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The Relationship between Web Accessibility Errors and Technological Advancement: A Comparative Analysis of Government and Non-Government Websites in 27 Countries across 6 Continents

Mohammed Raihan Ullah*, Rashidul Hasan, Md. Mazharul Islam, Partha Protim Paul

Institute of Information and Communication Technology,
Shahjalal University of Science and Technology, Sylhet, Bangladesh

*Corresponding Author: Mohammed Raihan Ullah (raihan-iict@sust.edu)

Abstract

Web accessibility means removing barriers so that people with disabilities can use technology. Web accessibility errors refer to issues or barriers that prevent people with disabilities from accessing and using websites effectively. This study examined the relationship between web accessibility errors and technological advancement by comparing government and non-government websites in 27 countries across six continents. Various accessibility checker tools were used to analyze 20 websites in each country. The results revealed a moderate correlation between the Global Innovation Index score and the Accessibility Score of government websites, while no such correlation was observed for non-government websites. Regional analysis also highlighted significant variations in web accessibility across continents and countries. African government websites performed poorly in terms of web accessibility errors, while North American non-government websites showed a high prevalence of errors. We believe that our research will provide valuable insights and serve as a foundation for future studies in this field.

Keywords: web accessibility errors, technological advancement, government websites, non-government websites, global innovation index, W3C.

1. Introduction

Disability includes a variety of deficiencies, activity limits, and participation restrictions that limit an individual's capacity to engage in daily activities. Disability is a state of decreased functioning associated with disease, injury, or other health conditions, which in the context of one's environment is experienced as an impairment, activity limitation, or participation restriction. [1] Physical, cognitive, sensory, or psychological disabilities might be present at birth or acquired later in life.

Web accessibility refers to the ability of people with disabilities to use the Internet. More specifically, web accessibility means that people with disabilities can perceive, understand, navigate, and interact with the Web.[2] Web accessibility benefits a wide range of users regardless of the type of disabilities (physical, sensory, intellectual, and cognitive), including older people or people with temporary impairments. [3] In recent years, there has been a strong focus on digital accessibility, which relates to how well persons with disabilities can utilize digital technologies such as websites, software, and mobile apps. According to the Web Accessibility Initiative, around 16% of the global population is disabled [4], and as the world becomes increasingly digital, it is critical to guarantee that digital material is accessible to all users. In today's digital era, when the internet plays a major role in communication, education, and commerce, web accessibility has become a critical problem. Accessibility for all people, including those with disabilities, has become a legal and ethical requirement for website owners and developers. Despite online accessibility guidelines and standards, many websites continue to have accessibility difficulties. In this article, we look at government and nongovernment websites from 27 countries across six continents to investigate the relationship between online accessibility errors and technological advancements. We will utilize the Global Innovation Index (GII) to rate technical advancements. The Global Innovation Index is an annual index that assesses the performance of countries worldwide in terms of innovation. The index measures a country's degree of innovation using a variety of factors such as research & development spending, patents, and human capital [5]. This index is a valuable tool for evaluating the link between technical advancement and web accessibility since nations with greater levels of

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innovation are more likely to prioritize digital accessibility in their laws and standards. There are many web accessibility assessment tools, such as WAVE[6], Tenon.io[7], AChecker[8], Axe dev tools[9], and accessi.org[10] to examine accessibility problems. To the best of our knowledge, little research has been undertaken regarding the relationship between web accessibility errors and technological advancements. Nonetheless, several publications and research have researched the significance of web accessibility, including the value of adopting regulations, standards, and assessments to ensure that all persons have equal access to online information and services. Nonetheless, several publications and research studies have investigated the importance of web accessibility, including the importance of implementing regulations, standards, and assessments to ensure that all people have equal access to online information and services.

2. Background Study

2.1 Context and Background

Regardless of hardware, software, language, location, or ability, the Web is designed to work for all people. Web meets this goal only when it is accessible to people with a diverse range of hearing, movement, sight, and cognitive abilities. It is necessary for developers and organizations wanting to create high-quality websites and web tools without excluding people from using their products and services. [11] Web accessibility is the degree to which a website is designed to be usable by people with disabilities, even people with visual, auditory, cognitive, and motor impairments. Common accessibility barriers include images without alternative text, insufficient color contrast, inaccessible forms, and videos without captions or transcripts. To address these barriers, various international standards and guidelines have been developed, such as the Web Content Accessibility Guidelines (WCAG) [12] by the World Wide Web Consortium (W3C) [13].

Despite the existence of these standards and guidelines, web accessibility remains a challenge, particularly for government and non-governmental organizations (NGOs) that are responsible for providing information and services to the public. In addition, there is a lack of research on the relationship between web accessibility and technological advancements, which may affect the extent to which websites are accessible. To fill this research gap, this work aims to investigate the relationship between web accessibility errors and technological advancement by conducting a comparative analysis of government and non-government websites in 27 countries across 6 continents. The study will use Global Innovation Index (GII) 2021 [5] as the ranking tool for technological advancement and evaluate the accessibility errors using five different accessibility checker tools.

The Global Innovation Index (GII)[14] is an annual ranking of countries published by the World Intellectual Property Organization (WIPO) [15], in partnership with other organizations. The GII measures a country's innovation performance by looking at a range of indicators related to innovation, including inputs (such as human capital, research and development funding, and infrastructure) and outputs (such as patent applications and scientific publications).

The findings of this study can contribute to a better understanding of the factors that affect web accessibility and inform strategies for improving web accessibility for people with disabilities.

