

Novel method to explore the efficiency of e-commerce websites for persons with disabilities

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Received: 2024-09-24 | Accepted: 2025-07-11 | Publication: 2025-11-11

Abstract: With an expanding number of e-commerce websites, many people with disabilities rely largely on online purchasing because they find it difficult to travel freely. However, many users, including those with disabilities, are unable to access the website's content, creating an inequitable barrier for people with visual impairments. Many websites are sometimes accessible, but it takes a while to understand what the website's effectiveness means. Therefore, this paper proposes a novel method entitled AMEEW (A Method to Examine the Efficiency of Websites), which computes the efficiency of websites for persons with disabilities. The purpose of the paper is to evaluate the most popular e-commerce sites and provide guidance to website designers on how to create effective websites that are easy to use for all user groups, including those who are disabled. Initially, the data are analysed using four plots, including a run sequence plot, lag plot, histogram, and normal probability plot. The experiment's findings indicate that 5.08% of top e-commerce websites are ineffective for those with visual impairments.

Keywords: Accessibility, Readability, E-Commerce, Efficiency, Exploratory data analysis, People with Disabilities

1. Introduction

E-commerce has altered the way that companies and consumers communicate on a global scale. While providing consumers with the ease of purchasing at any time and from any location, it enables businesses to sell globally. By eliminating the need to visit physical locations, internet shopping can benefit persons with impairments. According to (*International Trade Administration, U.S., 2024*), it had an 18% proportion of all worldwide retail sales in 2020 and is expected to rise at a rate of over 1% annually, reaching a roughly 22% share of all global retail sales by 2024, depicted in Figure 1. Because increasing accessibility attracts a wide range of visitors, regardless of their disability, it helps e-commerce companies continue to grow. Additionally, accessible e-commerce platforms help people with disabilities avoid physical infrastructure constraints. Around 15% of the world's population, of which 2-4% have serious functional challenges, live with a disability, according to the (*World Report on Disability, 2018*) study. Globally, 2.2 billion people live with near or distance vision impairment, and at least 1 billion of these cases could have been prevented or remain unaddressed due to gaps in access to eye care, affordability, or awareness (*WHO, 2023*).

Figure 1: Global retail e-commerce sales worldwide from 2014 to 2024 (in billion USD)



Universal accessibility stands as a foundational principle of the World Wide Web, as articulated by its creator, Tim Berners-Lee. This principle demands that e-commerce platforms maintain fully accessible interfaces, ensuring equal access for users regardless of disabilities. Tim Berners-Lee believes that the web's strength lies in its ability to be accessed by everybody, regardless of disability (Berners-Lee, T., 2013). Accessibility aims to create products or web content enabling everyone to perceive, comprehend, engage with, navigate, and interact with all aspects of the real and digital environment (Sonowal, 2023). Accessibility enables persons with visual impairments to explore, communicate, and engage autonomously in a world built for the sighted.

Additionally, a key feature of the website is its readability. However, a persistent challenge remains: while many websites strive to be accessible, not all users can comprehend the language in which the content is presented. Thus, readability estimates a text's quality by determining how simple it is to read. The content offered by numerous websites is often difficult to comprehend due to poor readability. Therefore, readability ensures that information is clear and understandable, allowing people with visual impairments to conveniently access content via screen readers, magnifiers, or Braille displays.

It can be observed that readability and accessibility are considered crucial elements in achieving the standards of a practical website for persons with visual impairments. In addition, accessibility and readability are not limited to people with visual impairments; they also include people with cognitive disabilities. Clear design, plain language, and predictable navigation allow people with dyslexia, ADHD (attention-deficit/hyperactivity disorder), memory problems, or learning difficulties to participate independently and confidently.

In recent years, there has been growing recognition of the importance of website accessibility and readability for people with disabilities, reflecting a broader commitment to inclusive design as a fundamental human right (Sonowal, 2025). Existing literature has proposed diverse methodologies to enhance website accessibility and readability, along with guidelines to address existing shortcomings. However, to the best of our knowledge, no prior study has systematically evaluated the efficiency of websites in meeting the needs of users with disabilities. In this context, we define efficiency as the extent to which a website concurrently fulfils accessibility and readability criteria, thereby reducing the time required for users to accomplish tasks. To address this gap, we introduce a novel metric for quantifying website efficiency, derived from the harmonic mean of standardised readability and accessibility error scores.

The objectives of this study are

- To evaluate website accessibility using AChecker, a standardised web accessibility evaluation tool;
- To assess readability through six established readability algorithms;
- To analyse data patterns using four diagnostic plot methods (run sequence, lag plot, histogram, and normal probability plot);
- To propose and validate the novel AMEEW (Accessibility and Measured Effectiveness Evaluation for Websites) methodology by comparative analysis with existing approaches.

The structure of the paper is given below: Section 2 conducts a systematic review of the literature on web accessibility and readability, analysing their critical role in removing barriers to digital inclusion for diverse users. The proposed method of the paper is explained in Section 3. Section 4 analyses the data under four key assumptions: random sampling, fixed distribution, fixed location, and fixed variation. The result of the experiment is shown in Section 5. Section 6 discusses the issues of the proposed method while evaluating and depicting the conclusion of the paper shown in Section 8.

2. Related Works

The literature on website accessibility outlines a variety of problems based on inaccessible website content and offers a large selection of strategies to lessen the force of the obstacles.

(Akgül, 2024) evaluated 112 national e-government websites in Turkey, focusing on public values such as accessibility, public participation, transparency, security, service quality, and accountability. It also assesses usability through criteria like bounce rate, design optimisation, and page response time. Readability is measured using Flesch–Kincaid Reading Ease, Grade Level, and Gunning Fog Index. Findings indicate significant shortcomings in e-government services in Turkey, with poor usability, performance, readability, and security. The study highlights critical implications for policy and practice, suggesting that current Turkish e-government websites need substantial improvement in design, usability, and public engagement to enhance overall effectiveness.

(Campoverde-Molina et al., 2023) conducted a systematic literature review (SLR) to consolidate, analyse, and interpret accessibility findings from 42 studies on university websites. Using Kitchenham’s SLR methodology, the review examined 38,416 web pages, 91,421 YouTube videos, and 28,395 PDFs from 9,140 universities across 67 countries. Evaluations employed manual, automated, and combined methods, with most sites assessed against ISO/IEC 40500:2012 and Section 508 standards. Commonly violated accessibility guidelines include adaptable, compatible, distinguishable, and keyboard accessible. The review reveals widespread accessibility issues in university websites and media, highlighting critical trends and areas for improvement in global higher education institutions.

