COMMUNICATION

Accessibility analysis of higher education institution websites of Portugal

Abid Ismail[1] · K. S. Kuppusamy[1] · Sara Paiva[2]

Abstract

The higher education institutions across the globe are steadily increasing their usage of the web platforms to disseminate information to its stakeholders. In this background, it becomes important to make these resources inclusive. An inclusive website of a higher education institution will facilitate seamless access to its resources for Persons with Disabilities (PwDs). This paper presents an accessibility analysis of 59 higher education websites of Portugal. Both Polytechnic (19) and University (40) websites were incorporated into the study.The accessibility analysis is carried out with three major tools: *AChecker, WAVE, and aXe*. With respect to the AChecker tool, the average of known problems was observed almost doubled in Universities than Polytechnic Institution websites of Portugal under all levels of conformance. With respect to WAVE tool, we found that the average of alerts, structural elements, and HTML5 & ARIA in terms of web accessibility status of websites of Polytechnic Institutes are less than the Universities, but contrast errors are found with more frequency in Polytechnic Institutes than in universities, and the average of errors and features are almost the same in both of the cases. Also, we found that the average number of violations and needs of review guidelines as per aXe tool are 50.84 and 21.47 in Polytechnic Institutes' websites and 30.75 and 27.83 in Universities websites belonging to Portugal, respectively. Based on scores obtained by these accessibility analysis tools, the *outliers of accessibility violations* are calculated with respect to websites of Polytechnic Institutes and Universities of Portugal. Moreover, we also suggested and discussed the important clues to solve the accessibility violations of websites along with their issue descriptions among the selected websites in this study. Hence, this analysis report provides the feedback to website administrator and web developers to improve the accessibility evaluation status of these websites.

Keywords Web accessibility · Web evaluation tools · Accessibility issues · Accessible guidelines · Portugal institutes and universities websites · World wide web consortium (W3C) · Statistical inferences

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1 Introduction

Currently, accessibility research is an active area of research due to the huge impact of websites on their usability and accessibility over common people.

According to *Tim Berners Lee*, founder of the World Wide Web, *the power of the web is in its universality. Access by everyone regardless of disability is an essential aspect.*

Accessibility in the News 20th October 2017 defined by *Debra Ruh*, founder of TecAccess, is that *accessibility allows us to tap into everyone's potential.* Also, *Marcus Osterberg*, author of Web Strategy for Everyone[1] defined accessibility in the News 27th October 2017 that *When speaking of disabilities, the blind and their needs are most often used as an example. It is deceivingly simplistic since*

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1 https://webstrategyforeveryone.com/.

accessibility is something most of the population can benefit from.

The modern age is the age of technology based on web resources (Internet) to share information everywhere irrespective of any type of group. With respect to group or groups, the ambition to make websites barrier-free is not limited up to only standards and laws but has been on the agendas of all governments and public agencies sometimes. As per World Report on disability (WRD), there are more than 1 billion means corresponding to 15% world population that have some form of disability [25]. So, bringing the people whether connected (abled) or unconnected (disabled) under the same umbrella is the main motive of universality.

To achieve universality of websites successfully, World Wide Web Consortium (W3C) has framed various types of guideline standards or classifications to make the web resources universally acceptable. The W3C proposed various types of guideline standards namely Web Content Accessibility Guidelines (WCAG 1.0 and 2.0), Authoring Tool Accessibility Guidelines (ATAG) 2.0, WAI-ARIA 1.0, UAAG, etc., for web accessibility evaluations.

The WCAG 2.0 guidelines are a stable and referenceable technical standard. It consists of Twelve (12) guidelines categorized under four principles abbreviated as *POUR* stands for Perceivable, Operable, Understandable and Robust. Each principle in POUR have 4, 4, 3, 1 guidelines, respectively, and each guideline has corresponding testable success criteria.[2] The corresponding detail of these guidelines are presented in Sect. 4.

Therefore, in this study, we focused to check the accessibility evaluation of Polytechnic Institutes and Universities of Portugal websites. There are nineteen (19) and forty (40) websites Polytechnic Institutes and Universities in Portugal, respectively, as a source of data was chosen for our accessibility analysis.

The remainder of this paper is organized as follows: The objectives of the paper are provided in Sect. 2. Background of the literature, which is performed by different researchers in terms of accessibility and readability of websites, is presented in Sect. 3. Measurement of websites in terms of accessibility guidelines is discussed in Sect. 4. In Sect. 5, we provide the tools which are used for analysis of these websites and their results obtained during the evaluation process. The said reports are explored in Sect. 6 statistically. Section 7 provides some useful suggestions and discussion points to solve the issues of accessibility and readability of websites. Finally, we conclude our study in Sect. 8 along with future directions of the research.

2 Objectives

The primary objective of this study is to highlight the necessary steps that need to be taken to improve the accessibility of websites. Following are the detailed objectives of the paper, which are:

1. To analyze Higher Education Institution websites of Portugal in terms of accessibility.
2. To find the major obstacles faced by websites, which become the barriers to the achievement of the web accessibility successfully.
3. To find the problems and warnings in terms of W3C guidelines under WCAG 2.0 Levels.
4. To find the trend on how to increase accessibility and usability of the websites.
5. To provide some useful suggestions based on the study to website administrators and web developers, how to make the web pages accessible for all.

3 Review of literature

In this section, we briefly explain the related work corresponding to the accessibility of websites and the evaluation tools used so far.

An empirical study on accessibility and usability evaluation of online government services was conducted by Al-Faries et al. [2] in Saudi Arabia. They conducted accessibility based on W3C-WCAG 2.0 guidelines and usability based on expert reviews. They found that there are one or more accessibility violations, and the usability testing is usable and well designed as per citizen among the top e-government services in Saudi. Thus, there is a little need to work further to make the e-government services more usable and accessible to citizens of Saudi.

Kamal et al. [15] carried out an accessibility evaluation study of 36 Jordanian universities and education institutes websites. They used different automatic evaluation tools for the measurement of these websites. The result found that there are significant weaknesses among university websites and also the guideline variations when used with different accessibility evaluation tools for the measurement of websites.

An exploratory study on 302 websites of Indian Universities was carried out by Ismail et al. [11], based on both accessibility and readability. They used online automatic evaluation tools and found that there are major accessibility violations. Also, they found 13.22 Gunning fog index score falls in *College Freshman* by grade. They provide some useful suggestions to enhance the accessibility and readability score of websites.

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[2] https://www.w3.org/WAI/intro/wcag.php.

Researchers like Goodwin et al. [9] present the global analysis of the web accessibility of national government portals of 192 UN member states. The calculated result is in the percentage of accessibility barriers, and these barriers exist for all evaluated member states. They found that there is a substantial correlation between anti-disability discrimination laws and the reached accessibility scores.