2.2 Literature Review

The concept of Web Accessibility involves designing websites that are accessible to the greatest number of people possible. Although it is typically associated with accommodating individuals with disabilities, ensuring accessibility also benefits other groups such as mobile device users and individuals with slow network connections. [16] While technical compliance with accessibility standards is crucial, non-technical factors also play a significant role in determining the accessibility of websites. These factors include:

- **Policy Enforcement:** The effectiveness of accessibility laws and regulations varies widely across countries. For example, in the United States, Section 508 of the Rehabilitation Act and the Americans with Disabilities Act (ADA) mandate accessibility for federal and public websites, respectively [26, 27]. However, in countries with weaker enforcement mechanisms, compliance with accessibility standards may be inconsistent. Studies have shown that even in countries with strong legal frameworks, enforcement can be uneven, leading to gaps in accessibility implementation [19, 24].

- **Cultural Attitudes:** Cultural attitudes toward disability can influence the prioritization of accessibility. In societies where disability is stigmatized or overlooked, web accessibility may receive less attention from developers and policymakers [17]. For instance, in some regions, there may be a lack of awareness about the importance of accessibility, leading to lower adoption of accessibility standards [22]. Research has highlighted that cultural perceptions of

disability can significantly impact the allocation of resources and the prioritization of accessibility initiatives [18].

- **Resource Availability:** The availability of resources, such as funding, training, and technical expertise, can significantly impact the implementation of accessibility measures. Smaller organizations, particularly in developing countries, may struggle to meet accessibility standards due to limited budgets or a lack of skilled developers [24, 29]. For example, a study on Ugandan government websites found that resource constraints were a major barrier to achieving full accessibility compliance [24].

- Awareness and Education: A lack of awareness or education about accessibility best practices among web developers and designers can lead to unintentional accessibility errors [18]. For example, developers may not be familiar with WCAG guidelines or may not understand how to implement them effectively. Training programs and awareness campaigns can help address this issue [30]. Research has shown that targeted training initiatives can significantly improve accessibility outcomes, particularly in regions where accessibility is not yet a cultural norm [22].

By considering these non-technical factors, future research can provide a more holistic understanding of the barriers to web accessibility and inform strategies for overcoming them. For instance, case studies of countries or organizations that have successfully implemented accessibility measures despite resource constraints could offer valuable insights [24, 29].

United Nations Disability Inclusion Strategy [17] highlights the necessity of accessibility as a fundamental human right and the significance of ensuring that digital technology is usable by everyone. Similarly, Shawn Lawton Henry explores the challenges that individuals with disabilities face when accessing web material and the need to ensure accessibility through design and policy [18].

Some researchers researched various government and non-government websites from various countries, such as Bangladeshi government websites [19], Philippines government websites [20], Pakistani government websites [21], Kyrgyz government websites [22], Turkish local and state government sites [23], Ugandan government websites [24], Spain, Chile, and Mexico university websites [25] etc. But it is a matter of great sorrow that there isn't much mentionable work on the relationship between web accessibility and technological advancements, and also if there is any difference between government and non-government websites.

The study "The Relationship between Web AccessibilityErrors and Technological Advancement: A Comparative Analysis of Government and Non-Government Websites in 27 Countries across 6 Continents" examines the relationship between web accessibility errors and technological advancement. The study compares government and non-government websites in 27 countries across six continents, focusing on the prevalence of web accessibility errors and how they vary across different levels of technological advancement, also if there is any difference between the government and non-government websites' error levels.

2.3 Web Content Accessibility Guidelines

By following accessibility guidelines and standards, software developers can create products that are usable by a wider range of people, including those with disabilities. This not only promotes equality and inclusiveness but can also improve the user experience for all users, regardless of their abilities.

The Web Content Accessibility Guidelines (WCAG) are the most widely recognized international standards for web accessibility, developed by the World Wide Web Consortium (W3C). WCAG 2.1, the version used in this study, provides a comprehensive framework for making web content accessible to people with disabilities. The guidelines are organized into four principles: Perceivable, Operable, Understandable, and Robust (POUR), which form the foundation of accessible web design.

WCAG 2.1 defines three levels of conformance: A (minimum), AA (mid-range), and AAA (highest). Each level builds upon the previous one, with stricter criteria for accessibility. In this study, we evaluated websites against Level A and Level AA criteria, as these are the most commonly adopted standards globally and are often required by law in many countries.

There are different guidelines out there around the world. We can differentiate them into two main categories:

1. Global Guidelines

2. Regional Guidelines

1) Global Guidelines

The most widely recognized international accessibility guideline is the Web Content Accessibility Guidelines (WCAG) 2.1 [12], developed by the World Wide Web Consortium (W3C) [13]. WCAG 2.1 provides a set of comprehensive and internationally recognized standards for web accessibility. It covers a wide range of accessibility issues, including text alternatives for non-text content, providing equivalent alternatives for time-based media, and making it possible to use the content

without a mouse. WCAG 2.1 [12] is widely adopted and used as the benchmark for web accessibility by governments, organizations, and individuals around the world.

Here are the main guidelines from WCAG 2.1 [12], the websites must be:

1. **Perceivable:** Ensuring that text alternatives are provided for non-text content (e.g., images, videos), and that content is adaptable to different user needs (e.g., resizable text, high contrast).
2. **Operable:** Ensuring that all functionality is available via keyboard navigation, and that users have enough time to read and interact with content.
3. **Understandable:** Ensuring that text is readable and understandable, and that web pages operate in predictable ways.
4. **Robust:** Ensuring that content is compatible with current and future user tools, including assistive technologies.