(Macakoğlu et al., 2023) analysed the accessibility, performance, and security of prospective student web pages from 330 universities across Europe, North America, and Oceania. The universities were chosen based on the Webometrics ranking, and automated online testing tools were used for the evaluation. Findings reveal that North American universities scored highest in accessibility and usability, followed by institutions in Oceania and Europe. Compliance with WCAG 2.0 guidelines was generally low across all regions. While no major usability or security issues were detected, several areas for improvement were identified. The study provides

recommendations for developers and administrators to enhance accessibility, usability, and security, ensuring equitable information access for all users.

The expansion of mobile devices has shifted user interaction from desktop to mobile platforms, introducing challenges in usability and accessibility. When desktop websites or applications are rendered on mobile devices, smaller screens and different interaction methods often increase cognitive load, user dissatisfaction, and disengagement. Moreover, many sites fail to cater to users with varying accessibility needs, exacerbating barriers. (Fipke, 2024) Addressed these issues by reducing cognitive load in mobile applications and enhancing accessibility, making systems more user-friendly for all. It specifically investigates the usability improvements and challenges of adapting a student help system from a desktop to a mobile-friendly version, highlighting the need for accessible design to meet diverse user requirements.

(Acosta-Vargas et al., 2022) analysed fifty of the best-ranked 50 e-commerce websites based on the e-commerce DB classification. They used an automatic review technique based on a modification of the Website Accessibility Conformance Evaluation Methodology (WCAG-EM) 1.0 to assess the online accessibility of e-commerce sites. The Web Accessibility Evaluation Tool (WAVE) was utilised to assess accessibility. The results showed that, according to Spearman's Rho, there is a low positive correlation (0.329) between the ranking of e-commerce websites and accessibility barriers. Furthermore, the WAVE analysis showed that Nike, Sainsbury's Supermarkets, Walmart, Target Corporation, Macy's, IKEA, H&M Hennes, Chewy, Kroger, and QVC are the top ten most accessible websites. The majority of accessibility obstacles are related to contrast errors, which need to be fixed for e-commerce websites to be made as accessible as possible. Perceivable accessibility is the most neglected principle, accounting for 83.1% of all accessibility, followed by operable accessibility (13.7%), robust accessibility (1.7%), and understandable accessibility (1.5%).

(Macakoğlu & Peker, 2022) provided an analysis of 58 Turkish university hospital websites' accessibility. Two distinct online automated testing tools were used to analyse the websites of the chosen university hospitals for this purpose. The findings indicated that, in terms of WCAG 2.0 compliance, university hospital websites in Turkey had low levels. Even the minimal requirements for compliance level A were not met by the majority of the websites. Approximately one-third of the websites experienced issues with mobile device access, and nearly all of them had broken links. Furthermore, this study also discusses a few significant hints that highlight issues with website accessibility. Using a sample of 65 websites from different ministries, Paul (2023) evaluates the accessibility of Indian e-government websites using the WCAG 2.1 standard. They discovered that most e-government websites do not comply with WCAG 2.1 at Level A. According to the results, to achieve universal accessibility, e-government website designers and developers should give accessibility features careful consideration while creating these websites.

(Balaji & Kuppusamy, 2016) carried out yet another investigation of accessible websites. Achecker, WAVE (Web Accessibility Evaluation Tool), and EvalAccess were all used in the author's investigation of the Indian Railway websites under WCAG 2.0 requirements. The majority of websites were seen to be inaccessible by this paper, which also included an accessibility recommendation.

(V.Balaji & K.S.Kuppusamy, 2017) addressed another intriguing issue about the accessibility issue for those who are visually impaired when browsing the multilingual web. People with visual impairments were used in this study's preliminary study while they browsed multilingual web pages. A 22-question online survey was created for this purpose and placed in the AccessIndia

online community for people with visual impairment. Based on the feedback, it was concluded that the multilingual website had accessibility problems, and recommendations were given for using the internet without any barriers. Digital technologies are being used by a lot of teachers to deliver online courses

(Sonowal, 2021) Zoom is a widely used digital technology that many institutions utilised during the lockdown. Sharing information is a very comfortable process for both the teacher and the student. While regular students seem to be quite happy with this tool, visually impaired students encountered some challenges here. This essay looks at the Zoom app for students who have vision problems. Based on the analysis, it is necessary to improve the Zoom app for students who have visual impairments.

(Kurt, 2017) employed evaluative techniques based on the World Wide Web Consortium and observed that many home pages did not adhere to the minimum criteria for web accessibility. This study specified that every university website consists of at least one of a variety of elements that make the website inaccessible to some users.

Another interesting exploration was prepared on the top universities in Kyrgyzstan, Kazakhstan, Azerbaijan, and Turkey using automated assessment tools by (Ismailova & Inal, 2018). The outcomes demonstrated that university websites are more prevalent in Turkey, and in Turkish universities, developers provide careful consideration to the performance of the websites, followed by websites of Azerbaijani, Kyrgyz, and Kazakh universities. Most of the university websites in the investigation did not meet the WCAG 2.0 accessibility criteria. In light of the outcomes, it was resolved that colleges incorporated into the present examination require giving more weight to building their websites to be more accessible for their customers.

One more assessment of the government websites of Kerala based on Indian government guidelines and the five-point investigation of accuracy, authority, objectivity, currency, and coverage (S & B.I, 2016). This study conducted experiments on four categories of twenty government websites: secretariat departments, directorate/Commissionerate's, government institutions, and local self-governance.

The effectiveness and usability of Indian health information websites on the World Wide Web are examined. Cross-sectional research of Indian health information websites was conducted by (Raj et al., 2016) Out of fifty (50) websites evaluated for quality (LIDA Tool) and readability (Flesch Reading Ease Score, Flesch-Kincaid Grade Level, and SMOG), it was found that only thirty-two (32) websites were exclusively focused on providing health information. Only three sites had high LIDA scores, and only five sites met the required readability level for sixth grade, according to the results.

