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Web Accessibility Compliance of Saudi Higher Education Institutions: A Comparative Automated Evaluation using A Checker, TAW, and WAVE

Nadia Al-Ghreimil*

*Corresponding author, College of Computer and Information Sciences, King Saud University, Riyadh 11451, Saudi Arabia. E-mail: ghreimil@ksu.edu.sa

Duaa AlSaeed

College of Computer and Information Sciences, King Saud University, Riyadh 11451, Saudi Arabia. E-mail: dalsaeed@ksu.edu.sa

Heyam H. Al-Baity

College of Computer and Information Sciences, King Saud University, Riyadh 11451, Saudi Arabia. E-mail: halbaity@ksu.edu.sa

Fatimah Almohaimeed

College of Computer and Information Sciences, King Saud University, Riyadh 11451, Saudi Arabia. E-mail: 439203819@student.ksu.edu.sa

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Abstract

This study aims to evaluate the compliance of 44 Saudi university websites with the Web Content Accessibility Guidelines (WCAG). The analysis was conducted by evaluating the homepages of 44 Saudi university websites against the Web Content Accessibility Guidelines (WCAG). The evaluation was based on the four core accessibility principles—Perceivable, Operable, Understandable, and Ro-bust (POUR)—and assessed across three conformance levels: A, AA, and AAA. The adopted ap-proach was to use three automated heuristic evaluation tools, namely, A Checker, TAW, and WAVE. The results of the study showed that all evaluated websites failed to comply with the WCAG guide-lines, with major violations found at level A in the Perceivable and Operable principles. It also showed wide variability in issues detected by the three tools. A large number of issues are related to missing alternative text for images or fields, as well as color contrast errors. The findings suggest that Saudi university websites are not accessible to individuals with disabilities, which limits their ability

to access educational content and services. A substantial proportion of the identified accessi-bility issues could be addressed by providing appropriate alternative text and labels, as well as im-proving color contrast. Additional improvements include ensuring the proper semantic use of empha-sis and strong tags instead of relying solely on italic and bold formatting. Furthermore, using multi-ple tools in the evaluation can highlight different issues, but additional expert opinions are needed. This study can be beneficial for future improvements in the accessibility of Saudi university web-sites and contribute to a more inclusive web environment.

Keywords: Accessibility; Usability; Heuristic Evaluation; Universities websites; Arabic Interfac-es; Visual Impairment; inclusive education.

Introduction

Today's education scenario is rapidly evolving, especially after the Covid-19 pandemic, which changed the globe during the past few years, making people and organizations all over the world even more dependent on technology for work, education, health, and other fields. In addition, Saudi Arabia's Vision 2030 promotes digital transformation across all sectors in the Kingdom. Its goal is to innovate the government digitally in order to improve services for all residents, inclusively. Needless to say, the internet is a crucial part of this process of change. This rapid global technological development and the Saudi government's vision drove higher education institutions in Saudi Arabia to develop their web portals, as they serve as an interface and a communication channel between all their current and future stakeholders. Such portals must be accessible for all users regardless of their abilities.

The International Organization for Standardization (ISO) defines accessibility as "the usability of a product, service, environment or facility by people with the widest range of capabilities". This means that for a website to be accessible for specific users, including visually impaired (VI) users, it must be usable by those users. In Saudi Arabia, there are about 44 universities (29 public and 15 private). Furthermore, according to the According to the Authority for the Care of People with Disabilities (2017), 7.1% of the Saudi population lives with a disability, of which 2.46% are affected by visual impairment. Therefore, it is crucial to ensure that universities' websites are accessible to everyone, including those with disabilities, so that they may view, understand, and navigate the web on an equitable basis.

Accessibility compliance evaluation for websites can be conducted either manually, with the assistance of accessibility experts, or automatically through the use of evaluation tools. Automated tools scan a website's underlying code to identify violations of accessibility guidelines and provide a fast and cost-effective alternative to manual testing, particularly for preliminary evaluations (Vigo et al., 2013; Roy et al., 2014; Alismail & Chipidza, 2021; Hassan et al., 2021; Sierkowski, 2002). Several studies have examined automated

accessibility evaluation across different types of websites, including governmental, healthcare, educational, and financial websites (Sierkowski, 2002). These studies emphasize the importance of accessibility testing and provide insights into the accessibility levels of various website categories.

This study aims to evaluate the accessibility of Saudi university websites using an automated evaluation approach using three automated tools, to highlight the major accessibility issues in these websites, and to compare the tools' results. This study also intends to raise awareness of the importance of designing accessible solutions that provide equal access to all users.

The rest of this paper is structured as follows. The next section will present background information on accessibility, followed by the related work in Section 3. Section 4 will describe the methods we used in detail, including types of automatic heuristic evaluation tools. Section 5 will show the results of the evaluation. Finally, section 6 concludes this paper and provides suggestions for future work.

Accessibility

In accordance with the UN Convention on the Rights of Persons with Disabilities (UNCRPD), access to information and communication technologies, including websites, is recognized as a fundamental human right. It is imperative to prioritize the needs and requirements of individuals with disabilities when designing websites. Web accessibility encompasses the ability for all users, regardless of disability, geographical location, language barriers, or any other factors, to understand and fully interact with a website's content (Sierkowski, 2002).

"The power of the Web is in its universality. Access by everyone regardless of disability is an essential aspect," said Tim Berners-Lee, World Wide Web Consortium (W3C) Director and inventor of the World Wide Web[1]. According to Tim Berners-Lee, accessibility is defined as a feature of the web that makes its services accessible to all people, regardless of their hardware and software specifications, network infrastructure, language of birth, culture, geographic location, or physical and mental attitude.

To ensure web accessibility, the World Wide Web Consortium (W3C) introduced the Web Content Accessibility Guidelines (WCAG) in 1999 in collaboration with individuals and organizations worldwide. The goal was to establish a unified standard for web content accessibility that addresses the needs of individuals, organizations, and governments globally. The WCAG documents guide improving the accessibility of web content for individuals with disabilities. WCAG 2.0 and WCAG 2.1, released in 2008 and 2018, respectively, are stable and internationally recognized technical specifications. These guidelines are organized around

[1] https://www.w3.org/WAI/EO/Drafts/4betaW3org/accessibility-new-w3c#case

four core principles that form the foundation of accessible web content: content must be Perceivable, Operable, Understandable, and Robust (POUR). Collectively, these principles encompass 12–13 guidelines, each containing success criteria classified into three conformance levels: A, AA, and AAA, with Level A representing the minimum level of compliance.