In the country, India, the accessibility and readability evaluation of different states of government websites was carried out by researchers like [10, 12, 13]. During the evaluation processes of websites, they used different automatic evaluation tools such as AChecker, WAVE, Tenon, Alexa, Evalaccess, Cynthia Says, Hera, Mauve, etc. The formulas used for readability are Flesh Kincaid Reading Ease, Flesh Kincaid Grade Level, Gunning Fog Score, SMOG Index, Coleman Liau Index, Automated Readability Index, etc. From this study [10, 12, 13], the result found that there is still a lack of accessibility and readability components among the websites. The websites need to be improved by proper training and awareness programs to all types of people, which are involved in the whole process of accessibility and readability.

A study was carried out by Alahmadi et al. [3] on top-ranked university websites of the World, Oceania and Arab categories. They used AChecker tool for checking the accessibility of Home, admission and course description web pages belonging to websites of the World, Oceania and Arab categories. The result revealed a total of 30, 944 accessibility-related home page errors among the 180 evaluated web pages. Moreover, they found that there is no significant difference between accessibility errors and type of web pages in the accessibility domain.

An assessment study of web content accessibility levels of Spanish educational websites was performed by Roig-Vila et al. [23] by using TAW automatic analysis tool. They used the TAW tool for assessed 42 samples at two different depth levels of 21 educational websites. The result of Spanish educational websites does not match with levels of conformance requirements: that is, 97.62% under Level A, 54.76% under Level AA and over 50% under Level AAA of websites. The result found that the practical implementation remains unsatisfactory despite highly increasing number of accessibility measurement tools used.

In India, almost all government organizations adopted e-governance services, and its successful implementation in government organizations was carried out by Barua [4]. Furthermore, to provide governmental services electronically usually over the Internet called e-governance [20] involves the active participation of people affects the transparency and ease of access to services.

In addition, the researchers like [1, 5–8, 14, 16–19, 21, 22, 24], etc., throughout the world are keen to carried out the work to make the web pages universally accessible and readable for all. They evaluate or measured websites or web pages in terms of different parameters, involving the components like accessibility, usability, and readability of web pages or websites by using different automatic evaluation-cum-estimation tools and techniques.

Assessments of websites involving accessibility, readability, ranking, etc., and their practical applications to achieve universality of the web in spite of increasingly high number of assessments still remains unsatisfactory.

4 Evaluation guidelines

The aim of websites measurement is to provide the report along with feedback and proper suggestions to website developers and designers or website administrators on how to make the web pages universally accessible and the contents according to the level of human understanding.

For website accessibility, we used a current version of WCAG called WCAG 2.0 for our evaluation process. There is a total of 12 Guidelines of WCAG 2.0 with four principles—*(P, O, U, R)* are as under:

1. **Principle-P** stands Perceivable (out of 12 guidelines, only 4 comes under this principle). These are as:

   (a) P-1.1 called text alternative guidelines.
   (b) P-1.2 called time based media guidelines.
   (c) P-1.3 called adaptable guidelines.
   (d) P-1.4 called distinguishable guidelines.

2. **Principle-O** stands Operable (out of 12 guidelines, only 4 comes under this principle). These are as:

   (a) O-2.1 called keyboard accessible guidelines.
   (b) O-2.2 called enough Time guidelines.
   (c) O-2.3 called seizures guidelines.
   (d) O-2.4 called navigable guidelines.

3. **Principle-U** stands Understandable (out of 12, only 3 guidelines comes under this principle). These are as:

   (a) U-3.1 called readable guidelines.
   (b) U-3.2 called predictable guidelines.
   (c) U-3.3 called input assistance guidelines.

4. **Principle-R** stands Robust (out of 12, only 1 guideline comes under this principle). The said guideline is as:
   (a) R- 4.1 called compatible guidelines.

This grouping of guidelines WCAG 2.0 among principles is also called (4, 4, 3, 1) classification.

Based on these guidelines, there are different tools used for web pages or website evaluation processes. We are using

Table 1 List of URLs of polytechnic institutes of Portugal with IDs

List of polytechnic institutes of Portugal

ID	Name of polytechnic institutes	URLs
P1	Instituto Politécnico de Viana do Castelo	http://www.ipvc.pt
P2	Instituto Politécnico de Beja	http://www.ipbeja.pt/
P3	Instituto Politécnico de Bragança	http://portal3.ipb.pt/index.php/pt
P4	Instituto Politécnico de Castelo Branco	http://www.ipcb.pt
P5	Instituto Politécnico do Cávado e do Ave	https://ipca.pt
P6	Instituto Politécnico de Coimbra	http://www.ipc.pt
P7	Instituto Politécnico da Guarda	http://www.ipg.pt
P8	Instituto Politécnico de Leiria	http://www.ipleiria.pt
P9	Instituto Politécnico de Lisboa	http://www.ipl.pt
P10	Instituto Politécnico de Portalegre	http://www.ipportalegre.pt
P11	Instituto Politécnico do Porto	http://www.ipp.pt
P12	Instituto Politécnico de Santarém	http://www.ipsantarem.pt
P13	Instituto Politécnico de Setúbal	http://www.ips.pt
P14	Instituto Politécnico de Tomar	http://www.ipt.pt
P15	Instituto Politécnico de Viseu	http://www.ipv.pt
P16	CESPU - Instituto Politécnico de Saúde do Norte	https://www.cespu.pt/pos-graduacoes/entidades-parceiras/instituto-politecnico-de-saude-do-norte-vale-do-sousa-(ipsn-vs)/
P17	Instituto Superior Politécnico Gaya	http://www.ispgaya.pt/site/
P18	ISLA - Instituto Politécnico de Gestão e Tecnologia	http://www.islagaia.pt/pt/
P19	Instituto Politécnico da Maia	http://www.ipmaia.pt/pt

the most popular evaluation tools to evaluate the Polytechnic Institutes and Universities websites of Portugal in this study as in Sect. 5.

5 Accessibility analysis methods

In 2017–2018, we have collected 19 websites of Polytechnic Institutes and 40 websites of Universities of Portugal. And, their IDs, name, and URLs are presented in Tables 1 and 2, respectively. In this web accessibility analysis, we are using three automatic evaluation tools such as, *AChecker*,[3] *WAVE tool*,[4] and *aXe*.[5]

The AChecker tool based on WCAG 2.0 is used for evaluating all selected websites under all levels of conformance, namely Level A (sets the minimum (lowest) level of accessibility guidelines), Level AA (sets the mid-range level of accessibility guidelines), and Level AAA (sets the highest level of accessibility guidelines). Conformance means the

requirements to satisfy the success criteria at higher levels that is conformance at lower levels. Such as Level A conformance of webpage satisfies all the level A success criteria, Level AA conformance of webpage satisfies all the Level A and Level AA success criteria and the Level AAA conformance of webpage satisfies all the Levels A, AA, and AAA success criteria.

