

A Google Lighthouse–Based Assessment of front–End Website Quality among Higher Education Institutions in Central Java, Indonesia

Yohanes Suhari¹

¹Information Technology, Stikubank University, Indonesia

ABSTRACT : *The increasingly rapid digital transformation has increased the strategic role of university websites as medium for providing information, academic services, communication, and strengthening the institutional image. Website quality is a crucial factor in supporting user experience and the effectiveness of digital services. This study aims to evaluate the front-end quality of university websites in Central Java Province using Google Lighthouse and identify website quality characteristics based on a clustering approach. The study used descriptive and exploratory quantitative methods on 83 university websites that met the research criteria. Data collection was conducted using Google Lighthouse in mobile device emulation mode, with four measurement dimensions: Performance, Accessibility, Best Practices, and Search Engine Optimization (SEO). Analysis was conducted using descriptive statistics and K-Means Clustering. The results showed an average overall website quality score of 78.40, categorized as requiring improvement. The Best Practices dimension received the highest average score of 87.49, while the Performance dimension received the lowest score of 58.84. 90.36% of websites did not achieve the good category in the Performance aspect, indicating that optimizing access speed remains a major challenge. Cluster analysis yielded three groups of website characteristics: universities with mature digital governance but limited performance, universities with low technical optimization, and universities with high performance but low visibility. This research contributes to a large-scale evaluation of university website quality using an objective measurement approach based on Google Lighthouse and provides a basis for more targeted decision-making in university website development.*

KEYWORDS - *Front-end, Google Lighthouse, Universities, Website quality*

I. INTRODUCTION

1.1 Background

According to Central Bureau of Statistics (BPS) data from the 2024 Susenas Survey, 72.78% of Indonesia's population had access to the internet in 2024 and 69.21% in 2023. This high internet usage indicates that people have wider access to information sources and is an indicator of a country or region's readiness to face the era of digital transformation. The high number of internet users in Indonesia is inseparable from the rapid development of mobile phones. In 2024, 68.65% of the population in Indonesia owned a mobile phone. Computer ownership in households in 2024 was 18.52% [1].

The rapid digital transformation in higher education has increased the strategic importance of institutional websites. University websites are no longer limited to informational functions but have evolved into comprehensive platforms supporting academic services, student admissions, learning management systems,

research dissemination, stakeholder communication, and institutional branding. Findings from Ghorbanzadeh's research indicate that website features have a positive influence on encouraging value co-creation behavior, and participation behavior, which in turn enhances the university's brand image and reputation [2].

Studies on web quality have highlighted several influences on the quality of institutional websites. Research on the Narotama University website found that website quality (measured using three dimensions: Usability Quality, Information Quality, and Service Interaction Quality) influences user satisfaction [3]. Research conducted by Adawiyah, J.K., et al. shows that the results of the study indicate that the website quality factor has an effect on Corporate Website Favorability, corporate website favorability has an effect on the company's image and reputation, website quality also has an effect on the image and reputation of Padjadjaran University through corporate website favorability [4]. Research conducted by Piarna shows that website quality has a significant influence on e-commerce customer trust [5].

Front-end user interface quality is becoming increasingly important due to rising user expectations regarding loading speed, accessibility, mobile responsiveness, security, and search visibility. A suboptimal website can negatively impact user engagement and institutional credibility. Google Lighthouse has emerged as a widely accepted automated audit framework for evaluating website quality [6]. Lighthouse measures website performance across multiple dimensions, including: (1) Performance; (2) Accessibility; (3) Best Practices; and (4) Search Engine Optimization (SEO). These dimensions collectively represent critical aspects of modern web quality assessment.

1.2 Research Gap

Previous studies have largely focused on evaluating website usability using WebQual, SERVQUAL, User Experience (UX), or heuristic evaluation approaches. However, empirical studies using Google Lighthouse to evaluate higher education websites in developing countries, particularly in Indonesia, are still limited. Furthermore, most existing studies analyze only a small number of institutional websites, while comprehensive regional assessments covering multiple universities are rare.

1.3 Research Objective

This study aims to evaluate the front-end quality of university websites in Central Java Province using Google Lighthouse and identify strengths and weaknesses across four quality dimensions.