While our analysis focused on technical compliance with WCAG, it is important to note that achieving full accessibility often requires more than just meeting these criteria. Cultural attitudes, policy enforcement, and the availability of resources for web developers also play a significant role in the implementation of accessibility standards. For example, even if a website technically meets WCAG Level AA, it may still fail to provide an inclusive experience if developers lack awareness of the needs of users with disabilities or if there is insufficient enforcement of accessibility laws.

2) Regional Guidelines

There are many regional web accessibility guidelines around the world. Many countries follow their own guidelines. Some of these are:

- USA
- Section 508 of the Rehabilitation Act [26]: This is a federal law that requires electronic and information technology procured by the federal government to be accessible to people with disabilities. This law sets standards for the accessibility of software, websites, and other information technology products used by the government.
- The Americans with Disabilities Act (ADA) [27]: This is a federal civil rights law that prohibits discrimination based on disability. The ADA applies to all areas of public life, including the digital world, and requires that websites and software applications be accessible to people with disabilities.
- Europe
- European Standard EN 301 549 [28]: This is a standard for the procurement of accessible ICT products and services in Europe. This standard sets requirements for the accessibility of software, websites, and other information technology products and is widely used by government organizations and private companies in Europe to ensure that their products are accessible to people with disabilities.
- Bangladesh
- National Web Accessibility Guideline [29]: In Bangladesh, accessibility guidelines for people with disabilities are not yet fully developed and implemented. Recently A2i (Aspire to Innovate) Program [30], a program of the ICT division of the Bangladesh Government, made a guideline called National Web Accessibility Guideline, which follows the WCAG 2.1 [12] guideline. This guideline is still in the draft process.

2.4 Legislation

Digital accessibility standards and laws vary from country to country. In order to ensure that digital content is accessible to everyone, governments and organizations have passed various laws and acts. Some of these are:

- USA
- Section 508 of the Rehabilitation Act [26] and the Americans with Disabilities Act [27], requires federal agencies and organizations to ensure their digital content is accessible.
- Europe
- The European Standard EN 301 549 [28], which is a procurement standard for accessible ICT products and services.
- Australia
- Disability Discrimination Act [31], Advisory Notes on World Wide Web Access, created in 2002 and updated in 2010, contain guidelines for web accessibility. Australian government departments and agencies are required to adopt the WCAG [12]. The Digital Service Standard includes accessibility.
- Japan
- JIS X 8341 [32] is the ICT accessibility guidelines for older persons and persons with disabilities developed in 2004 with several updates. The JIS X 8341-3 [32] was updated in 2010 and is compliant with WCAG 2.0 [12]. These guidelines are mandatory for national and local government agencies, but voluntary for private companies.

3. Methodology

The goal of this research was to explore the relationship between web accessibility errors and innovation performance in 27 countries across 6 continents. To achieve this goal, a comparative analysis is conducted of government and non-government websites in each of these countries,

using a range of web accessibility testing tools and the Global Innovation Index (GII) as measures of innovation performance.

3.1 Data Collection

To collect data for this study, 10 government and 10 non-government websites were selected from each of the 27 countries included in the study. Websites were chosen based on their significance and representation of the country, as well as the availability and accessibility of website data. A total of 540 websites were examined. The countries were selected manually based on the Global Innovation Index. The websites were also manually selected and tested individually so that all selected websites were active and available.

To minimize selection bias, we used the following criteria for website selection:

- **Traffic and Popularity:** Websites with high traffic rankings (based on tools like Alexa or SimilarWeb) were prioritized to ensure they are widely used by the public.
- **Geographical Representation:** Websites were selected from different regions within each country to avoid overrepresentation of urban areas.
- **Diversity of Sectors:** For non-government websites, we included a mix of sectors (e.g., education, healthcare, commerce) to capture a broad range of accessibility practices.

Despite these efforts, it is important to acknowledge that the sample size of 20 websites per country may not fully represent the entire web accessibility landscape of a country. Future studies could expand the sample size or use stratified sampling to ensure greater representativeness.

3.2 Web Accessibility Testing

The websites were selected randomly. To assess web accessibility errors on each of the 540 websites, the following web accessibility testing tools were used: WAVE, Tenon.io, Axe dev-tools, accessi.org, and AChecker.

These tools were used to check the websites for compliance with the Web Content Accessibility Guidelines (WCAG) developed by the World Wide Web Consortium (W3C).

3.3 Technology Performance Measurement

To measure innovation performance, the Global Innovation Index (GII) was used. The GII measures innovation performance across a range of indicators, including institutions, human capital and research, infrastructure, market sophistication, business sophistication, knowledge and technology outputs, and creative outputs. GII scores were obtained for each of the 27 countries included in the study.

3.4 Data Analysis

The websites were analyzed using the selected tools manually and using automated scripts. The data collected from web accessibility testing tools and GII scores were analyzed using different visualization techniques to determine the relationship between web accessibility errors and innovation performance. The correlation analysis was used to explore the effect of web accessibility errors on GII scores, controlling for other factors that may influence innovation performance. As the number and types of errors detected by different accessibility tools differ by a great margin and we extracted a single error value from a combination of error values in multiple cases. For such cases, we used Average and Weighted Average to extract a single error value from a group of values. Also for normalizing the values, we used Min-Max Scaling. During the initial stages, we used a weighted average to find a single error value from each of the Accessibility Assessment tools. We used the "Accessibility Score" as the common unit to measure the accessibility level based on the error values found during the study. Accessibility Score was the normalized mean of the error values. Although it can't serve as a unique standard, it could be effectively used to analyze the accessibility standards and implementations in different countries around the world.

