0.576
2.3.5	Faculties/Schools			0.336

To ascertain which indicators should be discarded, the one with the highest coefficient, in absolute terms, was identified. These outcomes are presented in Table 3.

Table 3: Results of the Main Component Analysis of the quality indicators of universities.

Main Component	Number of Indicators	Indicators	Level of explanation
First	2	User Registration Tool and Registration Parameters	11.3%
Second	3	Routes or Specialties, Contact, and Option to Share Contents	10.3%
Third	3	Tool to Adjust Font Size, Visual Adaptation Tool, Directory Format	9.7%
Fourth	4	Cost, Virtual Tour, Virtual Tour Options, Electronic Directory	7.9%
Fifth	1	Official Email Support	8.0%
Sixth	3	Language Change for Portal Content, Site Languages, Faculties/Schools	6.6%

With these adjustments, a Bi-plot analysis was performed on the selected set of components outlined in Table 3. For this analysis, the first three components were chosen, as they make the most significant contributions to explaining the variance in the data. In the generated graphs, the orange color denotes the highest contribution, while the light blue color indicates the lowest.

Figure 2 HJ-Biplot of dimensions 1 and 2 highlighting the influence of the quality indicators of the analyzed websites.

Figure 2 displays the axes corresponding to dimensions 1 and 2, emphasizing that the cumulative variability explained by these two dimensions totals 21.6%. Within this context, it is discerned that a specific group of universities predominates in terms of their influence on these two dimensions. Notably, this group comprises institutions such as Universidad Técnica de Babahoyo, Universidad Técnica de Machala, Universidad Técnica de Ambato, Universidad Técnica de Manabí, Universidad del Rio, Universidad Técnica del Norte, Universidad Casa Grande, Universidad Tecnológica ECOTEC y Universidad del Azuay.

The significance of the websites of these universities stems from their notable presence in specific quality indicators. These include the efficacy of the user registration mechanism and the criteria applied for registration, the diversity of programs, courses, and specializations offered, the accessibility of contact methods, and the provision of facilities for sharing digital content.

Similarly, a Bi-plot graph was generated for dimensions 1 and 3. Figure 3 displays the generated graph, and it is evident that these dimensions explain 21% of the total data variability.

Within this context, the following universities stand out: Universidad de Artes, Universidad del Pacífico, Universidad Técnica de Manabí, Escuela Politécnica Nacional, Universidad

del Rio, Universidad Técnica del Norte, Universidad Bolivariana Del Ecuador y Universidad Técnica Luis Vargas Torres.

The significance of these universities is evident in the presence and performance of various indicators on their respective websites. These indicators encompass systems for user registration and the associated parameters, tools facilitating text size adjustment, options for visual customization of the site, and the format utilized for presenting directories.
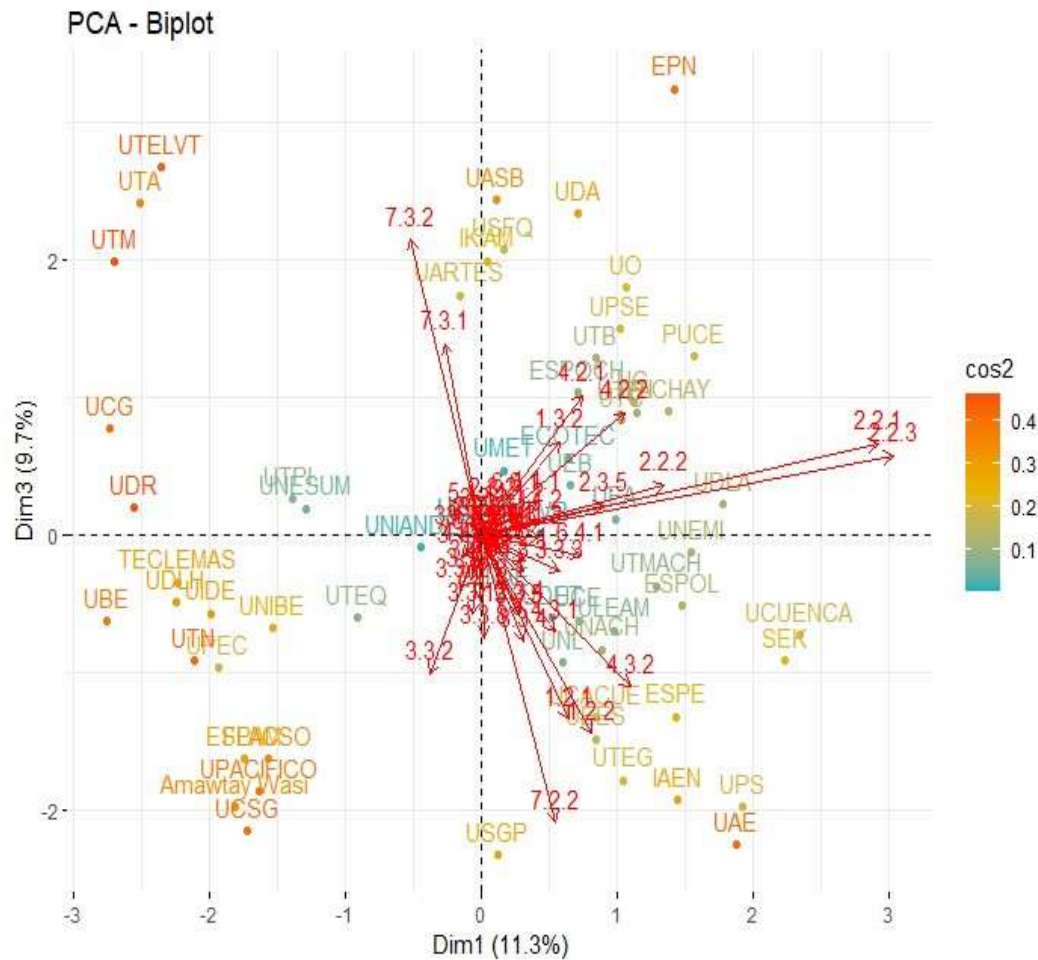