WAVE tool[6] used to evaluate the websites in terms of detection of number of errors, number of alerts, number of features and structural elements, number of HTML5 and ARIA, and contrast errors; the Chrome extension tool called *aXe*[7] is used for checking accessibility issues on the page in the current state of the web pages.

Furthermore, 18 URLs out of 19 Polytechnic Institutes of Portugal are evaluated by using WAVE and aXe tools. But, in AChecker evaluation tool all 19 URLs are evaluated. Also, out of 40 University websites of Portugal, only 38 URLs are evaluated in AChecker tool, whereas in WAVE and aXe tools all 40 University websites of Portugal are evaluated.

[3] https://achecker.ca/checker/index.php.

[4] https://wave.webaim.org/.

[5] https://www.deque.com/products/axe/.

[6] https://wave.webaim.org/.

[7] https://www.deque.com/products/axe/.

Table 2 List of universities of Portugal along with URLs and IDs

List of universities of Portugal

| ID	Name of universities	URLs
U1	Escola Superior Artística do Porto	http://www.esap.pt
U2	Escola Superior Gallaecia	https://esg.pt
U3	Escola Universitária das Artes de Coimbra	http://uniarea.com/directory/institution/escola-universitaria-das-artes-de-coimbra
U4	Escola Universitária Vasco da Gama	http://www.euvg.pt
U5	Instituto Superior de Ciências da Saúde Egas Moniz	http://www.egasmoniz.com.pt/pt-pt.aspx
U6	Instituto Superior de Estudos Interculturais e Transdisciplinares – Almada	https://www.ipiaget.org/faculdade/17
U7	Instituto Superior de Estudos Interculturais e Transdisciplinares – Viseu	https://www.ipiaget.org/faculdade/11
U8	Instituto Superior de Gestão	http://www.isg.pt
U9	Instituto Superior de Serviço Social do Porto	https://www.isssp.pt/isssp/si_main
U10	Instituto Superior Manuel Teixeira Gomes	http://www.ismat.pt/pt/
U11	Instituto Superior Miguel Torga	http://www.ismt.pt
U12	Instituto Universitário da Maia – ISMAI	http://www.ismai.pt/pt
U13	Instituto Universitário de Ciências da Saúde	https://www.cespu.pt/ensino/ensino-universitario/
U14	ISCTE - Instituto Universitário de Lisboa	https://www.iscte-iul.pt
U15	ISPA - Instituto Universitário de Ciências Psicológicas, Sociais e da Vida	http://www.ispa.pt/pagina/ispa-instituto-universitario-de-ciencias-psicologicas-sociais-e-da-vida
U16	Universidade Aberta	http://portal.uab.pt
U17	Universidade Atlântica	https://www.uatlantica.pt
U18	Universidade Autónoma de Lisboa Luís de Camões	http://autonoma.pt/pt/home.asp
U19	Universidade Católica Portuguesa	http://www.ucp.pt/site/custom/template/ucptplportalhome.asp?sspageid=1&lang=1
U20	Universidade da Beira Interior	http://www.ubi.pt
U21	Universidade da Madeira	http://www.uma.pt
U22	Universidade de Aveiro	http://www.ua.pt
U23	Universidade de Coimbra	http://www.uc.pt
U24	Universidade de Lisboa	https://www.ulisboa.pt/
U25	Universidade de Trás-os-Montes e Alto Douro	http://www.utad.pt/vEN/Pages/HomepageUtad.aspx
U26	Universidade de Évora	http://www.uevora.pt/
U27	Universidade do Algarve	https://www.ualg.pt/en
U28	Universidade do Minho	https://www.uminho.pt/EN
U29	Universidade do Porto	https://sigarra.up.pt/up/pt/ web_base.gera_pagina?p_pagina=home
U30	Universidade dos Açores	http://www.uac.pt/en
U31	Universidade Europeia	https://www.europeia.pt/en
U32	Universidade Fernando Pessoa	http://www.ufp.pt/
U33	Universidade Lusíada - Norte	http://www.fam.ulusiada.pt/
U34	Universidade Lusíada	http://www.ulusiada.pt/
U35	Universidade Lusíada - Norte Porto	http://www.por.ulusiada.pt/
U36	Universidade Lusíada - Lisboa	http://www.lis.ulusiada.pt/
U37	Universidade Lusófona de Humanidades e Tecnologias	https://www.ulusofona.pt/en/
U38	Universidade Lusófona do Porto	http://www.ulp.pt/
U39	Universidade Nova de Lisboa	http://www.unl.pt/en
U40	Universidade Portucalense Infante D. Henrique	http://www.upt.pt/
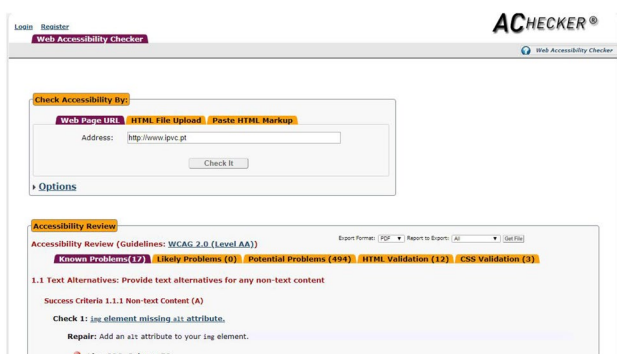
Fig. 1 Snapshot of AChecker tool

5.1 AChecker tool

The snapshot of website evaluation result of the AChecker tool as shown in Fig. 1.

The AChecker evaluation reports of 19 Polytechnic Institutes and 38 out of 40 universities websites of Portugal are shown in Table 3 and 4. Tables 3 and 4 presents the result in terms of WCAG 2.0 under levels A, AA and AAA with Known (KP), Likely (LP) and Potential(PP) problems along with HTML (HV) and CSS (CV) validation

of Polytechnic Institutes and Universities websites of Portugal.

5.2 WAVE tool

The output snapshot of the WAVE tool after entering the particular URL of the website as shown in Fig. 2. The WAVE tool report of Polytechnic Institutes (19) and Universities (40) websites of Portugal (47) as shown in Tables 5 and 6. These tables presented the status of both websites belongs to Polytechnic Institutes and Universities of Portugal. It includes multiple detected features and options of checking accessibility violations.

5.3 aXe tool

The evaluation snapshot of aXe tool as shown in Fig. 3.

The aXe tool report of Polytechnic Institutes (19) and Universities (40) of Portugal websites as shown in Tables 7 and 8, respectively. These tables presented the violations and needs review status of websites. That is, violations indicate the number of issues against standard web guidelines. Also, the needs review indicate the need for accessibility expert to review them.