1.4 Research Contribution

This study contributes by:

1. Providing a large-scale evaluation involving 83 university websites.
2. Identifying optimization priorities for university web administrators.
3. Expanding the application of Google Lighthouse in higher education website quality research.

II. LITERATURE REVIEW

2.1 Website Quality

Website quality refers to the ability of a website to meet user needs effectively and efficiently. University websites serve various stakeholder groups, including lecturers, the public, students, and administrative staff, making managing web quality very challenging. A literature review by Saleh et al. showed that there is a lack of studies on the quality of university websites compared to business websites; website designers lack adequate knowledge of interface design; and website quality evaluation is complex due to the lack of a specific evaluation model. The Webqual 4.0 model was used to evaluate the quality of university websites. From 24 studies, 79 quality factors were initially extracted. After comparison, screening, and recording, six quality factors were identified: information quality, specific content, usability, web appearance, service interaction quality, and functionality. This study provides a useful contribution in developing a university website quality model by extending the Webqual 4.0 model [7]. The results of experiments conducted by Bhandhari, U. et al confirm the significant

impact of design factors on emotions and quality perception. The study of usability provides a better understanding of how design influences user decision making [8].

2.2 Google Lighthouse

Google Lighthouse is an open-source automated audit tool developed by Google to assess the quality of websites [6].

The google lighthouse framework evaluates:

1. **Performance:** Measures how fast a page loads and becomes interactive. It evaluates critical metrics like First Contentful Paint (when the first text/image loads) and Largest Contentful Paint (when the main content loads).
2. **Accessibility:** Checks if your website is easily usable for everyone, including individuals with disabilities. Tests ensure proper color contrast, ARIA labels, and screen-reader compatibility.
3. **Best Practices:** Analyzes the overall code health and security of your webpage. It checks for things like HTTPS usage, modern image formats, and avoiding deprecated APIs.
4. **SEO (Search Engine Optimization):** Evaluates if the page is properly configured for search engine ranking. Checks include valid meta tags, descriptive anchor text, and mobile-friendliness.

Google Lighthouse was used by Jakopec & Kroflin to analyze the performance of homepages in the .hr domain. The analysis covered 111117 homepages, with data collected on key performance metrics: First Contentful Paint (FCP), Largest Contentful Paint (LCP), Speed Index, Total Blocking Time (TBT), and Cumulative Layout Shift (CLS). In addition to these metrics, data related to console errors, the number of network requests (HTTPS), page size, and HTTP(S) protocol usage were also analyzed. The query results revealed common issues such as console errors, unoptimized image content, and excessive resource usage that increase website load times [9].

Google Lighthouse was also used in research conducted by Nufus and Saputri entitled "Website Quality Evaluation Using WebQual 4.0 and Google Lighthouse." Google Lighthouse was used to assess the performance, accessibility, best practices, and search engine optimization (SEO) of several web homepages [10].

Google Lighthouse was also used by Faizin, M.A., et al., with the research title Indonesia E-Government Website Performance and Accessibility Evaluation using Automated Tool Lighthouse. Case studies on 87 website URLs consisting of one central government portal, 18 state institutions, 34 state ministries, and 34 provincial government URLs were used in this study. The experimental results showed that most of the website performance and accessibility scores were quite good, although some websites still need to improve their performance, especially in the State Ministry category.[11].

III. RESEARCH METHOD

3.1 Research Design

This study uses a descriptive and exploratory quantitative approach to evaluate the quality of university websites in Central Java Province. The evaluation was conducted on university homepages using the automated Google Lighthouse tool on mobile devices emulation mode. This approach was chosen because it provides objective measurements of a website's technical quality based on industry standards widely used in modern web development.

The research consists of two analyses:

1. Descriptive analysis to describe the state of website quality.
2. Clustering analysis to identify groups of website characteristics that share similar quality.

The research framework is shown in Figure 1.