According to the WCAG

- **Perceivable** means that "Information and user interface components must be presentable to users in ways they can perceive."
- **Operable** means that "User interface components and navigation must be operable."
- **Understandable** means that "Information and the operation of the user interface must be understandable."
- **Robust** means that "Content must be robust enough that it can be interpreted by a wide variety of user agents, including assistive technologies."

Literature Review

Automatic evaluation tools for usability and accessibility can be effective mechanisms to evaluate web accessibility and usability; they are designed to check whether the code or content of web pages complies with accessibility guidelines or not [3]. Several studies have focused on assessing the accessibility and usability of university websites by checking their compliance with international standards, such as the WCAG, by using various automatic tools, and providing recommendations for improvement.

In Akgül (2021), the accessibility of the websites of Romania's top 18 universities for individuals with visual impairments was evaluated using the automated tool Total Validator v12.0 based on the Web Content Accessibility Guidelines (WCAG) 2.0. The results revealed a low level of web accessibility, as none of the evaluated websites satisfied the first level of accessibility compliance.

Similarly, Zarish et al. (2019) employed three automated tools—Qualidator, Website Grader, and Website Analyzer—to assess the accessibility and usability of 10 public university websites in Khyber Pakhtunkhwa (KPK), Pakistan. The Qualidator tool was specifically used to evaluate accessibility, usability, and search engine optimization.The Website Analyzer tool assessed various aspects such as accessibility, content, design, mobile readiness, page analysis, performance, SEO, security, and usability. Additionally, the Website Grader tool assigned grades based on mobile readiness, performance, SEO, and security. The evaluation results indicated that, according to the Qualidator tool, the Peshawar website outperformed others in terms of usability. The Website Analyzer tool ranked the KUST Kohat

website as the best, while the Website Grader tool identified the USTB Bannu website as the top performer. Furthermore, the evaluation results highlighted specific flaws in the assessed websites.

AlMeraj et al. (2021) evaluated the conformance of 41 higher education institutions' websites in the State of Kuwait with the Web Content Accessibility Guidelines (WCAG) 2.0 standards. The authors assessed the homepages of the education institution websites using A Checker, Total Validator, WAVE, and HTML/CSS/ARIA. The results across all the used tools showed an urgent need to solve accessibility violations, as none of the evaluated websites met the minimal WCAG 2.0 conformance level, Level A.

In Turkey, Akgül (2021) assessed the accessibility, usability, quality performance, and readability of 179 university websites, including 110 state university websites and 69 private university websites. For accessibility evaluation, they used A Checker to assess the conformance of the homepages of evaluated websites to WCAG 2.0 standards. The accessibility evaluation results showed that the majority of the evaluated websites did not meet WCAG 2.0 accessibility criteria, where only 14 university websites attained Level A compliance. Also in Turkey, Macakoğlu and Peker (2021) analyzed the accessibility of 58 university hospital websites. The authors used the TAW evaluation tool to assess the websites' conformance with the WCAG 2.0 standards. The results showed that university hospital websites had low compliance levels according to the WCAG 2.0 standards, where most of the websites did not meet the minimum requirements of WCAG 2.0 Level A.

Methodology

The evaluation of the accessibility of Saudi university websites was carried out in accordance with the WCAG 2.0 guidelines. We first identified all the Saudi universities, both public and private. Then, we utilized three widely used automatic heuristic web accessibility evaluation tools. For each website, we evaluated its home page. This was done for several reasons. Firstly, the home page is considered the representative page of a website, as it serves as the main entry point for users. By focusing on the home page, we can gain valuable insights into the overall accessibility of the website and its adherence to WCAG guidelines. Additionally, the home page typically includes essential elements and navigation features that are present across the website. By assessing the accessibility of these foundational components, we can identify potential issues that may affect the overall user experience throughout the website.

The methodology workflow is depicted in Figure 1. In the next subsections, we discuss the website selection criteria and the heuristic evaluation tools used for automated accessibility evaluation.

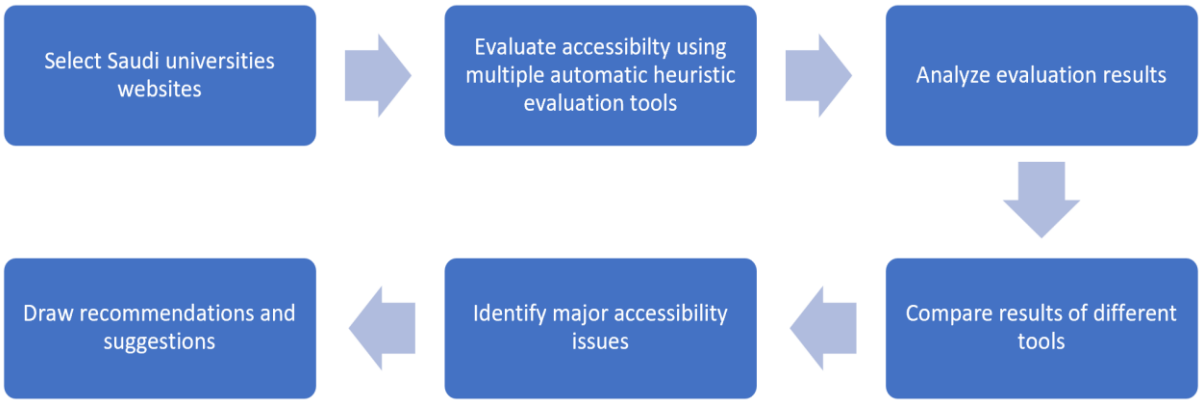

Figure 1. Methodology workflow

Saudi Universities' Websites

Saudi universities (both public and private) demonstrate incremental progression towards augmenting and replacing traditional processes with digital ones and providing their services through websites and applications. Therefore, university websites are important information gateways for past, current, and future students, faculty, and other stakeholders. The compliance of these websites with different accessibility guidelines plays a significant role in fulfilling users' needs and expectations, irrespective of their disabilities.

In this study, the accessibility of all Saudi university websites was evaluated, including 44 universities in total, of which 29 are public and 15 are private institutions. They are listed in Table 1 in alphabetical order for each sector.