Figure 3: HJ-Biplot of dimensions 1 and 3 highlighting the influence of the quality indicators of the analyzed websites.

On the other hand, Figure 4 illustrates the intersection of dimensions 2 and 3 through a Biplot graph. These two dimensions explain 20% of the total variability. In this context excels the Universidad del Azuay, Universidad Agraria Del Ecuador, Universidad Técnica de Babahoyo, Universidad Técnica de Machala, Universidad Católica de Santiago de Guayaquil, Universidad Andina Simón Bolívar y Universidad Tecnológica ECOTEC.

The websites of these universities distinguish themselves through the incorporation of features like font size adjustment tools, visual adaptation options for users, and the effective organization of online directories. Moreover, these institutions are characterized by offering comprehensive information about their programs and specialties, contact methods, and functionalities for content sharing on the web.
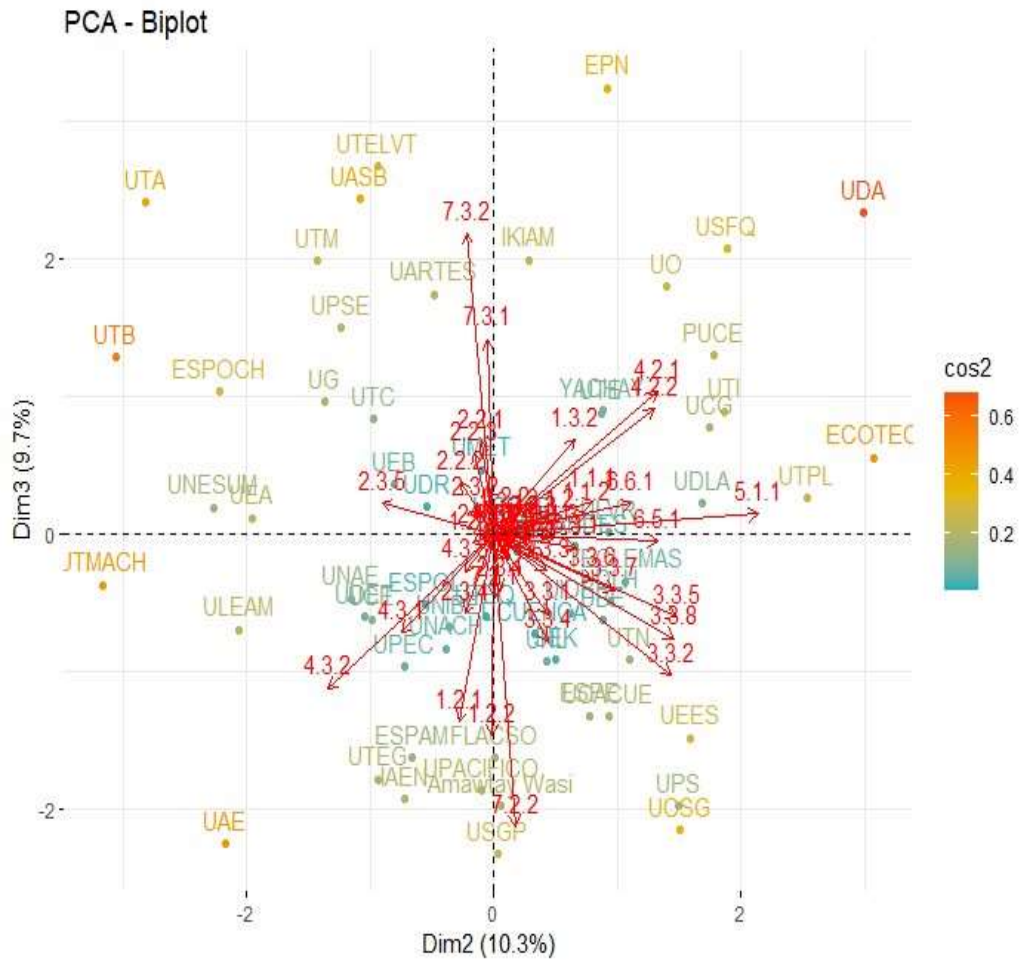
Figure 4: HJ-Biplot of dimensions 2 and 3 highlights the influence of the quality indicators of the analyzed websites.