4. Evaluation And Result Analysis

4.1 Evaluation

Evaluation Tools Score Weights

We evaluated the websites based on the error values found using the different Accessibility Evaluation Tools. During the evaluation, we used the weights in Table I for finding the weighted average as a single error value for each tool and website.

Issue Type	Weight Value
Errors (WAVE)	1
Contrast Errors (WAVE)	0.1
Warnings (WAVE)	0.01
Total Errors (Tenon)	1
Total Warnings (Tenon)	0.1
Known Problems (AChecker)	1
Likely Problems (AChecker)	0.1
Potential Problems (AChecker)	0.001
Critical Issues (AXE)	1
Serious Issues (AXE)	0.5
Moderate Issues (AXE)	0.1
Minor Issues (AXE)	0.01
Errors (Accessi)	1

TABLE I. Accessibility Issue Weights

4.2 Result and Analysis

1) Country Wise Error Evaluation

We found the error value for each country and each tool by averaging the weighted error values for the websites in that country and for that tool. The obtained error values for the respective countries and tools are given below.

Table II shows the mean of the Government websites error values found using each Accessibility tool.
Table III on the other hand shows the data for the Non-Government websites in the respective countries. From these error values, we found the Accessibility score in each country for both Government and Non-Government websites.

In Table IV are the Accessibility Score we found for each country in the case of both Government and NonGovernment websites. We also ranked the countries based on these two sets of Accessibility scores of Government and Non-Government Websites.
Aside from the complex scoring, we also calculated the sum of errors for each country by individual tools shown in Table V. The Total Errors in this table provide us with a sense of the countries' accessibility error serious situation.

Coming out of the Country focused calculations we measure the Accessibility Scores and Total Errors for both Govt and Non-Govt websites in different Continents where the results are shown in Table VI.

Country	WAVE	Tenon	AC	AXE	Acsi
Korea	8.6	7	7.04	1.51	64.3
Japan	3.13	7.82	3.32	0.9	161.6
India	13.86	28.64	14.78	1.53	185.9
Bangladesh	15.49	21.64	15.48	2.93	148.4
Nepal	34.92	13.45	42.78	4.78	168.3
Morocco	48.94	31.82	46.64	2.52	187.4
South Africa	19.27	12.36	19.7	7.44	97.6
Ghana	36.57	39.73	2.44	15.18	117.6
Nigeria	29.44	30.36	41.8	9.97	136.7
Uganda	31.24	31.73	58.29	7.93	127.8
France	8.35	1.55	8.11	1.28	12.1
UK	1.59	3	1.53	0.55	103.6
Ukraine	11.39	10.45	6.09	2.18	99.4
Azerbaijan	59.86	17.91	24.72	2.81	106.2
Albania	38.44	42.82	38.01	3.49	132.5
USA	2.18	6.27	1.86	1.34	71.9
Canada	14	0.73	13.89	0.95	92.3
Costa Rica	19.51	22.55	19.33	1.47	165.1
Guatemala	47.75	16.84	38.61	5.16	121.5
Honduras	37.15	10.64	54.14	3.82	188.2
Chile	32.88	13.64	32.68	3.31	138.2
Brazil	7.87	9.18	7.73	2.05	90.6
Argentina	8.2	1.82	4.38	1.87	43.2
Paraguay	21.55	17	27.5	4.85	134.4
Ecuador	7.45	6.55	8.61	1.43	64.7
Australia	8.66	6.55	8.51	2.19	101.3
New Zealand	4.15	2.55	4.09	0.99	74.1

TABLE II. Mean Values for Accessibility Evaluation Tools byCountry (Govt.)

Here, AC=AChecker, Acsi=Accessi

Country	WAVE	Tenon	AC	AXE	Acsi
Korea	17.51	17.75	31.26	1.49	264.6
Japan	26.49	9.33	34.5	2.52	247.2
India	12.03	5.5	12.4	2.04	144
Bangladesh	26.43	41.58	33.88	2.3	249.4
Nepal	45.16	34.67	42.19	2.39	52.7
Morocco	20.45	9.67	22.64	1.85	0
South Africa	33.57	9.67	38.6	2.33	0
Ghana	46.62	15.58	55.25	2.4	0
Nigeria	32.44	16.42	34.44	1.94	0
Uganda	59.1	19.67	55.81	1.94	0
France	24.48	7.42	31.45	1.95	0
UK	16.03	13.5	31.34	2.25	0
Ukraine	9.13	8.17	31.98	1.88	0
Azerbaijan	27.26	19	33.53	2.3	191.1
Albania	16.14	14.5	84.69	2.05	243.2
USA	19.88	2.75	13.71	1.86	377.6
Canada	5.85	7.08	43.54	1.63	117.1
Costa Rica	45.37	8.83	31.15	2.03	124.5
Guatemala	40.43	15.83	88.23	2.57	301.5
Honduras	43.34	6.92	107.81	2.77	270.3
Chile	44.77	16.67	43.97	2.58	299.2
Brazil	18.04	6.5	44.97	1.69	212.8
Argentina	2.53	5.08	42.03	2.38	316.5
Paraguay	7.29	25.84	57.36	2.23	421.8
Ecuador	23.09	4.17	62.01	1.99	221.3
Australia	2.33	10	20.62	1.74	138.3
New Zealand	14.56	6.2	7.48	1.78	62.11

TABLE III. Mean Values for Accessibility Evaluation Tools by Country (Non Govt.)