Table 1. Saudi Universities and their home pages – in alphabetical order by sector

#	Acronym	University name	University website
Public Sector			
1	BU	Al Baha University	https://bu.edu.sa/ar/home
2	HBU	Hafr Al batin University	https://www.uhb.edu.sa/Pages/Home.aspx
3	IAU	Imam Abdulrahman Bin Faisal University	https://www.iau.edu.sa/en
4	IMAMU	Imam Muhammad bin Saud Islamic University	https://imamu.edu.sa/en/Pages/default.aspx
5	IUM	Islamic University of Medina	https://www.iu.edu.sa/
6	JazanU	Jazan University	www.jazanu.edu.sa
7	JU	Jouf University	https://www.ju.edu.sa/
8	KAU	King Abdulaziz University	https://www.kau.edu.sa/Home.aspx
9	KAUST	King Abdullah University of Science and Technology	https://www.kaust.edu.sa/ar
1	KFUPM	King Fahd University for Petroleum and	http://www.kfupm.edu.sa/Default_en.aspx

#	Acronym	University name	University website
0		Minerals	
11	KFU	King Faisal University	https://www.kfu.edu.sa/sites/Home/
12	KKU	King Khalid University	https://www.kku.edu.sa/en/
13	KSAU-HS	King Saud bin Abdulaziz University for Health Sciences	https://www.ksau-hs.edu.sa/Arabic/Pages/default.aspx
14	KSU	King Saud University	https://www.ksu.edu.sa/
15	MU	Majmaah University	https://www.mu.edu.sa/en
16	NU	Najran University	https://www.nu.edu.sa
17	NBU	Northern Borders University	https://nbu.edu.sa/EN/Pages/default.aspx
18	PSAU	Prince Sattam Bin Abdulaziz University	https://www.psau.edu.sa/en
19	PNU	Princess Nora bint Abdul Rahman University	https://www.pnu.edu.sa/en/pages/home.aspx
20	QU	Qassim University	https://www.qu.edu.sa/
21	SEU	Saudi Electronic University	https://seu.edu.sa/
22	SU	Shaqra University	https://www.su.edu.sa/ar
23	Taibah U	Taibah University	https://taibahu.edu.sa/Pages/AR/Home.aspx
24	TU	Taif University	https://www.tu.edu.sa/
25	UQU	Umm AlQura University	https://uqu.edu.sa/
26	UB	University of Bisha	https://www.ub.edu.sa
27	UoH	University of Hail	http://www.uoh.edu.sa/Pages/default.aspx
28	UJ	University of Jeddah	https://www.uj.edu.sa/
29	UT	University of Tabuk	https://www.ut.edu.sa/ar/Pages/default.aspx
Private Sector			
30	YU	Al Yamamah University	https://yu.edu.sa/?lang=ar
31	AU	Alfaisal University	https://www.alfaisal.edu/en/
32	UM	Almaarefa University	https://www.um.edu.sa
33	AOU	Arab Open University	http://www.arabou.edu.sa/Pages/default.aspx

#	Acronym	University name	University website
34	DAU	Dar Al Uloom University	https://dau.edu.sa/
35	DAH	Dar Al-Hekma University	https://www.dah.edu.sa/en/Pages/default.aspx
36	EU	Effat University	https://www.effatuniversity.edu.sa/English/Pages/default.aspx
37	FBSU	Fahad bin Sultan University	http://www.fbsu.edu.sa/
38	UoM	Mustaqbal University	https://www.uom.edu.sa
39	PMU	Prince Mohammad Bin Fahd University	https://www.pmu.edu.sa/
40	PSU	Prince Sultan University	https://www.psu.edu.sa/en
41	REU	Riyadh Elm University	https://www.home.riyadh.edu.sa
42	SAU	Suliman Alrajhi University	https://sr.edu.sa/site/en/home/
43	UBT	University of Business and Technology	https://www.ubt.edu.sa/About/Home
44	UPM	University of Prince Mugrin	https://www.upm.edu.sa/ar

Automatic Heuristic Evaluation Tools

Heuristic evaluation is a method used to assess the usability of a website or application based on a set of predefined principles (Roy et al., 2014). Heuristic accessibility evaluation can be done manually and involves experts, or can be done automatically through the use of automatic heuristic accessibility evaluation tools. Several heuristic evaluation tools were developed to reduce manual processes and capture more defects in a short time. However, the effectiveness of identifying accessibility violations varies between these tools.

According to Alotaibi et al. (2020), the use of multiple heuristic evaluation tools can identify a greater number of accessibility issues and provide more reliable results in accessibility evaluations. Therefore, to identify the violations of the WCAG principles, we used three widely used evaluation tools, namely, A Checker[1], TAW[2], and WAVE[3],

- **A Checker** is an open-source accessibility tool that offers accessibility evaluation to be performed against various guidelines such as US Section 508, WCAG 1.0, and WCAG 2.0 (Level A, AA, AAA). Moreover, it provides HTML and CSS validators. It produces three types of outcomes: Known Problems, Likely Problems, and Potential Problems.

[1] https://achecker.achecks.ca/checker/index.php
[2] https://www.tawdis.net/.
[3] https://wave.webaim.org.

- **TAW** (Web Accessibility Test) is a free online automatic tool for validating the accessibility of web pages that supports HTML, CSS, and JavaScript analysis. It also offers a stand-alone application that is compatible with multiple platforms (i.e., Windows, MacOS, and Linux). TAW assesses the compliance of a web page to WCAG 2.0 and WCAG 2.1 (Level A, AA, AAA) guidelines. It produces three types of accessibility violation results: Problems, Warnings, and Not reviewed.
- **WAVE** is an automatic accessibility evaluation tool that allows users to assess compliance of web pages with WCAG and the US Section 508. It is provided as an online evaluation service and extensions for browsers (Chrome, Firefox, and Microsoft Edge). WAVE presents the accessibility evaluation as a visual representation, which in turn allows users to identify potential accessibility issues: red icons represent accessibility errors and color contrast issues, yellow icons indicate alerts, green icons indicate accessibility features, blue icons indicate structural or navigational elements, and purple icons refer to HTML5 structural elements and ARIA roles, states, or properties.

Results and Discussion

This section describes the results obtained from the three heuristic accessibility evaluation tools, starting with the raw results obtained for all university websites, categorized by level, principle, and issue type as provided by each tool. This is followed by the analysis of the results, addressing three aspects:

1. Violated principles and types of errors, which address the issues related to the four principles of WCAG 2.0 accessibility guidelines: Perceivable, Operable, Understandable, and Robust (POUR).
2. Tool performance, which compares the results found by each automated tool.
3. Website performance, which discusses the issues identified in each website and presents the most common issues.