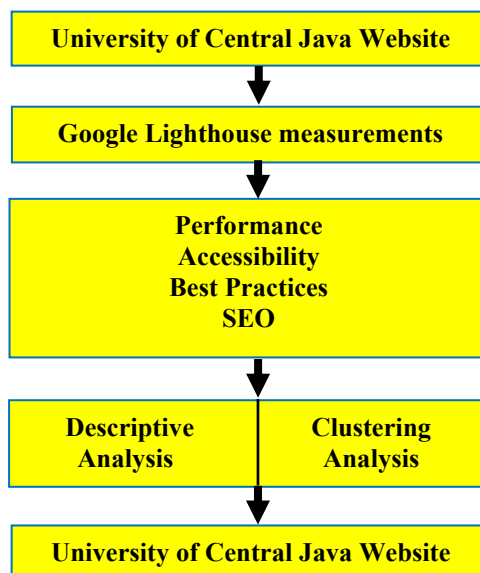


Figure. 1: The research framework

3.2 Population and Sample

The study population included all universities operating in Central Java Province and registered with the national higher education system. All universities that met the inclusion criteria were selected as sample objects.

Inclusion criteria:

1. University websites were accessible during the data collection period.
2. Had an active homepage.
3. Had no service disruptions during testing.

Based on these criteria, 83 university websites were selected as sample sites.

3.3 Data Collection

Data was collected using the open-source software Google Lighthouse, developed by Google. Testing was conducted in mobile device emulation mode, as the majority of internet access today comes from mobile devices. Each website was tested on its homepage to obtain four indicators of website quality (Table 1):

Table 1: Quality Dimensions

Dimension	Description
Performance	Measures page load speed and visual transitions.
Accessibility	Measuring website accessibility for all users
Best Practices	Checks for basic code security (such as using HTTPS), outdated JavaScript libraries, and error detection in the browser console.
SEO	Measuring website readiness for search engine indexing

All scores range from 0 to 100. Score interpretation follows Google Lighthouse standards (Table 2) :

Table 2: Scores Range and Categories

Score Range	Category
90–100	Good
50–89	Needs Improvement
0–49	Poor

3.4 Descriptive Analysis

This section uses descriptive statistics to describe the quality characteristics of university websites in Central Java. The statistics calculated include: Mean, Median, Standard Deviation, Minimum, Maximum, Frequency Distribution. This analysis is used to identify indicators with the highest and lowest performance.

3.5 Cluster Analysis

K-Means Clustering is used to identify patterns of website quality similarity. Prior to the clustering process, all variables were normalized using Z-score Standardization. K-Means aims to minimize within-cluster variation based on Euclidean distance. The number of clusters was set at three based on interpretability considerations and the need for website quality segmentation.

The resulting cluster consists of:

- Cluster 1: Balanced Digital Universities
- Cluster 2: Under-Optimized Universities
- Cluster 3: Fast but Invisible Universities

The clustering results are used to identify different website quality improvement strategies for each university group.

IV. RESULTS

4.1 Descriptive Statistics

The analysis was conducted on 83 university websites in Central Java Province using mobile devices using the Google Lighthouse instrument. The results of descriptive statistical processing are as follows (Table 3):

Table 3: Descriptive Statistics

Dimension	Mean	Median	Std. Dev	Minimum	Maksimum
Performance	58.84	59	17.99	18	100
Accessibility	83.36	84	9.22	51	100
Best Practices	87.49	96	14.22	31	100
SEO	83.90	85	15.78	40	100

The results show that:

- 1) Performance was the aspect with the lowest score (Mean = 58.84).
- 2) Best Practices received the highest score (Mean = 87.49).
- 3) Accessibility and SEO were in the middle category with averages above 80.
- 4) The greatest variability was found in Performance (SD = 17.99), indicating disparities in technical quality across university websites.

4.2 Dimensional Analysis

4.2.1 Performance

The number of universities for each category of performance is as follows Table 4:

Table 4: Sum and Percentage of Each Category of Performance

Category	Sum	Percentage
Good	8	9.64%
Needs Improvement	53	63.86%
Poor	22	26.50%

Performance is a major issue for university websites in Central Java (Table 3). Only 9.64% of websites were categorized as good, while the remaining 90.36% of websites had not yet reached the good category on performance.