Table 3 Result of Achecker tool of polytechnic institutes of Portugal under WCAG 2.0 levels of conformance

Achecker tool (WCAG 2.0)

ID	Level A					Level AA					Level AAA				
	KP	LP	PP	HV	CV	KP	LP	PP	HV	CV	KP	LP	PP	HV	CV
P1	22	1	449	16	3	23	1	510	16	3	23	1	515	16	3
P2	110	0	1073	524	72	284	0	1116	524	72	284	0	1079	524	72
P3	37	3	414	251	627	37	3	452	251	527	37	3	482	251	627
P4	3	0	10	3	494	3	0	12	3	494	3	0	17	3	494
P5	0	0	0	5	93	0	0	0	5	93	0	0	0	5	93
P6	29	0	361	59	62	36	1	377	59	62	36	1	385	59	62
P7	45	2	690	17	1	131	2	741	17	1	131	2	746	17	1
P8	0	0	420	6	51	2	0	437	6	51	17	0	446	6	51
P9	0	0	413	2	25	0	0	447	2	25	0	0	452	2	25
P10	53	1	679	86	228	103	1	719	86	228	103	1	724	86	228
P11	9	1	489	11	63	17	2	505	11	63	17	2	512	11	63
P12	7	0	521	14	8	8	0	536	14	8	8	0	567	14	8
P13	3	0	0	3	0	3	0	0	3	0	3	0	0	3	0
P14	2	0	5	2	0	2	0	7	2	0	2	0	9	2	0
P15	22	1	449	16	3	23	1	510	16	3	23	1	515	16	3
P16	9	0	289	42	756	16	0	319	42	756	16	0	328	42	756
P17	3	0	243	8	140	3	0	257	8	140	3	0	269	8	140
P18	2	0	519	38	80	14	0	531	38	80	19	0	541	38	80
P19	161	0	1141	0	87	163	1	1152	0	87	163	1	1149	0	87

Table 4 Achecker tool report of universities of Portugal under WCAG 2.0 levels of conformance

Achecker tool (WCAG 2.0) report of Portugal universities

ID	Level A					Level AA					Level AAA				
	KP	LP	PP	HV	CV	KP	LP	PP	HV	CV	KP	LP	PP	HV	CV
U1	1	0	281	9	25	19	0	302	9	25	27	0	315	9	25
U2	18	3	383	27	103	37	3	410	27	103	37	3	415	27	103
U3	192	0	586	23	27	210	0	638	23	27	79	0	644	23	27
U4	11	2	389	206	21	27	2	413	206	21	29	2	419	206	21
U5	8	0	242	10	55	23	0	262	10	55	23	0	267	10	55
U6	0	0	100	1	10	1	0	108	1	10	1	0	114	1	10
U7	19	0	376	2	23	20	0	389	2	23	20	0	396	2	23
U8	5	0	258	69	30	40	0	303	69	30	53	0	311	69	30
U9	18	0	255	29	26	19	0	267	29	26	19	0	299	29	26
U10	15	0	468	3	502	26	0	505	3	502	26	0	511	3	502
U11	25	0	298	79	63	25	0	308	79	63	25	0	313	79	63
U12	1356	0	1197	0	76	1357	1	1206	0	76	1358	2	1215	0	76
U13	9	0	235	20	746	16	0	242	20	746	16	0	252	20	746
U14	1	0	422	35	52	7	0	425	35	52	7	0	433	35	52
U15	13	1	296	46	1	13	1	322	46	1	15	1	329	46	1
U16	205	0	262	0	276	209	0	285	0	276	209	0	299	0	276
U17	504 Gateway time-out														
U18	2	0	586	13	43	4	0	596	13	43	4	0	633	13	43
U19	1	1	130	33	15	21	1	147	33	15	21	0	170	33	15
U20	1	5	759	5	39	14	6	780	5	39	15	6	785	5	39
U21	1	0	403	2	6	21	0	438	2	6	21	0	449	2	6
U22	13	1	379	0	1	13	1	386	0	1	13	1	408	0	1
U23	15	0	349	14	582	26	0	359	14	582	26	0	364	14	582
U24	3	1	1467	9	130	297	1	1528	9	130	294	1	1544	9	130
U25	12	0	393	112	38	12	0	401	112	38	133	0	406	112	38
U26	21	3	777	78	11	21	3	784	78	11	22	3	863	78	11
U27	13	2	215	12	54	13	2	223	12	54	13	2	240	12	54
U28	26	1	1037	166	283	89	2	1090	166	283	41	2	1109	166	283
U29	0	0	602	7	38	53	0	807	7	38	53	0	813	7	38
U30	14	0	155	22	52	34	0	164	22	52	14	0	174	22	52
U31	10	0	259	49	37	10	0	272	49	37	10	0	277	49	37
U32	23	0	416	0	80	23	0	432	0	80	23	0	463	0	80
U33	16	1	616	58	175	101	1	630	58	175	93	1	658	58	175
U34	1	0	34	2	28	2	0	44	2	28	2	0	49	2	28
U35	2	0	50	53	37	2	0	59	53	37	5	0	64	53	37
U36	51	0	1751	60	680	504 Gateway time-out									
U37	14	0	395	0	49	15	0	420	0	49	15	0	425	0	49
U38	3	0	473	0	80	5	0	499	0	80	5	0	505	0	80
U39	4	1	564	23	221	18	1	586	23	221	18	1	592	23	221
U40	6	0	763	23	36	29	0	789	23	36	12	0	796	23	36

6 Statistical inference

In this analysis, we are using the *Achecker, WAVE and aXe,* web accessibility analysis tools to evaluate the websites of Universities (40) and Polytechnic Institutes (19) of Portugal. The statistical inferences of these websites are as:

1. **AChecker Evaluation Tool** The statistical inference of AChecker tool web accessibility report of Universities and Polytechnic Institutions of Portugal websites, as shown in Fig. 4.

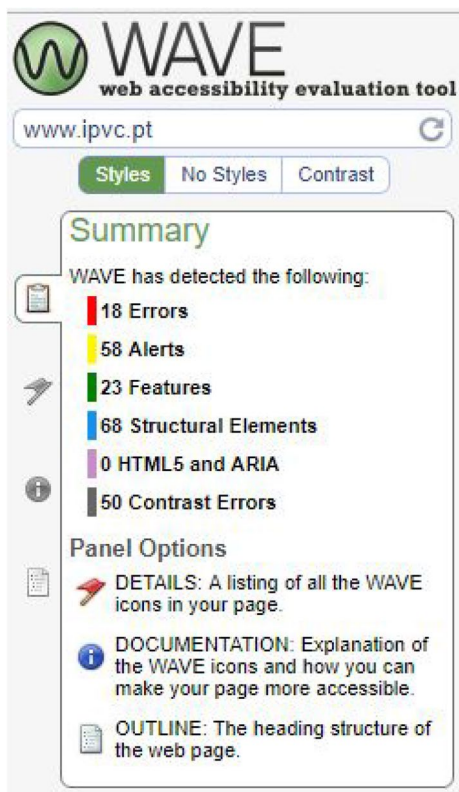Figure 4 indicates the total violations, mean, standard deviation, minimum and maximum web accessibil-

Fig. 2 Snapshot of WAVE Tool

ity status of these Portugal websites by using Achecker tool. The range of website violations of Universities and Polytechnic Institutes of Portugal lies between 222 and 7920 and between 18 and 5734, respectively.