Here, AC=AChecker, Acsi=Accessi

Country	AS-G	Rank-G	AS-NG	Rank-NG
Korea	0.86	7	0.7	11
Japan	0.75	11	0.44	18
India	0.41	16	0.87	6
Bangladesh	0.49	14	0.21	24
Nepal	0.22	20	0.26	22
Morocco	0	27	0.91	5
South Africa	0.51	13	0.64	13
Ghana	0.1	23	0.42	20
Nigeria	0.07	25	0.71	10
Uganda	0.02	26	0.43	19
France	1	1	0.85	7
UK	0.87	5	0.76	8
Ukraine	0.75	11	0.96	2
Azerbaijan	0.31	19	0.46	17
Albania	0.1	23	0.41	21
USA	0.93	4	0.69	12
Canada	0.81	8	0.92	4
Costa Rica	0.44	15	0.57	16
Guatemala	0.22	20	0.04	26
Honduras	0.15	22	0	27
Chile	0.37	18	0.16	25
Brazil	0.79	9	0.74	9
Argentina	0.95	2	0.58	14
Paraguay	0.41	16	0.26	22
Ecuador	0.87	5	0.58	14
Australia	0.78	10	0.94	3
New Zealand	0.94	3	1	1

TABLE IV. Accessibility score of government and non-government websites of different countries. Here, AS=Accessibility Score, TE=Total errors, G=Government, NG=Non-Government

4.3 Observation

4.3.1 GII score vs Accessibility Score

From figure 1 We found a strong relationship Between the Government Accessibility Score and GII Score. There is quite a match between those two. We can get a detailed overview of how these two values correlate with each other. These findings suggest a significant relationship between web accessibility and innovation, highlighting the potential benefits of promoting web accessibility as a means of fostering innovation and societal development.

Country	Total Errors
Korea	884.4
Japan	1767.78
India	2446.99
Bangladesh	2039.33
Nepal	2643.14
Morocco	3173.06
South Africa	1563.72
Ghana	2115.22
Nigeria	2482.69
Uganda	2569.88
France	313.84
United Kingdom	1102.75
Ukraine	1295.14
Azerbaijan	2115.02
Albania	2552.5
USA	835.56
Canada	1218.7
Costa Rica	2279.49
Guatemala	2298.51
Honduras	2939.33
Chile	2207
Brazil	1174.3
Argentina	594.6
Paraguay	2052.94
Ecuador	887.44
Australia	1272.05
New Zealand	858.69

TABLE V. Accessibility Test Results by Country

Continent	AS-G	AS-NG	TE-G	TE-NG
Asia	0.546	0.496	1956.328	2718.616
Africa	0.14	0.622	2380.914	960.71
Europe	0.606	0.688	1475.85	1626.622
North America	0.51	0.444	1914.318	3365.142
South America	0.678	0.464	1383.256	3773.538
Oceania	0.86	0.97	1065.37	1279.505

TABLE VI. Accessibility error in different continents.

4.3.2 *GII score vs Accessibility Score Non-Govt*

From figure 2 While we did find a correlation between the GII score and non-government websites, it was relatively weak, suggesting that there is not a significant relationship between the two.

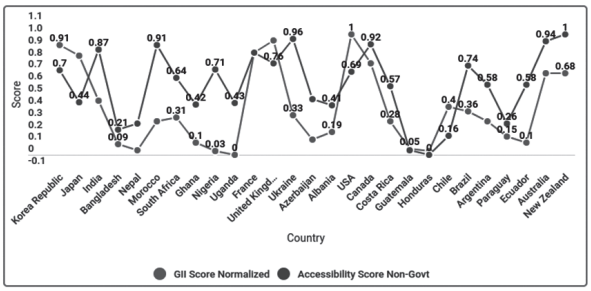

Figure 2. GII vs Accessibility score (Non-Govt)

Among all the values Fig 3 's heat map, we can observe a slight relation between the GII Score which is normalized, and the Accessibility Score of Govt. websites. But we also find a very weak relationship between the GII Score and the Accessibility Score of Non-Govt. websites. As such their corresponding rankings also exhibit the same relationship. This discrepancy may be attributed to several factors:

- **Lack of Regulatory Pressure:** Unlike government websites, which are often subject to strict accessibility regulations, non-government websites may face less legal pressure to comply with accessibility standards. This could result in lower prioritization of accessibility in the private sector.
- **Resource Allocation:** Non-government organizations, particularly smaller businesses, may lack the resources (e.g., funding, technical expertise) to implement comprehensive accessibility measures. In contrast, government agencies often have dedicated budgets and teams for accessibility compliance.
- **Technological Complexity:** Non-government websites, especially those in sectors like e-commerce and media, often use more complex frameworks and technologies (e.g., dynamic content, third-party plugins) that can introduce accessibility challenges. These complexities may not be adequately addressed by standard accessibility tools.
- **Awareness and Training:** There may be a lack of awareness or training among web developers in the non-government sector regarding accessibility best practices. This could lead to unintentional accessibility errors, even in technologically advanced countries.

Further research is needed to explore these factors in greater depth and identify strategies for improving accessibility in the non-government sector. For example, case studies of non-government organizations that have successfully implemented accessibility measures could provide valuable insights and best practices.