This indicates:

- 1) Page load times are still high.
- 2) Image sizes are not optimal.

- 3) Render-blocking resources are still widely used.
- 4) JavaScript and CSS are not optimally minified.
- 5) Excessive use of third-party scripts.

These conditions significantly impact the mobile user experience due to device bandwidth and computing power limitations.

4.2.2 Accessibility

The number of universities for each category of accessibility is as follows Table 5:

Table 5: Sum and Percentage of Each Category of Accessibility

Category	Sum	Percentage
Good	24	28.92%
Needs Improvement	59	71.08%

The average accessibility score reached 83.36 (Table3), indicating that most websites have addressed basic accessibility.

However, several weaknesses were still identified:

- 1) Inadequate color contrast.
- 2) Missing alternative text for images.
- 3) Non-hierarchical post structure.
- 4) Incomplete label forms.
- 5) Navigation components that are not yet screen reader-friendly.

These findings are important because accessibility relates to the inclusion of users with special needs.

4.2.3 Best Practices

The number of universities for each category of best practices is as follows Table 6:

Table 6: Sum and Percentage of Each Category of Best Practices

Category	Sum	Percentage
Good	55	66.27%
Needs Improvement	27	32.53%
Poor	1	1.20%

The Best Practices dimension has the highest score (mean = 87.49) (Table 3).

This indicates that most universities have:

- 1) Used HTTPS.
- 2) Avoided outdated APIs.
- 3) Implemented adequate browser security policies.
- 4) Used modern web technologies.

The maturity level of web development practices implementation can be categorized as quite good.

4.2.4 SEO

The number of universities for each category of SEO is as follows Table 7:

Table 7: Sum and Percentage of SEO

Category	Sum	Percentage
Good	36	43.37%
Needs Improvement	39	46.99%
Poor	8	9.64%

SEO achieved an average score of 83.90 (Table 3).

These results indicate that most websites have implemented:

- 1) Meta descriptions.
- 2) Title tags.
- 3) Mobile-friendly viewports.

- 4) Basic crawlability.

However, there are still weaknesses in:

- 1) Heading structure.
- 2) Social media metadata.
- 3) Internal linking.
- 4) Structured data schema.

These conditions have the potential to reduce website visibility in search engines.

4.3 Overall Website Quality

Website quality is calculated using the average of four Lighthouse dimensions. The average website quality score was 78.40. The lowest quality university website in Central Java had a score of 51.75, and the highest was 95.75. Percentage of quality categories of university websites in Central Java is as follows Table 8:

Table 8: Sum and Percentage of Each Category of Quality

Category	Sum	Percentage
Good	4	4.82%
Needs Improvement	79	85.18%
Poor	0	0%

Only 4 (4.82%) of universities achieved the overall good category. A total of 95.18% of websites still require improvement, particularly in terms of performance. These findings indicate that the digital transformation of higher education institutions in Central Java has been successful in terms of security, accessibility, and basic SEO, but not yet optimal in terms of front-end technical quality. Universities whose website quality is in the good category are as shown in Table 9 below:

Table 9: The quality of the university website is in the good category (score 90-100)

Ranking	Universities	Scor
1	Bima Sakapenta University	95.75
2	Muhammadiyah University of Brebes	91.75
3	Dharma AUB University of Surakarta	91.25
4	Muhammadiyah University of Surakarta	91.00

Websites in this category have: high performance, excellent accessibility, near-perfect best practices, and optimal SEO

4.4 Cluster Analysis

4.4.1 Profile of Each Cluster

After clustering the quality of university websites in Central Java Province, the results were 3 clusters as follows Table 10:

Table 10: Profile of each cluster

Cluster	Sum of Universities	Performance	Accessibility	Best Practices	SEO
C1	51	60.84	83.37	96.02	88.51
C2	24	44.88	82.00	68.38	88.13
C3	8	88.00	87.38	90.50	41.88

Cluster 1 – Medium-Quality Website with Good Technical Governance

Sum of members = 51 (61.45%)

Characteristics: very high best practices, high SEO, good accessibility, and moderate performance. This profile indicates that the majority of universities have implemented modern and secure web development practices, but page speed optimization still needs improvement.