2. **WAVE Evaluation Tool** The statistical inference of WAVE tool web accessibility report of Universities and Polytechnic Institutions of Portugal websites, as shown in Fig. 5.

   Figure 5 indicates the total violations, mean, standard deviation, minimum and maximum web accessibility status of these Portugal websites by using Achecker tool. The range of website violations of Universities and Polytechnic Institutes of Portugal lies between 16 and 845 and 3 and 472, respectively.

3. **aXe Evaluation Tool** The statistical inference of aXe web accessibility report of Universities and Polytechnic Institutions of Portugal websites, as shown in Fig. 6.

   Figure 6 indicates the total violations, mean, standard deviation, minimum and maximum web accessibility status of these Portugal websites by using Achecker tool. The range of website violations of Universities and Polytechnic Institutes of Portugal lies between 5 and 151 and 17 and 198, respectively.

Based on the evaluation tools used, we fix the outliers of accessibility violations. That is, minimum and maximum

Table 5 Evaluation result of WAVE tool of polytechnic institutes of Portugal

| WAVE-web accessibility evaluation tool					
ID	Errors	Alerts	Features	Structural elements	HTML5 and ARIA	Contrast errors
P1	25	62	24	70	0	48
P2	48	83	77	44	0	59
P3	8	190	24	28	18	2
P4	Result not available due to security					
P5	5	15	21	54	18	36
P6	25	6	16	17	6	112
P7	36	24	26	53	0	4
P8	4	38	27	24	20	22
P9	3	10	17	41	9	70
P10	55	54	28	42	18	159
P11	10	27	30	64	2	111
P12	5	13	33	31	0	19
P13	3	1	0	0	0	0
P14	2	1	0	0	0	0
P15	26	67	25	72	0	49
P16	7	21	0	44	1	101
P17	2	3	11	31	3	0
P18	4	33	14	45	5	20
P19	180	11	7	26	209	39

Table 6 Evaluation result of WAVE tool of universities of Portugal

WAVE tool report of Portugal universities						
ID	Errors	Alerts	Features	Structural elements	HTML5 and ARIA	Contrast errors
U1	10	3	12	34	40	70
U2	27	46	18	29	25	7
U3	42	15	12	36	33	6
U4	7	6	10	32	81	33
U5	19	26	3	28	5	17
U6	0	5	1	10	0	15
U7	7	3	3	41	0	29
U8	13	20	8	39	10	24
U9	17	45	27	18	40	1
U10	16	24	38	55	20	12
U11	16	29	10	11	4	16
U12	181	10	14	24	212	35
U13	8	33	2	22	1	21
U14	6	8	19	25	21	57
U15	6	88	17	28	4	15
U16	48	5	7	16	14	7
U17	15	23	9	46	12	50
U18	3	86	53	22	11	34
U19	2	37	26	17	0	13
U20	6	19	24	64	23	52
U21	3	86	11	52	0	100
U22	10	20	15	15	17	78
U23	20	4	0	24	10	9
U24	182	34	47	166	18	100
U25	6	20	17	17	4	12
U26	24	131	57	12	0	2
U27	18	14	3	12	10	24
U28	21	40	26	100	260	50
U29	2	205	6	251	9	8
U30	15	2	5	7	7	8
U31	14	10	2	36	44	21
U32	22	20	20	27	0	13
U33	8	81	83	30	0	5
U34	1	1	0	9	1	4
U35	10	100	61	44	4	34
U36	45	626	18	125	3	28
U37	10	20	13	29	7	55
U38	20	64	17	43	9	93
U39	31	35	19	73	32	10
U40	12	15	14	77	10	42

values of accessibility violations indicate highly accessible and less accessible websites, respectively.

The minimum and the maximum value of accessibility violations, that is, 3 and 7920 shown by Polytechnic Institute and University of Portugal website, respectively.

Moreover, Table 9 presents the statistical inferences in terms of total violations 79321, 7686, 2343, means 1983, 192, 59 and standard deviations 1482, 163, 36, about web accessibility analysis of universities of Portugal by using different automatic evaluation tools namely Achecker, WAVE and aXe tools, respectively.

Fig. 3 Snapshot of aXe Tool
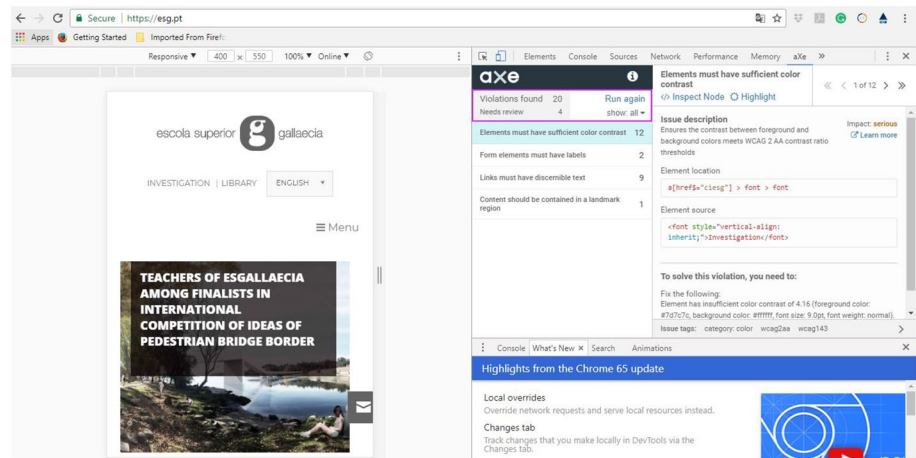
Table 7 Result of aXe tool of polytechnic institutes of Portugal

aXe tool

ID	Violations found	Needs review
P1	60	20
P2	127	24
P3	15	12
P4	21	39
P5	12	5
P6	81	5
P7	19	17
P8	14	14
P9	38	108
P10	182	16
P11	99	27
P12	2	33
P13	47	5
P14	20	8
P15	61	20
P16	98	23
P17	Not available	
P18	27	26
P19	43	6

Table 8 Result of aXe tool of universities of Portugal

aXe tool report of Portugal universities

ID	Violations	Needs review	ID	Violations	Needs review
U1	7	9	U21	11	122
U2	24	2	U22	24	14
U3	41	7	U23	27	82
U4	43	32	U24	30	66
U5	21	14	U25	14	32
U6	8	8	U26	31	47
U7	8	35	U27	16	16
U8	43	10	U28	20	95
U9	20	7	U29	3	25
U10	16	35	U30	12	0
U11	47	34	U31	30	6
U12	40	33	U32	26	13
U13	18	34	U33	49	41
U14	81	3	U34	1	4
U15	21	42	U35	30	8
U16	51	6	U36	16	124
U17	3	3	U37	63	0
U18	10	32	U38	88	3
U19	18	32	U39	138	13
U20	55	2	U40	26	22

Similarly, Table 10 presents the statistical inferences in terms of total violations 39423, 3333, 1374, means 2075, 175, 72 and standard deviations 1479, 124, 53, about web accessibility analysis of universities of Portugal by using different automatic evaluation tools namely Achecker, WAVE and aXe tools, respectively.