The aforementioned literature shows that many studies were done based on accessibility and readability, but they did not mention the efficiency of the website in accessing. Hence, this paper proposes a novel method to explore the efficiency of the websites so that the developers pay attention to designing the websites more efficiently for everyone, irrespective of persons with disabilities

3. Methodology

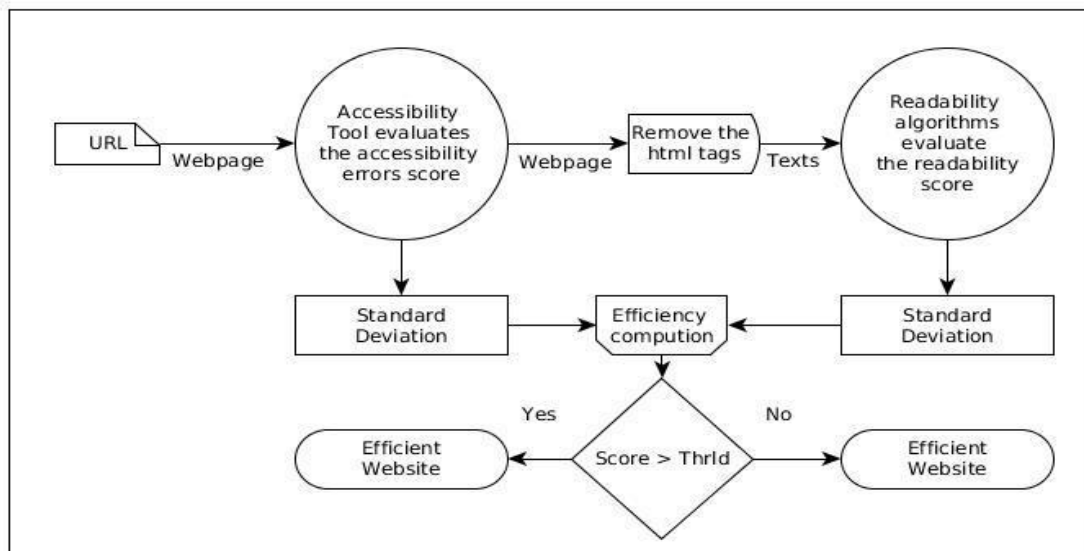
The proposed method, accessibility score evaluation, and readability score evaluation are all included in this section. The proposed method provides details for determining the efficiency of

the website. The method needs readability and accessibility scores to determine efficiency. In this section, the approach is covered in great detail.

3.1. The proposed method

In this section, the proposed method is explained, which is applied to evaluate the efficiency of the website, and the architecture of the computing method is shown in Figure 2. The method initially computes the accessibility error score using AChecker to collect and categorise errors (Known Problems, Likely Problems, Potential Problems, HTML Validation, and CSS Validation) across pages, then computes the standard deviation (σ) of these errors to measure consistency rather than relying solely on total error counts. This σ -based approach enables fair comparisons across websites of varying sizes and technologies by normalising results. For instance, a large website (100+ pages) with 200 total errors and low σ (1.0) demonstrates better accessibility consistency than a small site (10 pages) with fewer total errors (50) but high σ (5.0), indicating erratic error clustering. By focusing on error distribution rather than absolute numbers, this method provides a more accurate assessment of true accessibility compliance, effectively identifies problematic error concentrations, and helps prioritise remediation efforts where they are most needed, making it particularly valuable for comprehensive accessibility audits across diverse web properties. Similarly, the method computes the readability score of the websites and subsequently computes the standard deviation of the scores. Finally, the efficiency method is applied to compute the efficiency of the website and compare it with the threshold value. If the efficiency score is above the threshold value, then the website is regarded as inefficient; otherwise, it is efficient. It is known that a more readable website leads to a more accessible website, which implies fewer accessibility errors. Thus, the accessibility error scores increase, then the readability score decreases, and both scores are inversely proportional to each other. Therefore, the method computes the harmonic mean of both scores to evaluate the efficiency of the website.

Figure 2: Architecture of the proposed Method



Assume, for a website (W), the method computes the accessibility scores $A = \{a_1, a_2, \dots a_n\}$ and the readability scores $R = \{r_1, r_2, \dots r_n\}$. Subsequently, the method computes the efficiency using equation (1).

$$AMMEW(W) = 2 \times \frac{\sigma(A)(R)}{\sigma(A)+\sigma(R)} \quad (1)$$

Where the (σ) denotes the standard deviation.

Assume the scores $X = \{x_1, x_2, \dots, x_n\}$ and the ($\sigma(X)$) is defined by (2).

$$\sigma(X) = \sqrt{\frac{\sum_{i=1}^n (x_i + \bar{x})^2}{n-1}} \quad (2)$$

Where the $\bar{x}$ denotes the mean of X , which is given by (3).

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i \quad (3)$$

3.2. Accessibility Score Evaluation

The accessibility of a website page is assumed to as an imperative aspect of everyday life. Accessibility refers to the design of the website for persons with disabilities. The Web Accessibility Initiative (WAI) of the World Wide Web Consortium (W3C) has developed the Web Content Accessibility Guidelines (WCAG). There are currently two versions of the guidelines: the 1995 publication of the first, WCAG 1.0 (Web Content Accessibility Guidelines 1.0, 1999), and the 2008 release of the second, WCGA 2.0 (Web Content Accessibility Guidelines (WCAG) 2.0, 2008). Besides, WCAG 2.1 was published on 5 June 2018, and WCAG 2.2 is scheduled to be published in 2021(Kirkpatrick, A. et al., 2018). Accessibility contains four principles: Perceivable, Operable, Understandable, and Robust.

3.2.1. Perceivable

The term “perceivable” describes a user’s capacity to recognise and comprehend the information displayed on a website or application. This includes making sure the material is accessible to those with various disabilities, such as vision or hearing impairments, and that it is offered in a variety of formats, including text, audio, and video. To make the content easy to read, readability also entails offering clear and consistent navigation and content structure, as well as using the right colour contrasts and font sizes.

3.2.2. Operable

Operable describes a website’s or application’s capacity to be used by a user to navigate and interact using a variety of input methods, including a keyboard, mouse, or touchscreen. This includes making sure that all functionality is accessible via a keyboard, offering simple and reliable navigation, and avoiding content that flashes or moves quickly because it may induce seizures or other health difficulties for some people. Along with allowing users to pause, halt, or hide any time-based media, operability also entails giving them enough time to read and interact with the information.

3.2.3. Understandable

The term “understandable” describes a user’s capacity to comprehend and decipher the information and features of a website or application. This entails speaking plainly and succinctly, refraining from using jargon and technical phrases, explaining difficult ideas, and making sure that the layout and design are uniform and easy to understand. Additionally, to aid users in navigating and comprehending the information offered, intelligible content should be structured logically and predictably with headings, lists, and other visual cues. Providing alternative formats or

translations for users who might have trouble understanding the primary language or format of the content is another aspect of comprehensible accessibility.