The raw results are shown in Table 2 for A Checker and TAW and in Table 3 for WAVE, where universities are sorted by total errors according to the first tool used (A Checker). This order is maintained in the following figures for easier comparison.

Table 2. A Checker and TAW results by level and by principle

#	University	A Checker								TAW							
		Level			Total	Principle				Level			Total	Principle			
		A	AA	AAA		P	O	U	R	A	AA	AAA		P	O	U	R
Public Sector																	
22	SU	2	0	0	2	0	0	2	0	23	0	59	82	13	62	4	3
2	HBU	3	0	0	3	0	1	2	0	1	0	0	1	0	0	1	0
14	KSU	6	6	0	12	5	7	0	0	24	0	21	45	15	25	0	5
23	TaibahU	17	3	0	20	11	6	3	0	30	0	7	37	13	14	4	6
15	MU	21	1	0	22	19	2	1	0	216	0	4	220	47	19	3	151
9	KAUST	19	7	0	26	4	20	2	0	63	0	24	87	21	47	2	17
11	KFU	12	15	1	28	22	4	2	0	211	0	45	256	32	47	4	173
29	UT	25	6	0	31	16	13	2	0	239	0	1	240	100	27	42	71
1	BU	6	17	12	35	30	3	2	0	88	0	70	158	31	119	2	6
26	UB	34	14	0	48	38	6	3	1	55	0	31	86	21	39	1	25
24	TU	15	34	4	53	40	8	4	1	22	0	16	38	7	21	2	8
5	IUM	14	44	0	58	51	6	1	0	54	0	18	72	30	31	2	9
28	UJ	49	0	11	60	35	21	4	0	40	0	1	41	13	22	2	4
25	UQU	6	55	0	61	54	5	2	0	EA	EA	EA		EA	EA	EA	EA
3	IAU	84	2	0	86	72	7	6	1	EA	EA	EA		EA	EA	EA	EA
16	NU	35	57	0	92	83	6	3	0	70	0	37	107	43	47	1	16
13	KSAU-HS	86	4	16	106	58	45	3	0	239	0	8	247	75	130	3	39
18	PSAU	103	3	0	106	101	4	0	1	1	0	0	1	0	0	1	0
8	KAU	24	13	79	116	104	12	0	0	18	0	7	25	3	20	0	2
6	JazanU	123	0	0	123	120	0	2	1	69	0	62	131	21	62	2	46
12	KKU	19	108	0	127	114	13	0	0	1	0	0	1	0	0	1	0
19	PNU	46	80	5	131	112	10	8	1	69	0	13	82	20	22	7	33
27	UoH	124	7	1	132	121	10	0	1	66	0	26	92	28	51	1	12
20	QU	50	77	16	143	115	25	3	0	134	0	18	152	42	80	7	23
10	KFUPM	89	37	19	145	126	15	3	1	123	0	15	138	31	29	2	76
4	IMAMU	128	33	4	165	137	22	5	1	158	0	8	166	53	36	8	69

#	University	A Checker								TAW							
		Level			Total	Principle				Level			Total	Principle			
		A	AA	AAA		P	O	U	R	A	AA	AAA		P	O	U	R
21	SEU	114	108	4	226	178	38	9	1	97	0	10	107	21	62	14	10
17	NBU	258	1	1	260	233	20	6	1	264	0	28	292	39	44	3	206
7	JU	812	0	0	812	788	12	11	1	376	0	57	433	129	88	7	209
Private Sector																	
44	UPM	12	0	0	12	6	6	0	0	26	0	3	29	9	8	3	9
42	SAU	0	18	0	18	16	2	0	0	54	0	20	74	5	36	0	33
32	UM	21	0	0	21	7	14	0	0	54	0	37	91	7	51	1	32
38	UoM	11	24	0	35	24	11	0	0	74	0	29	103	28	37	1	37
40	PSU	23	19	0	42	30	9	2	1	50	0	18	68	16	26	2	24
37	FBSU	11	14	22	47	38	8	1	0	25	0	1	26	2	17	2	5
31	AU	36	14	0	50	30	14	5	1	41	0	11	52	8	27	3	14
30	YU	47	12	1	60	35	25	0	0	92	0	35	127	48	75	0	4
41	REU	35	21	12	68	48	17	2	1	106	0	33	139	28	58	3	50
36	EU	70	0	0	70	28	39	3	0	86	0	90	176	57	103	2	14
35	DAH	54	44	1	99	54	38	6	1	89	0	40	129	12	78	4	35
39	PMU	21	73	33	127	112	12	3	0	117	0	11	128	12	23	5	88
33	AOU	29	129	0	158	143	14	1	0	40	0	7	47	17	21	3	6
34	DAU	258	10	2	270	259	8	2	1	99	0	14	113	54	38	5	16
43	UBT	NM	NM	NM		NM	NM	NM	NM	GT	GT	GT		GT	GT	GT	GT
EA: Error in Analysis GT: Gateway Time-out NM: Not enough Memory																	

Table 3. WAVE results by type

#	University	WAVE					
		Errors	Contrast Errors	Alerts	Features	Struc. Elements	HTML5 & ARIA
Public Sector							
22	SU	32	101	275	82	45	12
2	HBU	2	76	52	2	33	11
14	KSU	23	63	61	44	147	167
23	TaibahU	18	11	56	38	86	36
15	MU	22	0	102	21	67	20
9	KAUST	40	69	1	124	30	193
11	KFU	15	43	29	11	42	27
29	UT	67	65	134	28	128	17