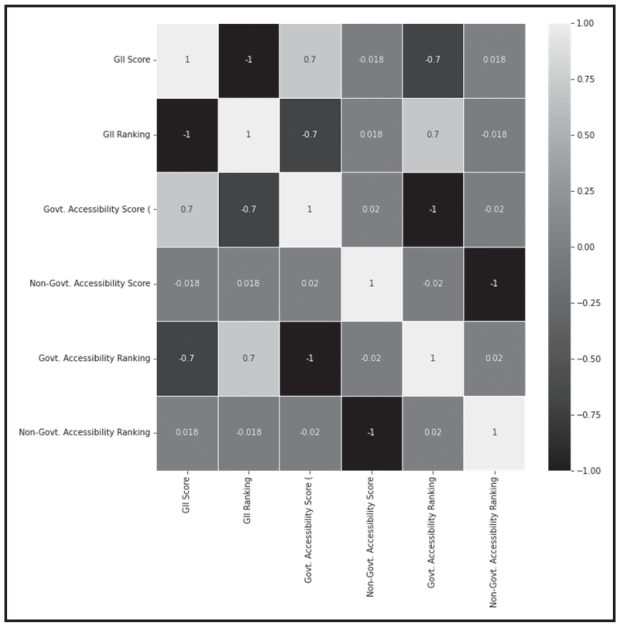

Figure 3. Heat map of Pearson's Correlation Test

4.3.3 *Government vs Non-Government Websites*

From figure 4, It is apparent that there is a correlation between the GII score and government accessibility score, but non-government websites deviate significantly from this relationship. From figure 5, Korea Republic attained the top rank despite scoring lower in government website errors, but significantly worse in non-government websites. On the other hand, Japan performed well on government sites but scored poorly on non-government sites. India and Nepal also had lower scores on government sites but better scores on non-government sites. Bangladesh, however, achieved a relatively decent score in government sites but performed poorly in non-government sites. From figure 6, It is evident that South Africa performed well in both government and non-government sites, while all other countries scored lower in government sites but had better scores in non-government sites.

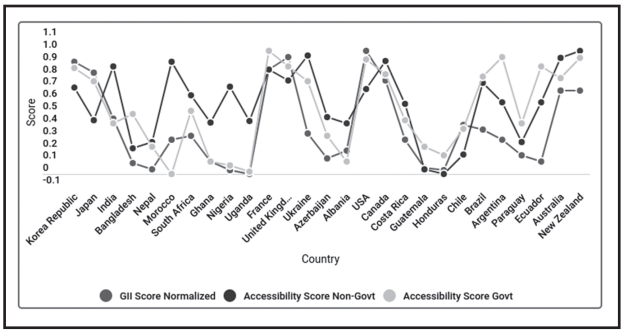

Figure 4. GII vs Accessibility score (Non-Govt) vs Accessibility score (Govt)

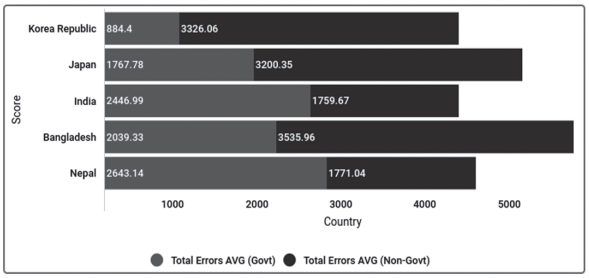

Figure 5. Total Errors - A sia

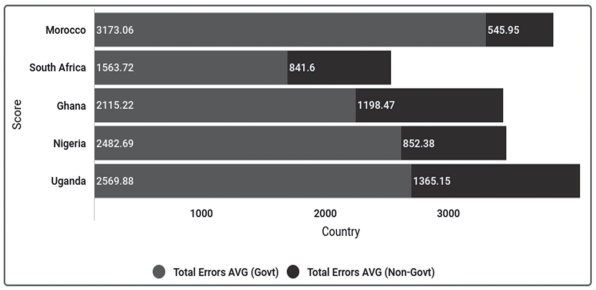

Figure 6. Total Errors - Africa

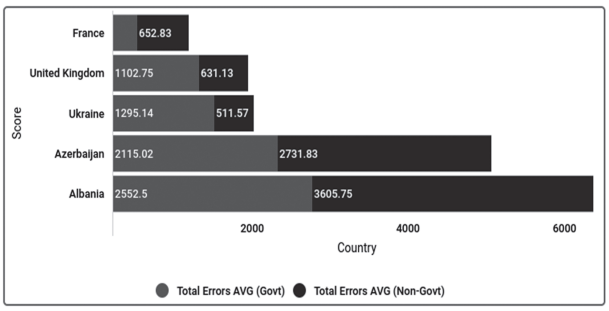

Figure 7. Total Errors - Europe

In figure 7, France demonstrated strong performance in all areas, while the United Kingdom and Ukraine performed well in non-government sites despite their poor performance in government sites. Conversely, the other two countries performed poorly in both government and nongovernment sites. The United States took the lead in the government sites ranking among North American countries, but their performance in non-government sites was similar to that of the bottom two countries. On the other hand, Canada and Costa Rica had comparable scores for both government and non-government sites.