3.2.4. Robust

A website or program is said to be robust if it can be accessed and utilized by a variety of assistive devices, including screen readers, braille displays, and voice recognition software. Ensuring that the website or application is accessible with multiple assistive technologies entails following accepted coding practices and web standards and guidelines, such as the Web Content Accessibility Guidelines (WCAG). Providing users with additional access points to functionality or content, such as keyboard shortcuts or alternative navigation techniques, is another aspect of robust accessibility. This makes it possible for users who have restrictions or disabilities to access the website or application and use it in the way that best meets their needs. The accessibility tool assists users in measuring the accessibility error of the website so that the website can be refined to be accessible to all categories of users. AChecker is one of the leading accessibility evaluation tools that work based on a variety of international accessibility guidelines (Gay & Li, 2010). The tool checks for compliance with the Web Content Accessibility Guidelines (WCAG) 2.0 and 2.1, which are international standards for web accessibility. It checks for issues such as missing alt text on images, improper use of headings, and insufficient colour contrast. AChecker identifies the barriers of the website, which are classified under three categories: known problem, likely problem, and potential problem. Assume, the $A_i = \{a_1, a_2, a_3\}$ is the problem of the websites; the proposed method evaluates the standard deviation of the problems $\sigma(A_i)$ as explained in section 3. This method implemented the AChecker tool using a Python script using a “Web Service ID”, which is generated once successfully registered into AChecker.

3.3. Readability Score Evaluation

The readability of a text describes how simple or complex it is for a reader to comprehend written material. It considers elements like vocabulary, sentence structure, and overall text complexity. A text with high readability is simple to read and grasp, whereas a text with poor readability may be challenging to understand and demand more work from the reader. To ensure that written content is accessible and understood by a diverse audience of readers, including individuals with varying levels of literacy or language proficiency, readability is crucial. Six significant readability algorithms have been adopted in this paper and are listed below:

- Automated readability index: The Automated Readability Index (ARI) is a formula used to determine the readability level of a written text. It considers the number of characters, words, and sentences in a text to calculate a score that represents the grade level required to comprehend the text (Smith & Senter, 1967). The formula for ARI is shown in equation (4):

$$ARI = 4.71 \left(\frac{C}{W} \right) + 0.5 \left(\frac{W}{S} \right) - 21.43 \quad (4)$$

Where C denotes the characters and numbers, W denotes the words that are, the number of spaces, and S denotes the sentences. The resulting score is typically a whole number between 1 and 14, with higher scores indicating a higher level of readability. For example, a score of 1 would be equivalent to a text written for a first-grade reading level, while a score of 14 would be equivalent to a text written for a college-level reading level.

- Flesch-Kincaid Readability Test: The Flesch-Kincaid Grade Level is another formula used to determine the readability level of a written text. It considers the average number of syllables per word and the average number of words per sentence to calculate a score that represents

the grade level required to comprehend the text (Flesch, 1948). The formula for Flesch-Kincaid Grade Level is shown in equation (5)

$$FKGL = 0.39 \left(\frac{W}{S} \right) + 11.8 \left(\frac{Sy}{W} \right) - 15.59 \quad (5)$$

Where W is the total number of words, S is the total number of sentences, and Sy is the total number of syllables. The resulting score is typically a whole number between 1 and 12, with higher scores indicating a higher level of readability. For example, a score of 1 would be equivalent to a text written for a first-grade reading level, while a score of 12 would be equivalent to a text written for a college-level reading level.

- The Flesch Reading Ease Score (FRES) is a formula used to determine the readability level of a written text. It considers the average number of syllables per word and the average number of words per sentence to calculate a score that represents how easy or difficult the text is to read. The formula for FRES is shown in equation (6)

$$FRES = 206.835 - 1.015 \left(\frac{W}{S} \right) - 84.6 \left(\frac{Sy}{W} \right) \quad (6)$$

Where W are the total words, S is the total sentences, and Sy is the total syllables. The resulting score is typically a number between 0 and 100, with higher scores indicating an easier text to read. For example, a score of 90-100 would be equivalent to a text that is very easy to read, while a score of 0-30 would be equivalent to a text that is very difficult to read.

Gunning Fog Index: An American businessman (Gunning, 1952) created the Gunning Fog Index. The Gunning Fog Index is another formula used to determine the readability level of a written text. It considers the average number of words per sentence and the percentage of complex words (words with three or more syllables) to calculate a score that represents how difficult the text is to read. The following steps are used to calculate the Gunning Fog: The equation of the Gunning Fog Index is shown in equation (7)

$$GFI = 0.4 \left[\left(\frac{W}{S} \right) + 100 \left(\frac{CW}{W} \right) \right] \quad (7)$$

Where W stands for a word, S for a sentence, and CW for a complex word. The resulting score is typically a whole number, with higher scores indicating a more difficult text to read. For example, a score of 12 would be equivalent to a text that is difficult to read, while a score of 6 would be equivalent to a text that is easy to read.

SMOG Index: (Mc Laughlin, 1969) developed this SMOG index, and SMOG is widely used for checking health messages. The SMOG Index is another formula used to determine the readability level of a written text. It considers the number of polysyllabic words (words with three or more syllables) to calculate a score that represents how difficult the text is to read. The equation for SMOG to test the readability score is shown in (8).

$$SMOG = 1.0430 \sqrt{P \times \frac{30}{S}} + 3.1291 \quad (8)$$

Where P is the number of polysyllables and S is the number of sentences. The resulting score is typically a whole number, with higher scores indicating a more difficult text to read. For example, a score of 12 would be equivalent to a text that is difficult to read, while a score of 6 would be equivalent to a text that is easy to read.

- Coleman-Liau Index: (Coleman & Liau, 1975) developed the Coleman-Liau Index to calculate the readability score. The Coleman-Liau Index is another formula used to determine the

readability level of a written text. It considers the average number of characters per word and the average number of sentences per 100 words to calculate a score that represents how difficult the text is to read. The equation of the Coleman–Liau index (CLI) is shown in equation (9).

$$CLI = 0.0588L - 0.296S - 15.8 \quad (9)$$

L represents the average letter frequency per 100 words, while S is the average sentence frequency per 100 words. The resulting score is typically a whole number, with higher scores indicating a more difficult text to read. For example, a score of 12 would be equivalent to a text that is difficult to read, while a score of 6 would be equivalent to a text that is easy to read.

The method adopted six readability algorithms to measure the readability of the website. Assume, the $R_i = \{r_1, r_2, r_3, r_4, r_5, r_6\}$ be the readability score of the websites; the proposed method evaluates the standard deviation of the problems $\sigma(R_i)$ as explained in Section 3.

3.4. AMEEW Algorithm

The algorithm of the proposed method is shown in Algorithm 1. The AMEEW algorithm aims to assess and categorise websites as "Efficient" or "Inefficient" according to their readability and accessibility characteristics. Accessibility scoring, readability score (if necessary), and a final combined efficiency assessment are the three sequential evaluation stages it goes through after receiving a URL as input. By taking a tiered approach, the algorithm ensures that websites are evaluated methodically by prioritising accessibility tests before moving on to readability and efficiency assessments.