In conclusion, an HJ Biplot graph has been generated, categorizing university websites into groups based on the results obtained from the web quality indicators. This classification has yielded two mutually exclusive sets, with Group 1 (pink) corresponding to universities exhibiting poorer results in this evaluation. [Escuela Superior Politécnica Agropecuaria de Manabí (ESPAM), Escuela Superior Politécnica de Chimborazo (ESPOCH), Instituto de Altos Estudios Nacionales (IAEN), Universidad Agraria del Ecuador (UAE), Universidad Central del Ecuador (UCE), Universidad de Guayaquil (UG), Universidad de las Artes (UARTES), Universidad Estatal Amazónica (UEA), Universidad Estatal de Bolívar (UEB), Universidad Estatal del Sur de Manabí (UNESUM), Universidad Estatal Península de Santa Elena (UPSE), Universidad Laica Eloy Alfaro de Manabí (ULEAM), Universidad Nacional de Educación (UNAE), Universidad Politécnica Estatal del Carchi (UPEC), Universidad Técnica de Ambato (UTA), Universidad Técnica de Babahoyo (UTB), Universidad Técnica de Cotopaxi (UTC), Universidad Técnica de Machala (UTMACH), Universidad Técnica de Manabí (UTM), Universidad Técnica Luis Vargas Torres (UTELVT), Universidad Amawtay Wasi (Amawtay Wasi), Universidad Andina Simón Bolívar (UASB), Universidad Internacional SEK Ecuador (SEK), Universidad de Especialidades Turísticas (UDET), Universidad Del Pacífico (UPACIFICO), Universidad del Río (UDR), Universidad Iberoamericana del Ecuador (UNIBE), Universidad Tecnológica Empresarial de Guayaquil (UTEG), Universidad Israel (UISRAEL)].

Conversely, Group 2 (blue) corresponds to universities that have attained the best results in this evaluation. [Escuela Politécnica Nacional (EPN), Escuela Superior Politécnica del Litoral (ESPOL), Universidad de Cuenca (UCUENCA), Escuela Superior Politécnica del Ejército (ESPE), Universidad Estatal de Milagro (UNEMI), Universidad Nacional de Chimborazo (UNACH), Universidad Nacional de Loja (UNL), Universidad Regional Amazónica Ikiam (IKIAM), Universidad Técnica del Norte (UTN), Universidad Técnica Estatal de Quevedo (UTEQ), Universidad Yachay Tech (YACHAY), Facultad Latinoamericana de Ciencias Sociales Ecuador (FLACSO), Pontificia Universidad Católica del Ecuador (PUCE), Universidad Católica de Cuenca (UCACUE), Universidad Católica de Santiago de Guayaquil (UCSG), Universidad del Azuay (UDA), Universidad Laica Vicente Rocafuerte de Guayaquil (ULVR), Universidad Politécnica Salesiana (UPS), Universidad Técnica Particular de Loja (UTPL), Universidad Tecnológica Equinoccial (UTE), Universidad Casa Grande (UCG), Universidad de Especialidades Espíritu Santo (UEES), Universidad de Las Américas (UDLA), Universidad de los Hemisferios (UDLH), Universidad de Otavalo (UO), Universidad Internacional del Ecuador (UIDE), Universidad Metropolitana (UMET), Universidad Regional Autónoma de los Andes (UNIANDES), Universidad San Francisco de Quito (USFQ), Universidad San Gregorio de Portoviejo (USGP), Universidad ECOTEC (ECOTEC), Universidad Tecnológica Indoamérica (UTI), Universidad Bolivariana del Ecuador (UBE)].