#	University	WAVE					
		Errors	Contrast Errors	Alerts	Features	Struc. Elements	HTML5 & ARIA
1	BU	16	48	152	86	102	15
26	UB	44	37	141	8	95	117
24	TU	14	3	34	25	42	4
5	IUM	17	32	12	20	87	36
28	UJ	18	159	24	11	89	6
25	UQU	15	26	28	16	93	342
3	IAU	29	11	17	32	25	24
16	NU	19	10	56	35	29	46
13	KSAU-HS	51	56	47	11	83	205
18	PSAU	6	11	12	12	22	134
8	KAU	24	1	7	4	15	0
6	JazanU	46	21	137	161	121	324
12	KKU	16	6	24	19	37	24
19	PNU	80	55	113	29	93	107
27	UoH	15	13	26	5	75	10
20	QU	17	65	11	9	18	1
10	KFUPM	144	10	242	82	12	28
4	IMAMU	24	11	54	14	63	46
21	SEU	23	8	66	17	54	5
17	NBU	133	8	19	5	44	6
7	JU	14	5	14	19	52	11
Private Sector							
44	UPM	9	40	44	27	54	35
42	SAU	84	1	162	322	108	606
32	UM	41	94	37	75	172	241
38	UoM	4	4	20	16	67	47
40	PSU	14	154	16	36	68	8
37	FBSU	28	6	55	68	36	38
31	AU	61	8	54	67	74	73
30	YU	8	4	15	42	56	55
41	REU	73	16	26	34	151	85
36	EU	33	19	12	33	138	11
35	DAH	71	4	55	79	48	177
39	PMU	29	36	55	63	64	114
33	AOU	18	99	37	47	39	100
34	DAU	50	24	56	30	116	210
43	UBT	420	16	466	109	1361	638

The evaluation results revealed that none of the 44 Saudi university websites passed the accessibility evaluation, without any known errors or problems using A Checker, TAW, and WAVE. Since Level A is the basic level, it is expected to find more errors at that level than at the following levels. But one can also see a variation in the number of errors detected by A Checker and TAW at those levels. The A Checker results show that webpages failed the accessibility evaluation with an average of 68.26 (Level A), 24.95 (Level AA), and 5.23 (Level AAA) known errors. In comparison, the TAW evaluation tool shows that the average number of problems was 88.19 (Level A), 0 (Level AA), and 22.26 (Level AAA) known errors. Yet the average of total errors for all levels for A Checker and TAW was 100.14 and 113.15, respectively.

0 2 shows the results of A Checker and TAW by level. It is noteworthy to see the variation in the results produced by the two tools. The results obtained by WAVE are not categorized by level and are therefore not directly compared to the results of A Checker and TAW. Yet, one can see further variation in the number of issues detected for each university by the different tools (see Figure 3). The average number of errors and contrast errors is 43.80 and 35.20, respectively.

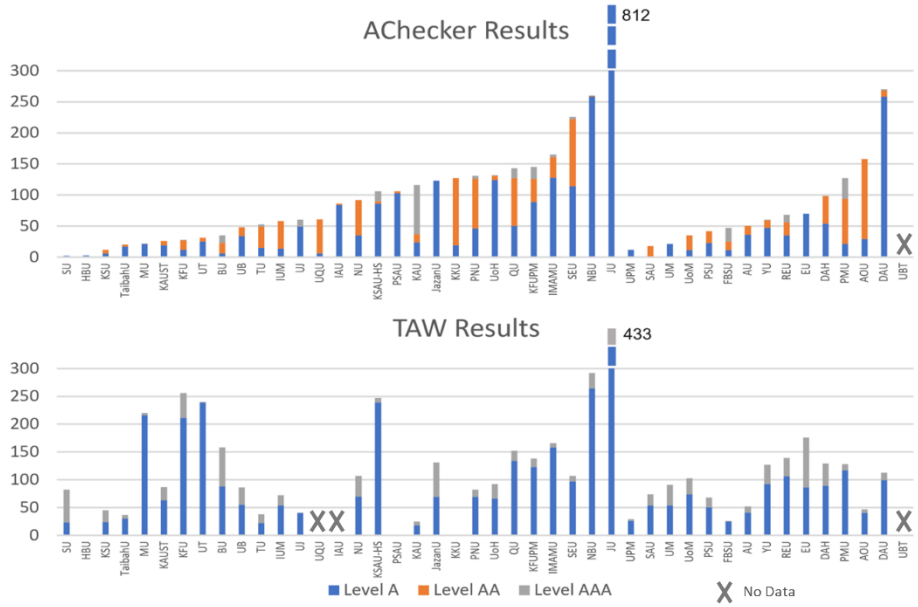

Figure 2. Comparison of Universities' A Checker and TAW results by level

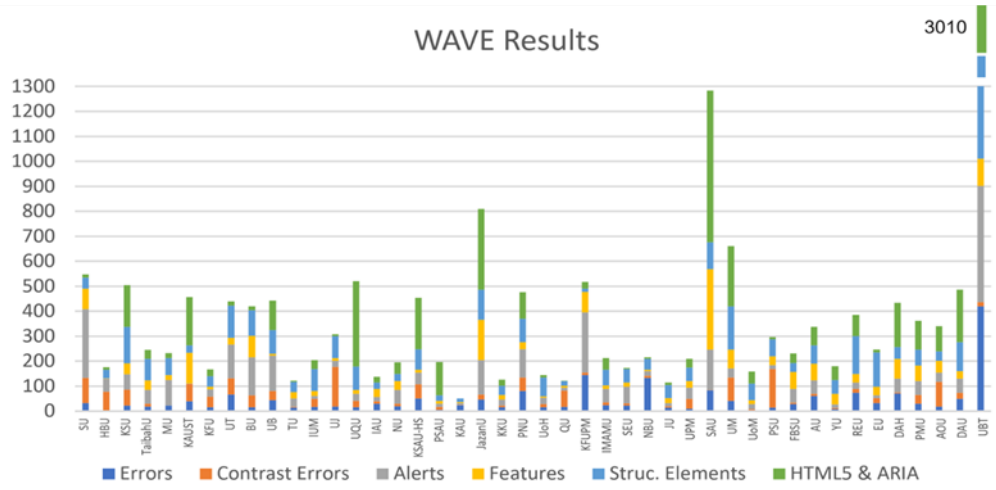

Figure 3. Universities' WAVE results

Violated WCAG principles

In this section, we summarize and discuss the identified errors based on the four violated WCAG principles (POUR).

0 4 visualizes the content of Table 2 related to principles. Similar to Figure 2, one can see the variation in the results produced by the two tools, but this time across principles. Blue, representing Perceivable, is very dominant in the A Checker results and constitutes 84% of the total number of errors, whereas the same principle constitutes only roughly 25% of TAW results (see 0 5). A Checker accounts for almost no errors in the Robust principle, whereas in TAW, it accounts for 34.19%.