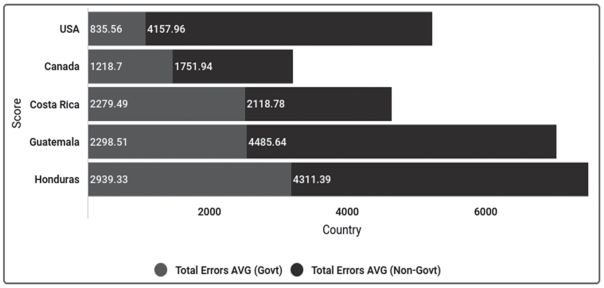

Figure 8. Total Errors - North America

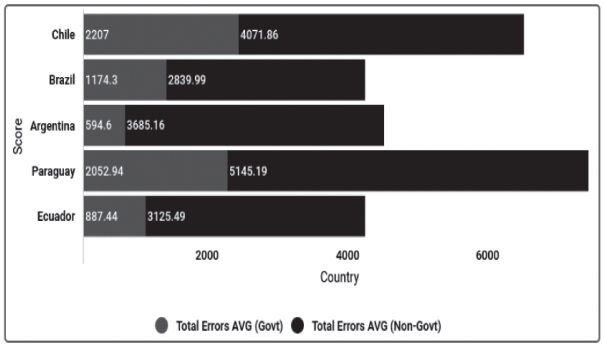

Figure 9. Total Errors - South America

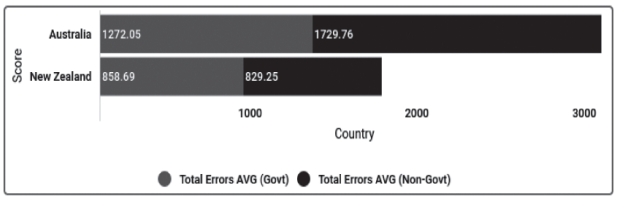

Figure 10. Total Errors - Oceania

Figure 8 From figure 9, it is apparent that Argentina performed remarkably well in terms of government websites, with Brazil and Ecuador following closely behind. However, the remaining two countries did not perform as well on government websites, and all of them scored low on non-government websites. From 10, we can see that New Zealand had a lower score than Australia in both the government sites and nongovernment sites categories, indicating that New Zealand performed relatively better in both categories compared to Australia. From figure 11, Guatemala, Paraguay, and Honduras are the countries responsible for the big share of errors while France, the United Kingdom, and New Zealand are responsible for the least. In the case of Continental ranking, we can clearly see African Government websites facing the highest amount of accessibility errors amounting to 23.40% of the total errors in our study. Other continents are closely matched as we can easily conclude from Fig 12 From Fig 13 we see huge changes in Africa and South America in case of errors in Non-Govt websites. African Non-Government websites have significantly fewer accessibility errors compared to other continents as well as Government websites which is only 7%. And in second place keeping a similar state to the Government websites Oceania occupies only 9.32% of the total errors in all the continents. North American Non-Government websites face the highest amount of web accessibility errors with a percentage of 24.52 From all of the errors of our study, the government side has a 42.4% error, while non-government sites have a rate of 57.6 % error.

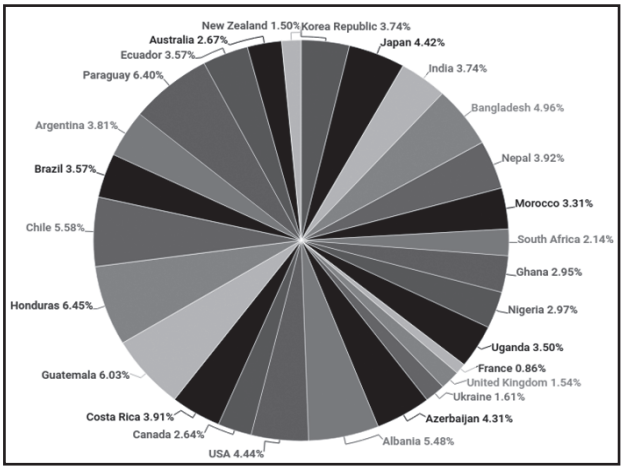

Figure 11. Continent Wise Combined Total Errors

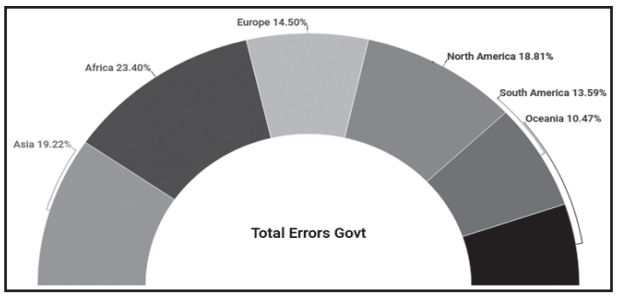

Figure 12. Total Errors By Continent (Govt)

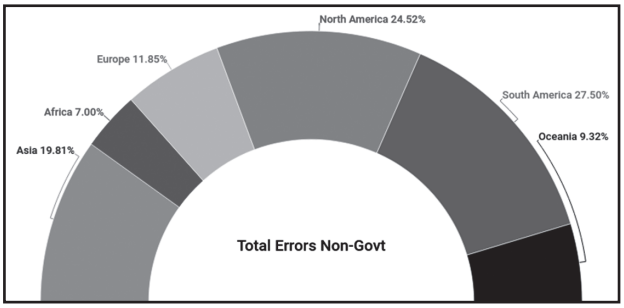

Figure 13. Total Errors By Continent (Non-Govt)

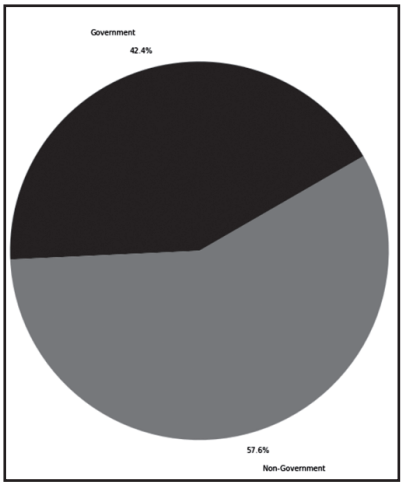

Figure 14. Total errors - Govt vs Non-Govt

4.3.4 User-Centric Analysis

While our study primarily focused on technical compliance with WCAG, we recognize the importance of incorporating feedback from users with disabilities, who are the primary beneficiaries of web accessibility. User testing or surveys could provide valuable insights into the real-world impact of accessibility errors. For example, users with visual impairments might highlight issues with screen reader compatibility, while users with motor disabilities might identify challenges with keyboard navigation.