The overall graphical representation of analysis data of both types of Portugal websites as shown in Fig. 7. Figure 7 indicates that the Achecker and aXe tools mean violations are higher in Polytechnic Institutes than in Universities, and the WAVE tool mean violation is higher in Universities than Polytechnic Institutes of Portugal websites. In addition, the standard deviation of AChecker and WAVE tools of Universities are higher than Polytechnic Institutes of Portugal websites, and the standard deviation of aXe tool of Universities is less than Polytechnic Institutes.
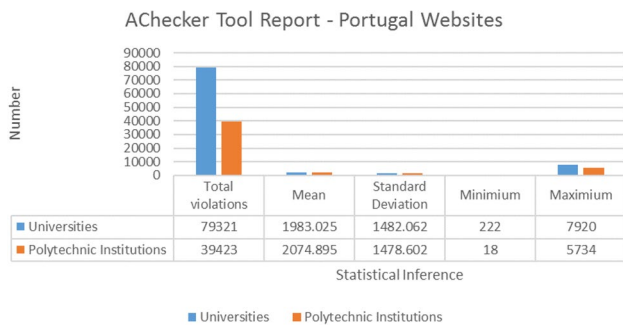
Fig. 4 AChecker Report: Statistical Inference of Web Accessibility Report of University and Polytechnic Institutions of Portugal websites
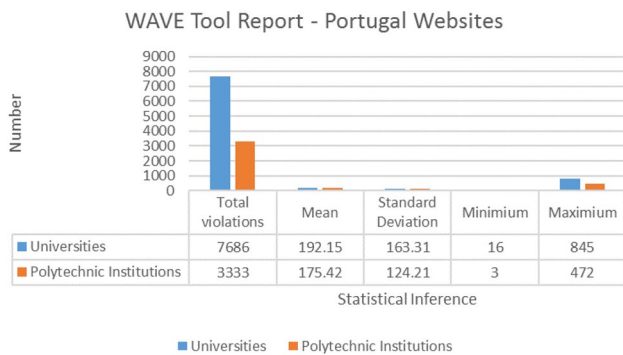

Fig. 5 WAVE Report: Statistical Inference of Web Accessibility Report of University and Polytechnic Institutions of Portugal websites
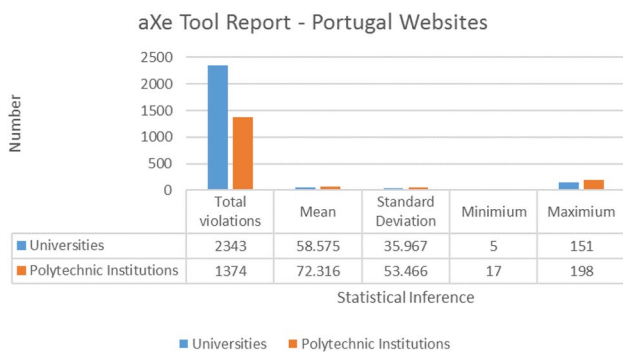

Fig. 6 aXe Report: Statistical Inference of Web Accessibility Report of University and Polytechnic Institutions of Portugal websites

Table 9 Statistical inference of universities of Portugal

Universities of Portugal			
Statistical inference	Achecker tool WCAG 2.0 (A, AA, AAA)	WAVE tool	aXe tool
Total	79321	7686	2343
Mean	1983.025	192.15	58.575
SD	1482.062	163.31	35.967

Table 10 Statistical Inference of Polytechnic Institutions of Portugal

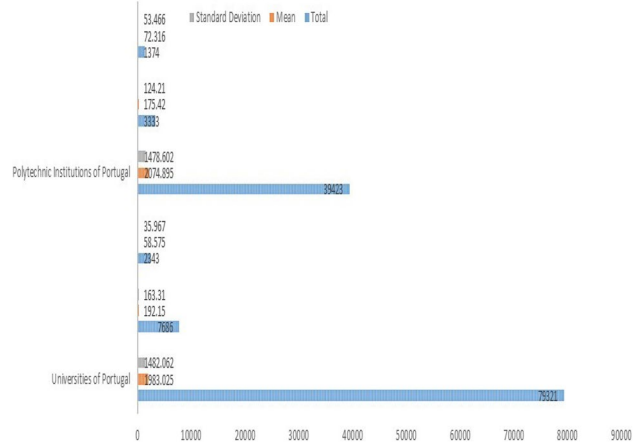| Polytechnic institutions of Portugal			
Statistical inference	Achecker tool WCAG 2.0 (A, AA, AAA)	WAVE tool	aXe tool
Total	39423	3333	1374
Mean	2074.895	175.42	72.316
SD	1478.602	124.21	53.466

Fig. 7 Overall web accessibility comparison of university and polytechnic institutions of Portugal websites by using AChecker, WAVE and aXe Tools

7 Suggestions and discussion

As per evaluation processes of Portugal websites of Polytechnic Institutes (19) and Universities (40), we provided Table 11 which is used to enhance the accessibility of websites by following the recommended steps to fix these types of issues. The given Table 11 also presents the issue description which is helpful for developers and website designers or website administrators.

Also, we found that the accessibility component features are almost absent in all websites.

So, it is suggested to include these accessibility features like *skip to navigation, zoom in, zoom out, font size, screen reader, accessibility statement, contrast, etc.* It does not involve any complex process, just to one step process to include them.

Therefore, we suggest the following above steps to improve the accessibility of these websites and also, by introducing simple to read terms in the web content so that the information resources can be made more and more accessible.