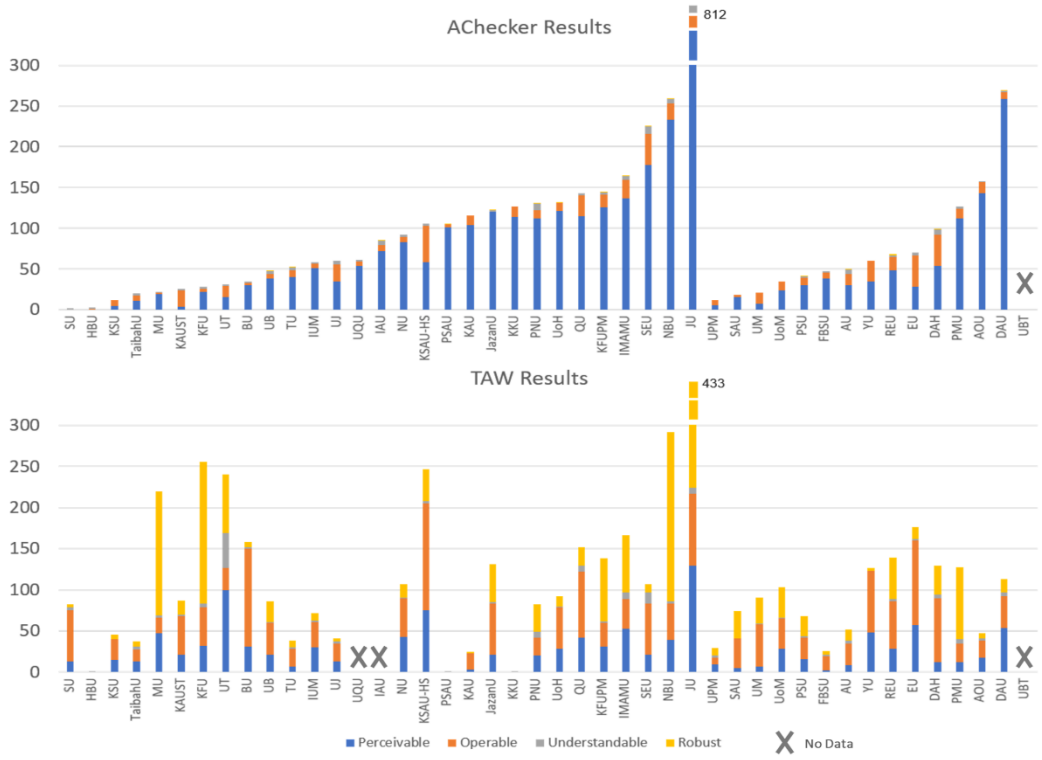

Figure 4. Comparison of Universities' A Checker and TAW results by principle

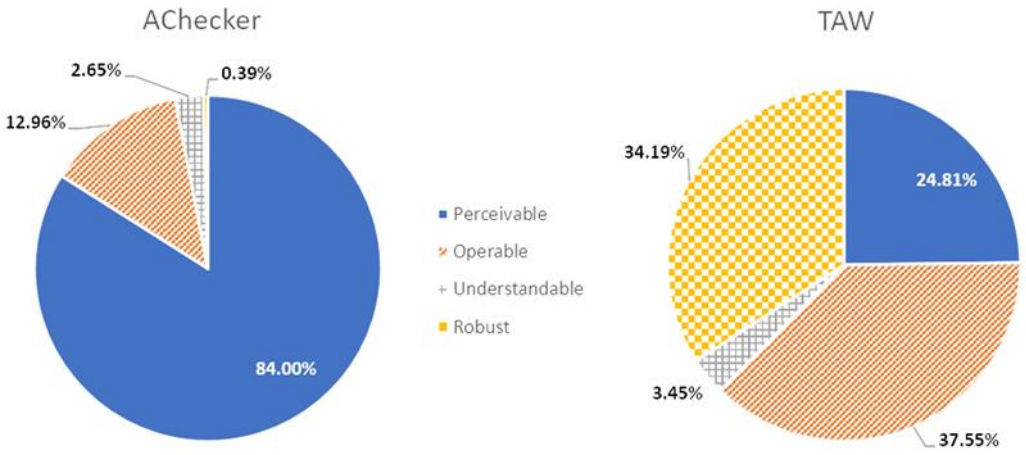

Figure 5. Distribution of A Checker and TAW results by principle

Table 4. Types of errors detected by A Checker, in descending order for each level

WCAG Principle	Error	Total
Level A		
P	img element missing alt attribute	1868
O	Anchor contains no text.	505
P	Image used as anchor is missing valid Alt text	296
U	Label text is empty.	90
P	input element type of "text" missing an associated label.	55
P	input element type of "text" has no text in label	39
P	Image used for input element is missing Alt text.	21
P	select element missing an associated label	20
R	id attribute is not unique.	17
U	Right to left reading order not marked or marked incorrectly	9
U	Document has invalid language code	9
P	textarea element missing an associated label.	8
U	Document language not identified	5
P	input element type of "checkbox" has no text in label.	2
O	Document missing title element.	1
P	input element type of "password" missing an associated label	1
O	script not keyboard accessible - onmouseout missing onblur	1
U	input element has more than one associated label	1
P	input element type of "password" has no text in label	1
P	input element has alt attribute	1
P	Form missing fieldset and legend to group multiple radio buttons.	1
O	onmouseover event handler missing onfocus event handler	1
Level AA		
P	i (italic) element used.	917
P	The contrast between the colour of text and its background for the element is not sufficient to meet WCAG2.0 Level AA	86
P	b (bold) element used	43
O	Header nesting - header following h2 is incorrect.	31
P	The contrast between the colour of selected link text and its background is not sufficient to meet WCAG2.0 Level AA	14
O	Header nesting - header following h3 is incorrect	11
O	Header nesting - header following h1 is incorrect.	7
O	Header nesting - header following h4 is incorrect.	1
Level AAA		
P	The contrast between the colour of text and its background is not sufficient to meet WCAG2.0 Level AAA.	174
P	The contrast between the colour of selected link text and its background is not sufficient to meet WCAG2.0 Level AAA	37
P	The contrast between the colour of active link text and its background is not sufficient to meet WCAG2.0 Level AAA	15
P	Link text colour must provide high contrast with its background colour	15
P	The contrast between the colour of visited link text and its background is not sufficient to meet WCAG2.0 Level AAA	3

Table 4 shows a listing of the types of errors produced by A Checker sorted for each level.