Algorithm 1: AMEEW algorithm

Input:	URL
Output:	Efficient, Inefficient
1	AMEEW(URL)
	website $\leftarrow$ eWebsite(URL)
	A_score $\leftarrow$ eAccessibility(website)
2	if A_score = 0 then
3	return Efficient
4	else
5	cWebsite $\leftarrow$ rWebsite(website)
	R_score $\leftarrow$ eReadability(cWebsite)
6	if R_score = 0 then
7	return Inefficient
8	else
9	E_score $\leftarrow$ eEfficiency(A_score, R_score)
	if E_score $\geq$ Threshold then
10	return Inefficient
11	else
12	return Efficient
13	end
14	end
15	end

Using the function `eWebsite(URL)`, the algorithm first extracts and examines the webpage's content. The function `eAccessibility(website)` then assesses the extracted data for accessibility compliance (e.g., conformance to WCAG standards) and produces an accessibility score (`A_score`). The website is instantly categorised as "Efficient," since it satisfies the maximum accessibility criterion without additional assessment if it receives a perfect accessibility score (`A_score = 0`). This stage demonstrates how the algorithm prioritises accessibility as a basic necessity.

The algorithm then evaluates readability if the website's `A_score` is not zero. To make sure the readability assessment concentrates on the most important content, the `rWebsite(website)` function first refines the website's content by eliminating unnecessary components. `eReadability(cWebsite)` then assigns a score to the revised material, resulting in a readability score (`R_score`). An "Inefficient" classification results from a perfect readability score (`R_score = 0`). The last efficiency evaluation is triggered by `R_score` values that are not zero.

The algorithm uses the function `eEfficiency(A_score, R_score)` to calculate a composite `E_score` for websites with both accessibility and readability issues (`A_score > 0` and `R_score > 0`). This score balances the website's readability and accessibility, reflecting its overall effectiveness. When the `E_score` is compared to a predetermined threshold, the resulting categorisation is "Inefficient" if the score is at or above the threshold and "Efficient" if the score is below the threshold.

4. Analyse the data

Four assumptions have been considered to analyse the data: random drawings, fixed distribution, distribution with fixed location, and distribution with fixed variation. If the four underlying assumptions are true, we have reached probabilistic predictability—the capacity to make probability statements about both past and future processes. These procedures are referred to as being “in statistical control” in short (Filliben & Heckert, 2005). To test these assumptions, we have tested four exploratory data analysis techniques, including

- Run sequence plot: The run sequence plot will not drift and will be flat if the fixed location assumption is true. The run sequence plot's vertical spread will be roughly the same along the horizontal axis if the fixed variation assumption is true.
- Lag plot: The lag plot will be random and structureless if the randomness assumption is true.
- Histogram: The histogram will be bell-shaped if the fixed distribution assumption is true, specifically if the fixed normal distribution is true.
- Normal probability plot: The normal probability plot will be linear if the fixed distribution assumption is true, specifically if the fixed normal distribution is true.

As can be observed from Figure 3, the 4-plot depicts a process with a fixed location, fixed variation, and randomness. The normal probability plot indicates that the data is linear, but the histogram is not bell-shaped and displays a right-skew histogram. As a result, the data can be regarded as normal. Nor are there any outliers. The 4-plot depicts a process that is random, has a fixed location, has fixed variation, and appears to have a fixed approximately. The data is linear, as indicated by the normal probability plot, even though the histogram is not bell-shaped and displays a right-skew histogram.

Figure 3: The 4 plots for Accessibility data

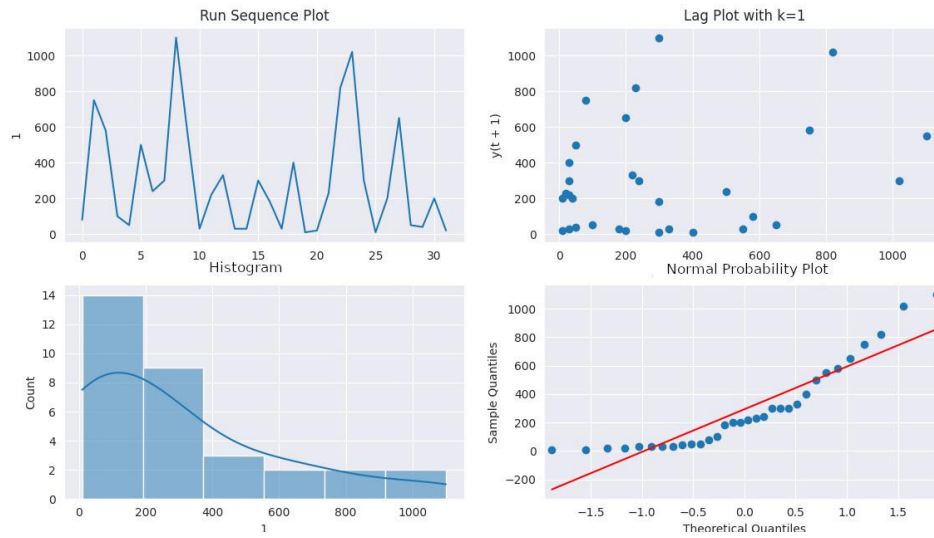
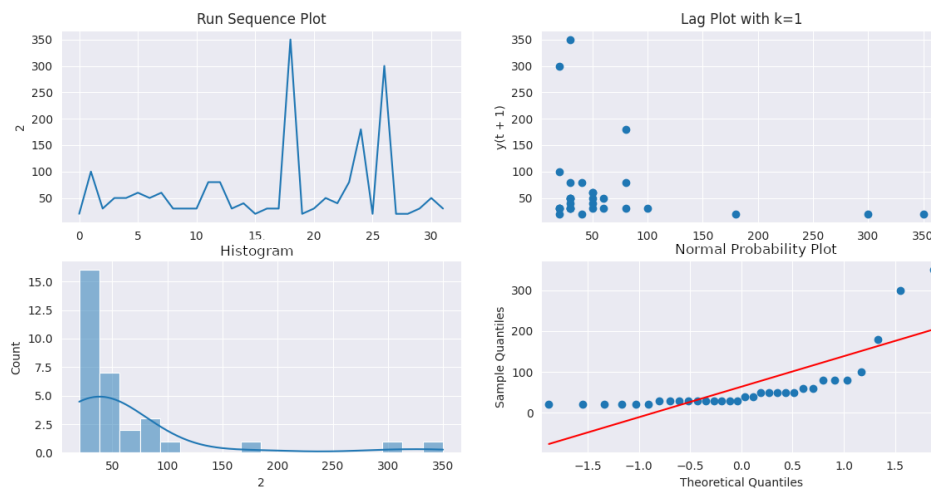


Figure 4: The 4 plots for Readability data



Consequently, in Figure 4, the 4-plot depicts a process with a fixed location, fixed variation, and randomness. The normal probability plot indicates that the data is linear, but the histogram is not bell-shaped and displays a right-skew histogram. As a result, the data can be regarded as normal. Nor are there any outliers. The 4-plot depicts a process that is random, has a fixed location, has fixed variation, and appears to have a fixed approximation. The data is linear, as indicated by the normal probability plot, even though the histogram is not bell-shaped and displays a right-skew histogram.