Table 11 Violation cum solution cum issue descriptions of websites

S.no.	Violations/review	To solve this violation, you need to	Issue description
01	Text of buttons and link should not be repeated in the image alternative	Element contains <img > element with alt text that duplicates existing text	Ensure button and link text is not repeated as image alternative
02	Elements must have sufficient color contrast	1. Element's background color could not be determined due to a background image (Review) 2. Element has a 1:1 contrast ratio with the background (Review) 3. Element has insufficient color contrast of 4.44 (foreground color: #ffffff, background color: #018a46, font size:12.8pt, font weight: normal) 4. Element has insufficient color contrast of 3.91 (foreground color: #53900b, background color: #ffffff, font size:13.5pt, font weight: bold) 5. Unable to determine contrast ratio (review) 6. Element's background color could not be determined because element contains an image node (review)	Ensures the contrast between foreground and background colors meets WCAG 2.0 AA contrast ratio thresholds
03	Headings must not be empty	1. Element does not have text that is visible to screen readers 2. Element's default semantics were not overridden with role = "presentation" 3. Element's default semantics were not overridden with role = "none"	Ensures headings have discernible text
04	<html> must have a lang attribute	The element <html> does not have a lang attribute	Ensures every HTML document has a lang attribute
05	Images must have alternate texts	1. Element does not have an alt attribute 2. Aria-label attribute does not exist or is empty 3. Aria-labeled by attribute does not exist references elements that do not exist or references elements that are empty or not visible 4. Element has no title attribute or the title attribute is empty 5. Element's default semantics were not overridden with role = "presentation" 6. Element's default semantics were not overridden with role = "none"	Ensures <img > elements have alternate text or a role of none or presentation
06	Image buttons must have alternate text	1. Element does not have an alt attribute 2. Aria-label attribute does not exist or is empty 3. Aria-labeled by attribute does not exist references elements that do not exist or references elements that are empty or not visible 4. Element has no title attribute or the title attribute is empty 5. Element's default semantics were not overridden with role = "presentation" 6. Element's default semantics were not overridden with role = "none"	Ensures <img > elements have alternate text or a role of none or presentation

Table 11 (continued)

S.no.	Violations/review	To solve this violation, you need to	Issue description
07	Form Elements must have labels	1. Aria-label attribute does not exist or is empty 2. Aria-labeled by attribute does not exist references elements that do not exist or references elements that are empty or not visible 3. Form element does not have an implicit (wrapped) 4. Form element does not have an explicit 5. Element has no title attribute or the title attribute is empty	Ensures every form element has a label
08	Links must have visible text	1. Element does not have text that is visible to screen readers 2. Aria-label attribute does not exist or is empty 3. Aria-labeled by attribute does not exist, references elements that do not exist or references elements that are empty or not visible 4. Element's default semantics were not overridden with role = "presentation" 5. Element's default semantics were not overridden with role = "none" 6. Element is in tab order and does not have accessible text	Ensures links have discernible text
09	Zooming and scaling must not be disabled	<meta> tag disables zooming on mobile devices	Ensures <meta name = "viewport"> does not disable text scaling and zooming
10	<marquee> elements are deprecated and must not be used	Element is visible	Ensures <marquee> elements are not used
11	Id attribute value must be unique	Document has multiple elements with the same id attribute: divsbody	Ensures every id attribute value is unique
12	and must only directly contain , <script> and <template> elements	List element has direct children that are not allowed inside elements	Ensures that lists are structured correctly
13	elements must be contained in or	List item does not have a , or role = "list" parent element	Ensures elements are used semantically
14	<dl> elements must only directly contain properly ordered <dt> and <dd> groups, <script> or <template> elements	1. When not empty, element does not have at least one <dt> element followed by at least one <dd> element 2. List element has direct children that are not allowed inside <dt> or <dd> elements	Ensures <dl> elements are structured correctly
15	Frames must have title attribute	1. Aria-label attribute does not exist or is empty 2. Aria-labeled by attribute does not exist, references elements that do not exist or references elements that are empty or not visible 3. Element has no title attribute or the title attribute is empty 4. Element's default semantics were not overridden with role = "presentation" 5. Element's default semantics were not overridden with role = "none"	Ensures <iframe> and <frame> elements contain a non-empty title attribute

Table 11 (continued)

S.no.	Violations/review	To solve this violation, you need to	Issue description
16	Active \<area> elements must have alternate text	1. Element has no alt attribute or the alt attribute is empty 2. Element has no title attribute or the title attribute is empty 3. Aria-label attribute does not exist or is empty 4. Aria-labeled by attribute does not exist, references elements that do not exist or references elements that are empty or not visible	Ensures \<area> elements of image maps have alternate text
17	Buttons must have visible text	1. Element has a value attribute and the value attribute is empty 2. Element has no value attribute or the value attribute is empty 3. Element does not have inner text that is visible to screen readers 4. Aria-label attribute does not exist or is empty 5. Aria-labeled by attribute does not exist, references elements that do not exist or references elements that are empty or not visible 6. Element's default semantics were not overridden with role = "presentation" 7. Element's default semantics were not overridden with role = "none" 8. Element is in tab order and does not have accessible text	Ensures buttons have discernible text
18	All the element and elements with role=columnheader or rowheader must datacells which it describes	Table data cells are missing or empty	Ensure that each table header in a data table refers to data cells
19	Certain ARIA roles must contain particular children	Invalid ARIA attribute value: aria- controls = "youtube-videogallery-iframe"	Ensures all ARIA attributes have valid values
20	Page must have means to bypass repeated blocks	1. No valid skip link found 2. Page does not have a header 3. Page does not have a landmark region	Ensures each page has at least one mechanism for a user to bypass navigation and jump straight to the content
21	Radio inputs with the same name attribute value must be part of group	1. All elements with the name "ctl00$ContentPlaceHolderabovefooter$SearchCriteria" do not reference the same element with area-labeledby 2. Element does not have a containing fieldset or ARIA group	Ensures related \<input type = "radio"> elements have a group and that the group designation is consistent
22	\<object> elements must have alternate text	1. Element does not have text that is visible to screen readers 2. Aria-label attribute does not exist or is empty 3. Aria-labeled by attribute does not exist, references elements that do not exist or references elements that are empty or not visible 4. Element has no title attribute or the title attribute is empty	Ensures \<object> elements have alternate text
23	\<audio> elements must have a caption track	A captions track for this element could not be found (review)	Ensures \<audio> elements have captions

Table 11 (continued)

S.no.	Violations/review	To solve this violation, you need to	Issue description
24	Documents must have <title> element to aid in navigation	Document does not have a non-empty <title> element	Ensures each HTML document contains a non-empty <title> element
25	<blink> elements are deprecated and must not be used	Element is visible	Ensures <blink> elements are not used
26	<dt> and <dd> elements must be contained by a <dl>	Description list item does not have a <dl> parent element	Ensures <dt> and <dd> elements are contained by a <dl>

In short, to become a better web developer and designer, we should understand the accessibility concepts, scope, and their impact.

8 Conclusions and future directions

The objective of our research is to calculate the current situation of Higher Education Institution websites of Portugal websites of web accessibility based on W3C guidelines and standards.