At Level A, errors in the Perceivable principle are the highest among all three WCAG levels, accounting for 78.4% of Level A known problems. The top five perceivable errors in Level A are (1) “img element missing alt attribute” which indicates that images do not have alternative text descriptions of their contents, (2) “Image used as anchor is missing valid Alt text” refers to the existence of image that is used as a link without providing alternative text to describes the link destination, (3) “input element type of "text" missing an associated label” which indicates that an associated label for an input element with a type of text is missing, (4) “input element type of "text" has no text in label” refers to the exitance of the input element type of text without the text in its associated label, and finally (5) “Image used for input element is missing Alt text” indicates that an input element with a type of image lacks alternative descriptive text.

At Level AA, errors in the perceivable principal errors constitute 95.5% of the total errors at Level AA, lying within 4 elements. They include “i (italic) element used”, and “b (bold) element used”. If the use of the <i> element and <b> element was meant for emphasis, then they should have been substituted with elements like or since these can be handled by screen readers by changing the tone or volume when reading, whereas italics and bold are not pronounced differently from other text by screen readers. The third and fourth error elements at Level AA were “The contrast between the colour of text and its background for the element is not sufficient to meet WCAG2.0 Level AA” and “The contrast between the colour of selected link text and its background is not sufficient to meet WCAG2.0 Level AA”.

At Level AAA, 100% of errors are in the perceivable principal. They were due to ignoring acceptable contrast ratios between the color of the background and the color of each of the following: text, selected links, active links, link text, and visited links.

These results indicate that websites have major obstacles where their contents cannot be perceived by some of their users and that many of the errors are as simple as providing alternative text to images or input fields.

Table 5. Types of errors detected by TAW, in descending order for each level

WCAG Principle	Error	Total
Level A		
R	Parsing	1428
O	Link Purpose (In Context)	807
P	Non-text Content	753
P	Info and Relationships	398
R	Name Role Value	158
U	Labels or Instructions	110
U	Language of Page	29
U	On Input	18
U	Consistent Navigation	2
O	Timing Adjustable	1
Level AAA		
O	Link Purpose (Link Only)	553
O	Section Headings	255
O	Keyboard (No Exception)	125
U	Change on Request	1
O	Interruptions	1

Table 5 shows a listing of the types of errors produced by TAW sorted for each level.

As stated before, none of the evaluated websites exhibit issues in Level AA. However, 42.8% of Level A errors were in the robust principle attributed to “Parsing” and “Name Role Value”, and 99.9% of Level AAA errors were in the operable principle attributed to “Link Purpose (Link Only)”, “Section Headings”, “Keyboard (No Exception)”, and “Interruptions”. “Parsing” issues indicate possible errors in syntax that could be due to incorrectly nested tags, missing attributes, or other reasons. They could affect how content is displayed in different browsers, potentially leading to broken layouts or unusable interfaces. “Name Role Value” issues could indicate faulty interface components; such failures can significantly hinder the ability of users with disabilities to navigate and interact with the site.

Unfortunately, not all automated heuristic evaluation tools report the errors categorized based on the WCAG principles and levels; WAVE is one of them. Thus, we have tried to manually map the violation errors to the WCAG principles. Table 6 shows the types of errors detected by WAVE, where the first two errors (low contrast and missing alternative text) make up 63% alone of the errors listed. It should be noticed that both belong to the Perceivable principle.

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Table 6. Types of errors detected by WAVE, in descending order

WCAG Principle	Error	Total
P	Very low contrast	1549
P	Missing alternative text	644
O	Empty link	470
P and O	Linked image missing alternative text	409
P, and O	Empty button	101
P, O, and U	Missing form label	96
P and R	Broken ARIA reference	73
O and R	Broken ARIA menu	65
P and O	Empty heading	53
U	Language missing or invalid	7
P and O	Image button missing alternative text	5
P and O	Image map area missing alternative text	2
P, O, and U	Empty form label	2

Tool performance

Although the way of producing results is different between all the used tools (A Checker, TAW, and WAVE), A Checker and TAW are similar in providing assessment to WCAG principles and levels, in contrast with WAVE, which doesn't provide specific results for the principles and levels. Therefore, in this section, we focus on the performance analysis for A Checker and TAW, where they can be compared.

Regarding the tool's performance on error detection based on WCAG levels, and as shown previously in Figure 2, we can see from the analysis that the performance of A Checker and TAW tools differed. TAW detected problems at the A and AAA levels, but did not detect any at the AA level. In contrast, A Checker detected errors in all levels. Figure 6 shows a comparison between A Checker and TAW based on total detected errors at each WCAG level across all websites.

Additionally, A Checker and TAW also performed differently regarding the WCAG principles, as was shown in **Error! Reference source not found.** 4 previously. According to TAW results, the most violated principle by the examined websites was Operable with 1742 errors, whereas from A Checker results, we can see that the most violated principle was Perceivable with 3617 total errors. Figure 6 shows a comparison between A Checker and TAW based on total detected errors for each WCAG principle. These differences may be due to the fact that the tools evaluate different aspects of website accessibility and emphasize different principles and guidelines.

It is worth noting that A Checker was unable to evaluate the accessibility of one website (UBT#43) because of its HTML size, whereas TAW was unable to evaluate 3 websites (IAU#3, UQU#25, and UBT#43) due to gateway time-out and error in analysis. Yet WAVE was able to evaluate all websites, including that of UBT#43.

It is equally important to note that the number of errors detected by each tool varied by website, WCAG levels, and principles. These differences indicate that different tools have different limitations depending on the specific characteristics of the websites being evaluated and that different tools may be better suited to evaluating different types of websites. Therefore, while the results of A Checker, TAW, and WAVE provide valuable insights into the accessibility of the Saudi university websites, it is important to employ different tools to increase the effectiveness of the accessibility evaluation, as suggested in (Semantic Scholar (2023)). By using multiple tools and comparing their results, web developers, designers, and administrators can gain a more comprehensive understanding of the accessibility of their websites and identify areas for improvement.