Universities in this cluster can be categorized as: Digitally Mature but Performance-Limited Universities

Example of a member:

- Muhammadiyah University of Surakarta
- Soegijapranata Catholic University
- Semarang University
- Satya Wacana Christian University
- Muria University of Kudus

Cluster 2 – Website with Low Technical Quality

Sum of members = 24 (28.92%)

Characteristics: low performance, low best practices, fairly good accessibility, and relatively good SEO

This profile indicates websites that do not optimally adhere to front-end development standards.

Possible issues:

- Use of outdated libraries
- Excessive resource blocking
- Inefficient code structure
- Inadequate caching optimization
- This group is a top priority for website quality improvement programs.

Example members:

- Stikubank University
- Muhammadiyah University of Semarang
- Batik Islamic University
- Veteran Bangun Nusantara University
- Pancasakti University of Tegal

Universities in this cluster can be categorized as: Technically Under-Optimized Universities

Cluster 3 – Fast Website but Weak on SEO

Number of members = 8 (9.64%)

Characteristics: very high performance, high accessibility, high best practices, and very low SEO

This phenomenon is interesting because it indicates that the website has been successfully optimized technically, but has not yet maximized search engine visibility.

Common problems encountered:

- Incomplete metadata
- Structured data is not available
- Suboptimal heading hierarchy
- Poor internal linking

Example members:

- Sultan Agung Islamic University
- Slamet Riyadi University
- Surakarta University
- AKI University
- Ronggolawe Technology University

This category can be called: High-Performance but Low-Visibility Universities.

Each cluster can be visually depicted in the form of a Cartesian diagram as follows (Figure 2):

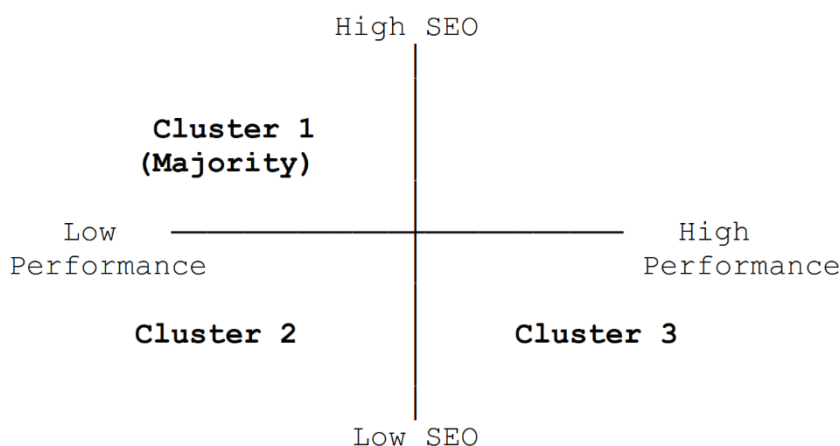


Figure 2: Conceptual Visualization of Clusters

V. DISCUSSION

The results of the study indicate that the front-end quality of university websites in Central Java Province has achieved a fairly good level of digital maturity, but there is still an imbalance between website quality dimensions. Although the Best Practices, Accessibility, and SEO dimensions achieved relatively high average scores, the Performance dimension scored the lowest. These findings indicate that while most universities have attempted to adopt modern technical and security standards for website development, optimizing user experience, particularly access speed, remains suboptimal.

The Performance dimension received an average score of 58.84 and is the aspect that requires the most attention. As many as 90.36% of higher education websites have not yet achieved the Good category according to Google Lighthouse standards. This condition indicates that there are still various technical issues that affect website performance, such as the use of large images, high use of render-blocking resources, JavaScript and CSS that have not been optimally minified, and excessive use of third-party scripts. This finding is in line with research by Jakopec and Kroflin which states that the high number of network requests, unoptimized resources, and large page sizes are the main factors causing low website performance [9].

From a user perspective, website performance directly impacts the perceived quality of digital services. Slow access speeds can decrease user engagement and impact user satisfaction. This is supported by research by Bhandari et al., which states that interface design and system quality influence users' emotional responses and perceptions of digital service quality [8]. In the context of higher education, a slow website can impact the experience of prospective students, current students, lecturers, and the general public in accessing academic information and institutional services.