5. Evaluation Result

This section discusses threshold evaluation, evaluation of metrics, and the result of our proposed model.

5.1. Threshold Evaluation

This subsection experimented to find the threshold value for the efficiency of the website. For this purpose, the top 32 e-commerce websites are gathered from (Similarweb, 2024). SimilarWeb provides the website's ranking based on a combined measure of unique visitors and pageviews. Our study analysed 32 websites across three critical performance metrics: accessibility error scores, readability scores, and overall efficiency ratings. These measurements provide insights into how technical compliance (accessibility), content clarity (readability), and user experience (efficiency) intersect in website design. Figure 5 presents the raw experimental data showing each website's performance across these metrics. We then calculated average scores for all websites, with these aggregated results visualised in Figure 6. This two-stage presentation allows readers to examine both individual cases and overall trends.

The analysis revealed an average efficiency score of 63.89 across all websites. The average accessibility error score stood at 298.87, while the average readability score was 49.22. These figures establish baseline performance levels that help contextualise individual website assessments. Examining the relationship between these metrics shows a clear pattern: websites demonstrating higher efficiency typically combine lower accessibility error scores with higher readability scores. This suggests that technical accessibility improvements and content clarity enhancements work synergistically to boost overall website performance.

These findings indicate that website optimisation should address both technical and content aspects simultaneously. Reducing accessibility barriers while improving content readability appears to be an effective strategy for achieving better overall website efficiency. Hence, the method selects 63.89 as the threshold value. If the website's efficiency is above the threshold, then it is regarded as an inefficient website; otherwise, it is an efficient website.

Figure 5: Performance of 32 websites

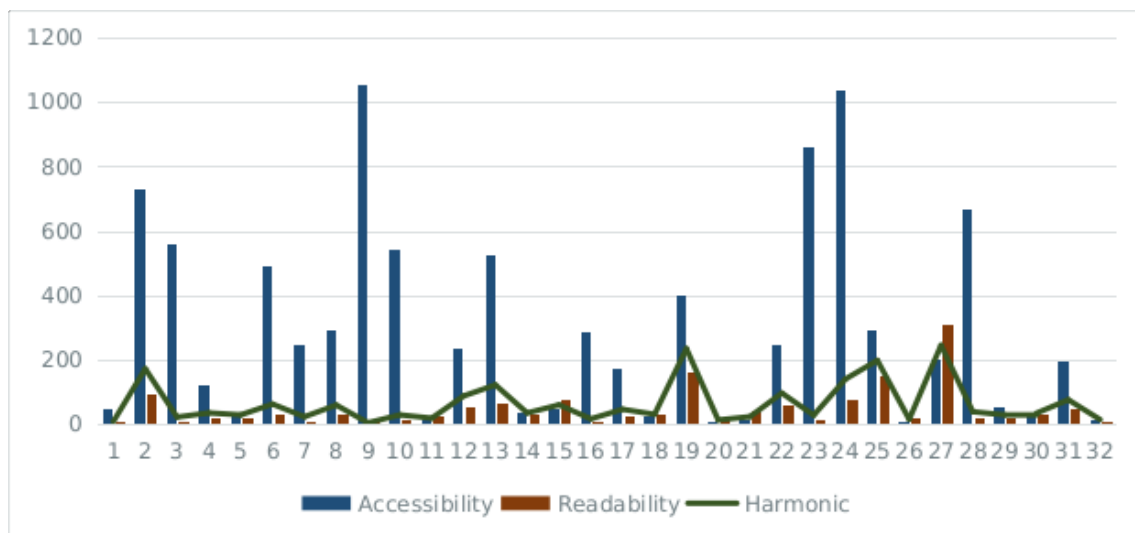
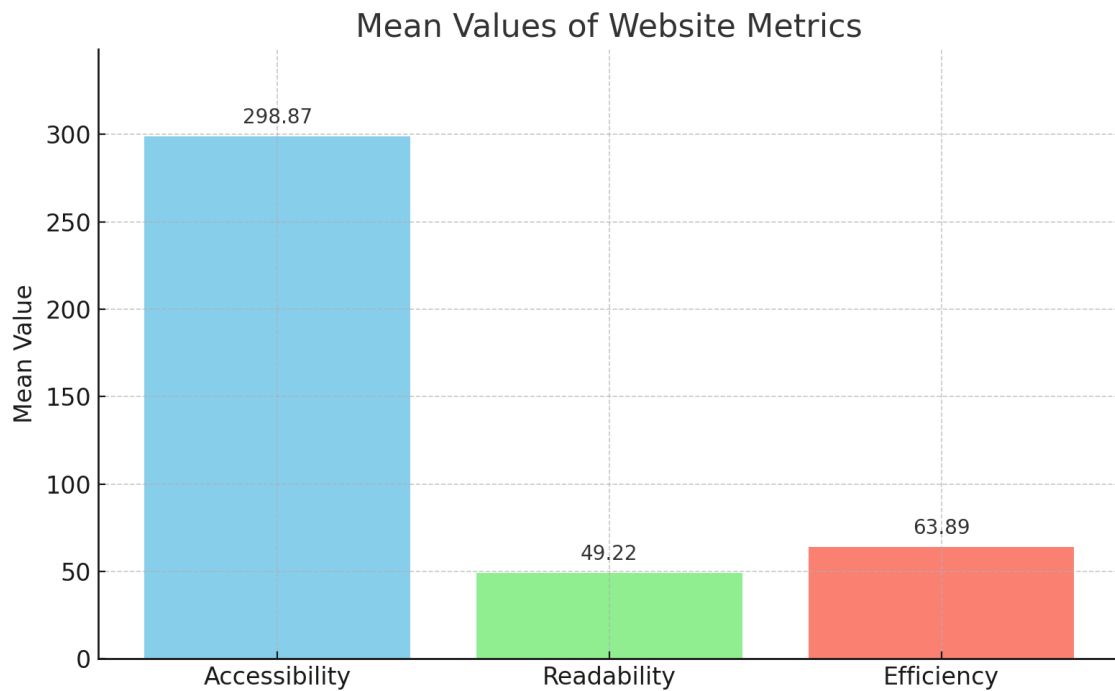


Figure 6: Average value of accessibility, readability, and efficiency score.



5.2. Evaluation of Metric

This section discusses the accuracy metrics, which are used to compute the performance of the method. Assume EP denotes the number of websites that are less than the threshold value, and IP denotes the number of websites that are above the threshold value.