Figure 5: Categorized HJ-Biplot based on the evaluation results

Equations should be provided in a text format, rather than as an image. Microsoft Word's equation tool is acceptable. Equations should be numbered consecutively, in round

brackets, on the right-hand side of the page. They should be referred to as Equation 1, etc. in the main text.

Results and Discussion

The presented results are preliminary and aim to understand the scope of multivariate statistical analysis techniques to identify the most relevant indicators in the evaluation of website quality. The proposed approach suggests employing Principal Component Analysis for the statistical processing of the 55 variables under study, with the aim of identifying components that account for a significant portion of the observed variance. [21].

The analysis unveiled noteworthy disparities in the digital presence of the scrutinized universities. The justification for employing a multivariate analysis methodology in this study is substantiated by prior research, exemplified by the work conducted by Susanto et al. [22], Susanto and his team underscored the significance of web quality in educational institutions, emphasizing their assessment of web quality and its influencing factors. In contrast, the current research broadens its scope to encompass crucial indicators such as accessibility, quality of academic content, and the effectiveness of interactive communication. [23], thus providing a broader perspective on optimizing the digital presence of universities.

Similarly, numerous studies provide justification for the development of the heuristic tool employed in this study [24],[25], This tool has facilitated the assessment of the quality of university websites through the incorporation of indicators, parameters, and fields. [26], These indicators validate the presence and effective operation of digital resources, with notable emphasis on functionalities such as the capacity to alter the website language, responsiveness to the official contact email, functionality of the search tool, and the capability to customize information searches on the web platform. These criteria underscore the significance of interactive communication as a key quality parameter for websites.   [27],
As they possess the capability to fulfill the informational requirements of the university community.

Conversely, accessibility emerges as an unresolved concern in the design of university websites in Ecuador. The assessments undertaken underscore the imperative to institute procedures and tools capable of accommodating diversity and employing resources tailored to the specific needs of students, teachers, administrators, and users in general. This is essential to guarantee access to the requisite information in the most appropriate format. [28], [29].

Finally, the results of this research align with what several researchers have expressed [30], [31], who emphasize the need for a unified framework to assess web quality. Although this study uses a unified framework, the results indicate the need to establish consistent standards   for   web   quality   evaluation.   [32].
Therefore, this study makes a valuable contribution to the ongoing discourse on best practices in the design and implementation of university websites, advocating for a meticulous examination of the digital presence of these institutions. It underscores the imperative to embrace such practices within the specific context of Ecuador.

Conclusions

This study offers an intricate analysis of the quality of university websites in Ecuador, employing a comprehensive approach that integrates heuristic tools and Principal Component Analysis (PCA). The results unveil noteworthy variations in web quality across

Ecuadorian universities, underscoring the crucial role of online presence in shaping institutional reputation and perception.

Utilizing Principal Component Analysis (PCA), the intricacy of the 55 web quality indicators has been streamlined, elucidating six principal components that account for a substantial proportion of the observed variability. This revelation not only enhances clarity regarding the pivotal factors influencing web quality but also provides a more efficient framework for future assessments.

The research has identified that an intuitive and functional web design not only elevates the image of a university but also positively influences students' trust and satisfaction. The incorporation of sound web quality practices, including accessibility, usability, and interactivity, is imperative for the creation of effective and efficient digital platforms.

This study makes a substantial contribution to the existing literature by introducing a novel and detailed method for assessing web quality in the educational sector.

Nevertheless, there is a recognized necessity to formulate a unified framework for web quality assessment, indicating a noteworthy area of interest for future research. Furthermore, exploring the correlation between web quality and other institutional performance indicators, such as student retention or academic success rates, would be highly valuable in identifying potential relationships between these variables.

Data Availability

The datasets utilized and/or analyzed during the current study are accessible from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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