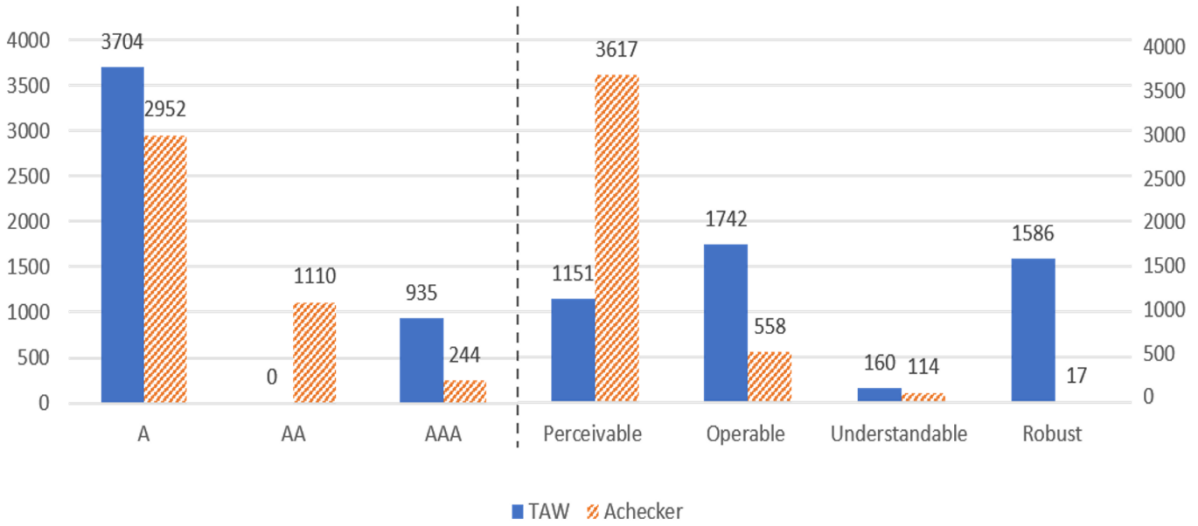

Figure 6. Comparison of the total number of errors detected by TAW and A Checker

Website performance

Since we evaluated a large number of websites, we couldn't examine each website's performance individually. Therefore, this section discusses the issues identified in the websites that have the highest or lowest number of errors in each principle and level.

As it is clear from the analysis results, none of the Saudi university websites passed the WCAG evaluation without any known errors and problems using all the tools (A Checker, TAW, and WAVE). Furthermore, the most repeated errors were image element missing alt attribute, Parsing, and very low contrast according to A Checker, TAW, and WAVE, respectively. However, it is important to acknowledge the limitations of automated accessibility evaluation tools. These tools may not assess all WCAG guidelines comprehensively, and there is a possibility of false positives or false negatives, which can create a false impression about the effectiveness of these tools in evaluating accessibility.

Therefore, while the analysis results provide valuable insights, they should be interpreted with caution.

According to Table 2, we can see that the websites of SU#22 and HBU#2 have the lowest errors with 2 and 3 errors, respectively, according to A Checker, whereas TAW results show that HBU#2, KKU#12, and PSAU#18 have the lowest errors of all levels with only one error. Meaning that HBU#2 has the lowest errors when combining A Checker and TAW results. Their issues were mainly in the Understandable principle. But notice that SU#22 shows 82 errors according to TAW, and PSAU#18 and KKU#12 show 106 and 122 errors, respectively, according to A Checker. This is just to illustrate the variation in results by the tools.

In contrast, the website of JU#7 has the highest errors with 812 (A Checker) and 433 (TAW) errors, and most of them were in level A. Furthermore, we can also notice from the A Checker result that the most violated principle by the website of JU#7 (which has the highest errors) was Perceivable, with 788 errors, while from the TAW results, the most violated principle by the website of JU#7 was the Robust principle, with 209 errors.

Finally, it is important to note that the evaluation of website accessibility in accordance with WCAG involves a multifaceted process influenced by various factors. As stated in the WCAG documentation[1], these factors include the type of website (such as static, dynamic, or mobile), the website's size, complexity, and the technologies employed (e.g., HTML, PDF). It is important to recognize that the size and complexity of a webpage can significantly impact the evaluation process and the number of WCAG violations identified. Larger and more intricate websites tend to have a higher probability of containing accessibility issues due to the increased number of elements, functionality, and content that need to be considered. By acknowledging the relationship between webpage size and complexity with the number of WCAG violations found during an accessibility evaluation, we can better understand the and comparing the accessibility of websites. Therefore, it is possible that the high number of errors detected in a Saudi university website may be partially attributed to the complexity of its content and vice versa. Further research could explore the relationship between website content complexity and accessibility errors in more detail, to guide web developers and designers on how to create accessible websites regardless of content complexity.

[1] https://www.w3.org/WAI/ER/conformance/ED-methodology-20131119

Conclusion

In this paper, we evaluated the compliance of 44 Saudi university websites with WCAG guidelines. Our findings indicate non-compliance across all evaluated websites, particularly with Level A criteria and the Perceivable and Operable principles of WCAG. The analysis offers a bird's-eye view for web developers, designers, and administrators, highlighting areas for improvement. Furthermore, a significant variation in the results provided by the three tools is apparent. Nevertheless, certain conclusions can be drawn regarding the found shortcomings. A majority of errors detected relate to missing alternative text for images or labels to fields, and others, along with parsing errors. Starting with addressing such basic issues will significantly enhance accessibility. The subsequent step involves better use of emphasis and strong tags instead of italics and bold to facilitate more accurate performance by screen readers by allowing raised volume or a different tone. In addition to resolving issues related to color contrast.

In terms of limitations, we recognize that our evaluation focused on the home page of each website, rather than assessing the entire website due to practical constraints, as evaluating the entire website would have required significant time and resources, which is out of the scope of this study. While the home page serves as a representative snapshot of the website's accessibility, it may not capture all potential accessibility issues that could be present on other pages or within specific sections of the website.

For future work, we aim to expand our evaluation scope to include a more comprehensive assessment across multiple pages or specific areas within the websites to gain a deeper understanding of overall accessibility compliance. Additionally, integrating manual expert evaluations alongside automated tools can offer more nuanced insights into compliance with accessibility guidelines.

While adhering to WCAG guidelines is an important aspect of website accessibility, usability testing with VI users and others could provide valuable insights. Due to challenges in conducting such studies, including the recruitment of participants, future studies could benefit from incorporating usability testing to provide a more comprehensive understanding of the accessibility of Saudi university websites.

Additionally, future work will include revisiting some of the university websites to evaluate their visual complexity since it is one of the identifiable measures for designing web pages that are simpler to engage with. And exploring the relationship between website complexity and accessibility errors. Moreover, conducting usability studies for selected university websites with more heuristic evaluation tools and with expert assessments will form part of ongoing research efforts.

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