Accuracy (efficient): The accuracy of the efficient websites of the proposed efficiency method is shown in equation (10).

$$Accuracy(efficient) = \frac{EP}{EP+IP} \quad (10)$$

Accuracy (Inefficient): The accuracy of the inefficient websites of the proposed efficiency method is shown in equation (11).

$$Accuracy(Inefficient) = \frac{IP}{EP+IP} \quad (11)$$

5.3. Result

The section discusses the result of the proposed method. For this purpose, the 60 e-commerce sites were chosen from publicly accessible directories such as (Similarweb, 2024) to ensure that the platforms we examined in our study represented important real-world usage patterns and a range of accessibility and readability feature implementations. Table 1 shows that the dataset captures 52.52% of global e-commerce traffic, covering major industries like retail (Amazon, Walmart), marketplaces (eBay, MercadoLibre), and speciality commerce (Etsy, Ticketmaster), as well as key regions including North America, South America, Europe, and Asia. The platforms listed are among the top performers in their respective countries, with massive monthly visits and unique visitor counts.

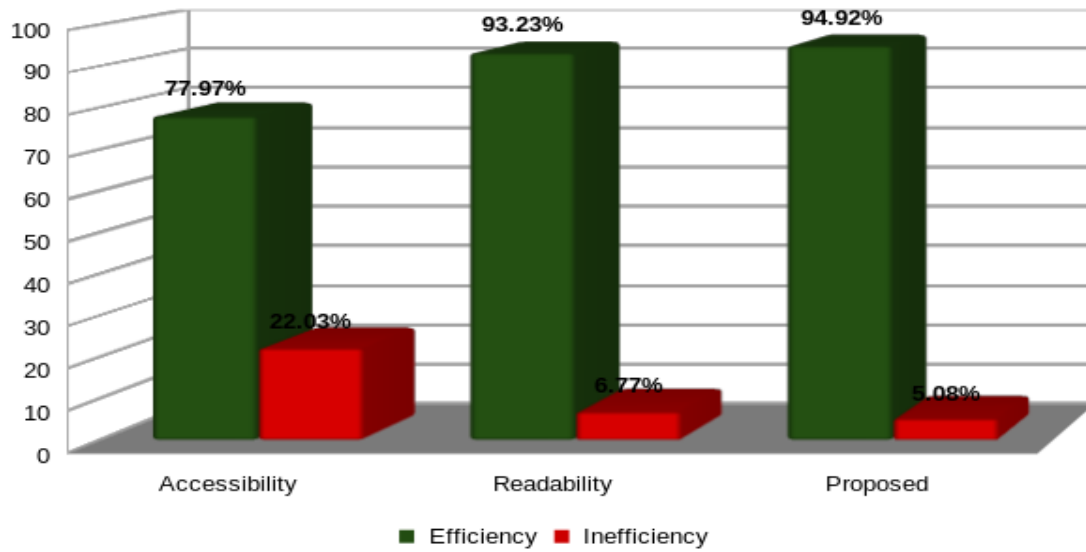
Table 1: Top 60 E-commerce websites

Sl No	Domains	Country	Traffic Share	MoM traffic change	Country rank	Monthly visits	Unique visitors
1	amazon.com	United States	9.25%	4.89%	#8	2.530B	493.6M
2	temu.com	China	4.82%	14.70%	#26	1.317B	383.1M
3	aliexpress.com	China	2.31%	0.24%	#51	630.6M	226.8M
4	ebay.com	United States	2.22%	5.73%	#42	606.8M	157.5M
5	amazon.co.jp	Japan	1.95%	4.55%	#47	532.6M	79.70M
6	ozon.ru	Russia	1.69%	5.22%	#44	462.6M	106.0M
7	walmart.com	United States	1.64%	5.04%	#65	448.7M	160.6M
8	rakuten.co.jp	Japan	1.59%	1.99%	#62	434.0M	63.23M
9	amazon.in	India	1.49%	8.06%	#58	408.1M	153.8M
10	amazon.de	Germany	1.46%	1.42%	#59	399.0M	71.18M
11	etsy.com	United States	1.41%	3.95%	#74	384.4M	152.8M
12	amazon.co.uk	United Kingdom	1.29%	2.62%	#78	351.5M	73.56M
13	wildberries.ru	Russia	1.26%	7.82%	#63	343.5M	54.33M
14	avito.ru	Russia	1.11%	1.55%	#80	303.5M	39.74M
15	coupang.com	South Korea	1.03%	4.96%	#102	282.0M	72.96M
16	mercadolivre.com.br	Brazil	0.86%	5.10%	#105	235.5M	56.43M
17	amazon.it	Italy	0.71%	1.94%	#126	195.2M	42.78M
18	taobao.com	China	0.71%	4.23%	#118	192.9M	37.82M
19	ebay.co.uk	United Kingdom	0.70%	2.47%	#138	190.9M	37.52M
20	amazon.fr	France	0.68%	5.63%	#129	184.7M	48.05M
21	amazon.ca	Canada	0.66%	8.54%	#122	180.8M	39.70M
22	amazon.com.br	Brazil	0.65%	5.91%	#158	177.1M	77.12M
23	flipkart.com	India	0.64%	9.42%	#153	174.8M	66.80M
24	allegro.pl	Poland	0.63%	1.15%	#142	173.4M	27.76M
25	target.com	United States	0.63%	1.70%	#189	171.8M	77.75M
26	rakuten.com	United States	0.57%	5.91%	#321	156.5M	62.56M
27	market.yandex.ru	Russia	0.52%	12.18%	#171	143.5M	36.73M
28	shopee.com.br	Brazil	0.51%	7.70%	#197	138.7M	49.08M
29	craigslist.org	United States	0.51%	5.88%	#109	138.3M	25.34M
30	mercari.com	Japan	0.50%	7.21%	#186	137.0M	39.80M
31	shopee.vn	Vietnam	0.50%	4.61%	#228	135.7M	44.17M
32	shop.app	United States	0.49%	9.53%	#313	134.8M	78.90M
33	shopee.co.id	Indonesia	0.46%	7.79%	#206	125.9M	34.34M
34	leboncoin.fr	France	0.45%	1.82%	#222	121.8M	19.54M