In future research, we recommend conducting user testing sessions with individuals representing a range of disabilities. This could involve:

- Task-Based Testing: Asking users to complete specific tasks on a website (e.g., finding information, making a purchase) and observing where they encounter difficulties.
- Surveys and Interviews: Collecting qualitative feedback on users' experiences with web accessibility, including any barriers they face and suggestions for improvement.

Incorporating user-centric analysis would provide a more holistic understanding of web accessibility and help bridge the gap between technical compliance and real-world usability.

5. Conclusions and Future Work

5.1 Conclusions

Based on the analysis during this study, it is observed that the Global Innovation Index (GII) score has a moderate correlation with the accessibility score of government websites. However, there appears to be a weak correlation between the GII score and the accessibility score of non government websites.

Moreover, when considering the continental rankings, African government websites have the highest percentage of accessibility errors, whereas North American non government websites face the highest number of web accessibility errors. On the other hand, African non-government websites have the lowest percentage of accessibility errors, with Oceania following closely behind.

It is also interesting to note that different countries perform differently on government and non-government websites. For instance, Korea Republic ranks the highest overall in Asia, despite scoring lower in government website errors but significantly worse in non-government websites. In contrast, Japan performs well on government sites but scores poorly on non-government sites.

Our findings highlight the need for continued efforts to improve web accessibility across different types of websites, particularly for government websites in Africa and non government websites in North America. Additionally, it emphasizes the importance of considering regional differences and the specific needs of different user groups when designing and developing websites to ensure that they are accessible to all.

Also, following the existing Accessibility Guidelines, the number of websites able to follow the guideline is minimal. And that's also only in the case of A level, where AA and AAA levels are even less. The standard guidelines should have the most adaptability in case of implementation. But its lack of implementation still shows its areas of improvement. The WCAG 3.0 though has not been finalized, it has made significant progress. In effect, rapid advancement has also made it harder to follow the existing guidelines. But the recent initiatives and laws by different organizations show the increasing importance of digital accessibility.

With the emergence of more advanced and complex technologies, maintaining web accessibility becomes more complex. Due to which regular modification to the accessibility standards and web improvements are required. This may also be one of the reasons the Non-Government websites which use more complex frameworks and technologies show greater errors than the Government websites.

Overall, our study provides valuable insights into the relationship between web accessibility errors and technological advancement, highlighting the need for continued efforts to improve accessibility and promote a more inclusive and accessible online world.

5.2 Future Work

While this study sheds light on the current state of web accessibility across different types of websites and regions, there are several avenues for future research.

Below, we outline specific research questions and hypotheses that could guide future investigations:

- **Non-Technical Factors:** What role do cultural attitudes toward disability, policy enforcement, and resource availability play in the implementation of web accessibility standards? For example, how do differences in legal frameworks across countries affect compliance with WCAG?
- **User-Centric Analysis:** How do users with disabilities experience web accessibility in practice? What are the most common barriers they face, and how can these be addressed through design and policy changes?
- Emerging Technologies: How do emerging technologies such as artificial intelligence (AI), virtual reality (VR), and voice assistants impact web accessibility? For example:
  - Can AI-driven tools improve the automatic detection and correction of accessibility errors?
  - How can VR experiences be made accessible to users with visual or motor impairments?
  - What are the challenges and opportunities of designing voice interfaces for users with speech impairments?
- Policy and Enforcement: How effective are current enforcement mechanisms in ensuring compliance with accessibility standards? What are the barriers to compliance for website owners and developers, and how can these be overcome?
- Global Trends: How do web accessibility practices vary across different regions and cultures? Are there regional best practices that could be adopted more widely?

By addressing these questions, future research can provide a more comprehensive understanding of web accessibility and inform strategies for creating a more inclusive digital world.

Another area that warrants further investigation is the impact of web accessibility on different user groups, particularly those with disabilities. In this study, we primarily focused on the technical aspects of web accessibility, such as compliance with WCAG guidelines. However, it would be valuable to explore the lived experiences of users with disabilities and how web accessibility (or lack thereof) affects their ability to access information, participate in online activities, and engage with society more broadly.

Additionally, as web accessibility is increasingly recognized as a legal requirement, it is essential to examine the enforcement and implementation of accessibility regulations. For example, how effective are current enforcement mechanisms in ensuring that websites are accessible, and what are the barriers to compliance for website owners and developers.

Furthermore, with the increasing use of emerging technologies such as voice assistants, virtual and augmented reality, and artificial intelligence, it is essential to explore how these new technologies can either hinder or enhance web accessibility. For example, how can designers and developers ensure that voice assistants are accessible to users with speech impairments or that virtual and augmented reality

experiences are accessible to users with visual impairments?

Overall, continued research in these areas will be crucial in promoting web accessibility and ensuring that the web remains an inclusive space for all users.

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