The Accessibility dimension showed an average score of 83.36, indicating that most websites met basic accessibility standards. However, several weaknesses were still found, such as low color contrast, the lack of alternative text for images, poorly organized heading structures, and inadequately labeled forms. Although these issues may seem simple from a technical perspective, they have a significant impact on users with special needs, especially those who utilize assistive technologies such as screen readers. Therefore, accessibility should not only be viewed as a technical aspect, but also as a form of institutional commitment to providing inclusive digital services.

The Best Practices dimension achieved the highest score, with an average of 87.49. These results indicate that most universities have implemented modern web development practices, such as the use of the HTTPS protocol, avoiding outdated APIs, and implementing browser security policies. These findings indicate a fairly good level of maturity in website technical governance. These results also align with research by Faizin et al. on e-government websites in Indonesia, which showed that the implementation of technical and security standards tends to be more mature than performance aspects [11].

The average Search Engine Optimization (SEO) dimension score was 83.90. These results indicate that

most websites have implemented basic SEO elements such as title tags, meta descriptions, and mobile-friendly display configurations. However, weaknesses were still found in heading structure, structured data schema, and internal linking. These deficiencies have the potential to reduce website visibility in search engines. For universities, digital visibility plays a crucial role because websites serve not only as information media but also as a means of institutional branding, promoting new student admissions, and publicizing academic activities.

The cluster analysis yielded three main characteristics of university websites. The first cluster (Digitally Mature but Performance-Limited Universities) was the largest group. This group indicates that the majority of universities have adequate website governance but still experience limitations in performance optimization. This situation indicates that the implementation of modern technology does not automatically result in an optimal user experience.

The second cluster (Technically Under-Optimized Universities) exhibits low performance and low Best Practices. This group is a top priority for website quality improvement programs due to weaknesses in several aspects. Low quality in this group may be influenced by limited technical resources, lack of regular website maintenance, or limited competency of website managers.

The third cluster (High-Performance but Low-Visibility Universities) exhibits a rather interesting phenomenon. Websites in this group have excellent technical performance but achieve low SEO scores. This finding suggests that technical website optimization alone is insufficient to improve search engine visibility.

This research contributes to a large-scale evaluation of university website quality using an automated approach based on Google Lighthouse. Unlike previous studies that generally employed user perception approaches such as WebQual or SERVQUAL, this study employed objective measurements based on technical indicators. The combination of descriptive analysis and clustering provides a stronger foundation for university website managers in determining website development priorities in a more targeted and data-driven manner.

VI. CONCLUSION AND RECOMENDATION

This study evaluated the front-end quality of 83 university websites in Central Java Province using Google Lighthouse based on four main dimensions: Performance, Accessibility, Best Practices, and Search Engine Optimization (SEO). The results indicate that, in general, university websites have achieved a fairly good level of digital maturity, with an average overall score of 78.40. However, there is still an imbalance in quality across the evaluated dimensions.

The Best Practices dimension received the highest average score, followed by SEO and Accessibility, indicating that most universities have implemented modern web development practices, security standards, and basic search engine optimization configurations quite well. Conversely, the Performance dimension received the lowest score, with an average score of 58.84, with approximately 90% of websites falling short of the Good category. This finding indicates that access speed and front-end technical optimization remain major challenges for university websites.

The cluster analysis identified three main characteristics of university websites: Universities with Mature Digital Governance but Limited Performance, Universities with Low Technical Optimization, and Universities with High Performance but Low Visibility. These results indicate that website quality issues are not uniform, necessitating more specific and targeted improvement strategies tailored to the characteristics of each group.

This research contributes to a large-scale evaluation of higher education website quality using an objective measurement approach based on Google Lighthouse. The combination of descriptive and cluster analysis provides a basis for more targeted decision-making for higher education website managers in determining data-driven development priorities. Future research can expand the study by integrating user experience aspects, back-end performance indicators, longitudinal analysis, and cross-regional comparisons to obtain a more comprehensive picture of website quality.

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