Moreover, accessibility and readability are the two concepts which are interrelated and interconnected for achieving the universality of a web by all categories of users irrespective of their disabilities.

In this paper, the results obtained from evaluation tools of 19 + 40 = 59 Higher Education Institution websites of Portugal provide a bird-view for web administrators to focus on the importance of accessibility concept and try to achieve it successfully in future.

Among the selected websites, we found that the major violations are in image contrasts, alternate text for images as well as buttons, links without visible text which mostly represent a lack of accessibility components. Further, we recommended that *Alt text* is provided for the image with other explanatory text also.

In addition to the range (minimum and maximum) score of accessibility violations of Polytechnic Institute websites (19) of Portugal is 18–5734 (AChecker Tool), 3–472 (WAVE Tool) and 17–198 (aXe Tool), respectively. Also, the range (minimum and maximum) score of accessibility violations of Universities websites (40) of Portugal is 22–7920 (AChecker Tool), 16–845 (WAVE Tool) and 5–151 (aXe Tool), respectively.

Table 11 presented in Sect. 7 provides issues description along with the solution for each problem detected in analyzed websites to help web developers, website designers or website administrators to develop more inclusive web platforms.

Conclusively, there is a need for awareness programs and proper training of web accessibility for developers, designers and administrators of the websites. In the future, we will focus on checking the *audits of websites* of progressive, performance, accessibility and best practices.

References

1. Aizpurua, A., Arrue, M., Vigo, M., Abascal, J.: Validating the effectiveness of evalaccess when deploying wcag 2.0 tests. Univers. Access Inf. Soc. **10**(4), 425–441 (2011)
2. Al-Faries, A., Al-Khalifa, H.S., Al-Razgan, M.S., Al-Duwais, M.: Evaluating the accessibility and usability of top saudi

e-government services. In: Proceedings of the 7th International Conference on Theory and Practice of Electronic Governance, pp. 60–63. ACM (2013)

3. Alahmadi, T., Drew, S., et al.: Accessibility evaluation of top-ranking university websites in world, oceania, and arab categories for home, admission, and course description webpages. J. Open Flex. Distance Learn. **21**(1), 7 (2017)

4. Barua, M.: E-governance adoption in government organization of india. Int. J. Manag. Public Sector Inf. Commun. Technol. **3**(1), 1 (2012)

5. Fogli, D., Colosio, S., Sacco, M.: Managing accessibility in local e-government websites through end-user development: a case study. Univers. Access Inf. Soc. **9**(1), 35–50 (2010)

6. Fuglerud, K.S., Røssvoll, T.H.: An evaluation of web-based voting usability and accessibility. Univers. Access Inf. Soc. **11**(4), 359–373 (2012)

7. Garrido, A., Rossi, G., Medina, N.M., Grigera, J., Firmenich, S.: Improving accessibility of web interfaces: refactoring to the rescue. Univers. Access Inf. Soc. **13**(4), 387–399 (2014)

8. Gonçalves, R., Rocha, T., Martins, J., Branco, F., Au-Yong-Oliveira, M.: Evaluation of e-commerce websites accessibility and usability: an e-commerce platform analysis with the inclusion of blind users. Univers. Access Inf. Soc. **17**, 1–17 (2018)

9. Goodwin, M., Susar, D., Nietzio, A., Snaprud, M., Jensen, C.S.: Global web accessibility analysis of national government portals and ministry websites. J. Inf. Technol. Polit. **8**(1), 41–67 (2011)

10. Ismail, A., Kuppusamy, K.S.: Accessibility analysis of north eastern india region websites for persons with disabilities. In: 2016 International Conference on Accessibility to Digital World (ICADW), pp. 145–148. IEEE (2016)

11. Ismail, A., Kuppusamy, K.S.: Accessibility of Indian universities' homepages: an exploratory study. J. King Saud Univ. Comput. Inf. Sci. **30**, 268–278 (2018)

12. Ismail, A., Kuppusamy, K.S., Kumar, A., Ojha, P.K.: Connect the dots: accessibility, readability and site ranking-an investigation with reference to top ranked websites of government of India. J. King Saud Univ. Comput. Inf. Sci (2017). https://doi.org/10.1016/j.jksuci.2017.05.007

13. Ismail, A., Kuppusamy, K.S., Nengroo, A.S.: Multi-tool accessibility assessment of government department websites: a case-study with jkgad. Disabil. Rehabilit. Assist. Technol. **13**, 1–13 (2017)

14. Ismailova, R., Inal, Y.: website accessibility and quality in use: a comparative study of government websites in kyrgyzstan, azerbaijan, kazakhstan and turkey. Univers. Access Inf. Soc. **16**(4), 987–996 (2017)

15. Kamal, I.W., Wahsheh, H.A., Alsmadi, I.M., Al-Kabi, M.N.: Evaluating web accessibility metrics for Jordanian universities. Int. J. Adv. Comput. Sci. Appl. **7**(7), 113–122 (2016)

16. Karaim, N.A., Inal, Y.: Usability and accessibility evaluation of Libyan government websites. Univers. Access Inf. Soc. **18**, 207–216 (2019)

17. Kožuh, I., Hintermair, M., Holzinger, A., Volčič, Z., Debevc, M.: Enhancing universal access: deaf and hard of hearing people on social networking sites. Univers. Access Inf. Soc. **14**(4), 537–545 (2015)

18. Kurt, S.: The accessibility of university websites: the case of turkish universities. Univers. Access Inf. Soc. **10**(1), 101–110 (2011)

19. Leitner, M.L., Strauss, C., Stummer, C.: Web accessibility implementation in private sector organizations: motivations and business impact. Univers. Access Inf. Soc. **15**(2), 249–260 (2016)

20. Manoharan, A.: Active Citizen Participation in E-Government: A Global Perspective: A Global Perspective. IGI Global, Hershey (2012)

21. Rau, P.L.P., Zhou, L., Sun, N., Zhong, R.: Evaluation of web accessibility in china: changes from 2009 to 2013. Univers. Access Inf. Soc. **15**(2), 297–303 (2016)

22. Rello, L., Baeza-Yates, R.: How to present more readable text for people with dyslexia. Univers. Access Inf. Soc. **16**(1), 29–49 (2017)

23. Roig-Vila, R., Ferrández, S., Ferri-Miralles, I.: Assessment of web content accessibility levels in spanish official online education environments. Int. Educ. Stud. **7**(6), 31–45 (2014)

24. Velleman, E.M., Nahuis, I., van der Geest, T.: Factors explaining adoption and implementation processes for web accessibility standards within egovernment systems and organizations. Univers. Access Inf. Soc. **16**(1), 173–190 (2017)

25. WRD: world report on disability. https://en.wikipedia.org/wiki/World_report_on_disability (2017)