Sl No	Domains	Country	Traffic Share	MoM traffic change	Country rank	Monthly visits	Unique visitors
35	shopping.yahoo.co.jp	Japan	0.44%	4.38%	#316	119.5M	45.83M
36	ebay.de	Germany	0.44%	0.77%	#254	119.2M	25.65M
37	kleinanzeigen.de	Germany	0.42%	1.26%	#237	116.2M	31.94M
38	sahibinden.com	Turkey	0.40%	1.62%	#159	110.7M	19.07M
39	amazon.es	Spain	0.40%	2.49%	#236	110.3M	27.48M
40	dmm.com	Japan	0.39%	8.33%	#354	107.2M	23.88M
41	ticketmaster.com	United States	0.39%	11.78%	#343	105.6M	58.95M
42	trendyol.com	Turkey	0.39%	0.94%	#273	105.6M	28.09M
43	shopee.co.th	Thailand	0.39%	3.09%	#287	105.3M	30.31M
44	mercadolibre.com.ar	Argentina	0.37%	9.39%	#216	100.4M	18.33M
45	mercadolibre.com.mx	Mexico	0.34%	10.38%	#277	93.11M	25.97M
46	shopping.naver.com	South Korea	0.34%	0.12%	#357	92.53M	14.07M
47	costco.com	United States	0.33%	10.18%	#341	91.51M	38.84M
48	amazon.com.mx	Mexico	0.33%	12.38%	#293	89.84M	36.16M
49	olx.com.br	Brazil	0.32%	1.62%	#346	88.30M	24.08M
50	wayfair.com	United States	0.32%	4.89%	#344	87.61M	37.49M
51	jd.com	China	0.31%	11.87%	#297	85.68M	22.98M
52	olx.pl	Poland	0.31%	2.29%	#314	83.64M	13.43M
53	alibaba.com	China	0.27%	0.88%	#413	73.62M	33.56M
54	kakaku.com	Japan	0.26%	4.46%	#527	72.47M	22.58M
55	dns-shop.ru	Russia	0.26%	13.14%	#448	72.13M	22.07M
56	bol.com	Netherlands	0.25%	4.72%	#445	68.25M	18.32M
57	slickdeals.net	United States	0.24%	3.41%	#724	66.44M	7.543M
58	tmall.com	China	0.24%	9.87%	#318	66.13M	16.38M
59	aliexpress.ru	Russia	0.24%	3.13%	#427	66.11M	18.60M
60	hepsiburada.com	Turkey	0.23%	0.49%	#519	63.94M	19.96M

Once the data were collected, the method evaluated the efficiency of the website using the accuracy parameter shown in section 5.2. The result of the investigation shows that 94.92% are efficient and the remaining 5.08% are inefficient for persons with disabilities. From the investigation, it is found that many websites are efficient for persons with visual impairments. It is good news that many websites are following the guidelines of accessibility and readability. However, there are still 5.08% of websites that fail to design their websites for persons with visual impairments. Moreover, the proposed method is compared with the accessibility and readability methods shown in Figure 7.

Figure 7: Evaluate the efficiency and inefficiency of websites



The figure shows that the efficient rate of the accessible method was evaluated at 77.97% and the inefficient rate at 22.03%. Moreover, the efficiency rate of the readable method was evaluated at 93.23%, and the inefficiency rate was 6.77%. However, our proposed method shows that 94.92% are efficient and 5.08% are inefficient. From the analysis, it can be revealed that while a significant number of top-ranked e-commerce sites originate from highly developed countries, their commercial success does not correlate with compliance with accessibility and readability standards.

6. Discussion

This paper proposed a novel method, “AMEEW”, to evaluate the efficiency of websites. The method successfully explored the e-commerce websites, and the result of the experiment shows that the method evaluated 94.92% as efficient websites and 5.08% are inefficient websites. Although this paper approached the novel method, there are some issues regarding implementing the method. Therefore, this section discusses these important issues and explains how the proposed method overcame this issue, as discussed below:

- One issue is that some of the websites provided identical scores for both the accessibility error score and the readability score. Hence, the method selected anyone’s score as efficient without further investigation.
- Another issue concerns the accessibility score. As some websites provide full accessibility. Hence, their accessibility score is zero (0). Therefore, the method overcame this issue by regarding the website as an efficient website without further examining the readability of the website, because the proposed method evaluated zero if one of the scores is zero.
- One more possible issue perhaps occurred, but in our evaluation, the method did not confront it; that is, the readability score is zero (0). The readability score of zero indicated that the website did not provide any text of the websites and outlined the website only images or some other technologies, which will be difficult for persons with disabilities because the persons with disabilities handle the website using the screen reader, and the screen reader only reads the text, and it is unable to read the image. As a result, the method of regarding the website as an inefficient website.

- The accessibility error and readability error cannot be together at zero because the accessibility error and readability are inversely proportional to each other. If the accessibility error is zero, it means it is a readable website; otherwise, if the website is not readable, then the website is not an accessible website, which prompts the expansion of the accessibility error score.
- The four assumption tests in our study have different but complementary purposes. Initially, the randomisation test (lag plot) confirmed whether or not error occurrences displayed systematic dependencies or followed an independent pattern. Non-random errors could reveal biases or technical problems in our data gathering process that needed to be fixed before analysis. Second, the run sequence plot, or fixed location test, determined whether the errors' central tendency held steady over measurements. This stability indicates constant performance over time for readability and website analytics, which is essential for accurately forecasting future behaviour. A crucial prerequisite for many statistical techniques, the fixed variation test (which also used a run sequence plot) made sure that the variation in error rates didn't change significantly across data. The normal probability plot and histogram distribution tests were used to confirm that we were using parametric statistical techniques. The normal probability plot's linearity suggested that, for analytical purposes, the data might be regarded as roughly normal, despite the histogram's noticeable right-skew. The data can be transformed using the Box-Cox transformation to address the data's non-normal distribution, as indicated by the histogram upon analysis.

7. Conclusion

This paper analysed the accessibility errors and readability scores of the top e-commerce websites and proposed a novel method, “AMEEW” to explore the efficiency of the websites using the accessibility error score and readability score. Initially, the model analysed 32 websites and calculated their efficiency scores using the proposed equation. The threshold was then determined by averaging these scores. Websites with efficiency scores above the threshold were classified as inefficient; otherwise, they were considered efficient. Finally, the method collected 60 current e-commerce websites from online sources and evaluated the efficiency scores of the websites. Moreover, this paper proposed two evaluation metrics to calculate the accuracy of both efficient and inefficient percentages. The result of the investigation shows that the method evaluated 94.92% of websites as efficient websites, and the other 5.08% are inefficient websites. Our analysis reveals that while a significant number of top-ranked e-commerce sites originate from highly developed countries, their commercial success does not correlate with compliance with accessibility and readability standards. This paper is an initial version of the accessibility and readability of the website.

In the future, the method will be enhanced and analysed by the other sectors of the websites for persons with disabilities.

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How to cite this article

Sonowal G., Kuppusamy K. S., Balaji V. (2025). Novel method to explore the efficiency of e-commerce websites for persons with disabilities. Journal of Accessibility and Design for All, 15(2), 175-194. <https://doi.org/10.17411/jacces.v15i2.568>.



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