

# Methodological process for the comparative analysis of automatic Web accessibility validators

## Proceso metodológico para el análisis comparativo de validadores automáticos de accesibilidad Web

José Montes-Gil<sup>1</sup>  
Luis Londoño-Rojas<sup>2</sup>  
Valentina Tabares-Morales<sup>3</sup>

<sup>1</sup> Universidad Nacional de Colombia (Colombia). Email: joamontesgi@unal.edu.co;  
orcid: <https://orcid.org/0000-0002-7117-3051>

<sup>2</sup> Universidad Nacional de Colombia (Colombia). Email: lflondonor@unal.edu.co;  
orcid: <https://orcid.org/0000-0002-9580-3898>

<sup>3</sup> Universidad Nacional de Colombia (Colombia). Email: vtabaresm@unal.edu.co;  
orcid: <https://orcid.org/0000-0002-8078-8525>

Received: 06-08-2019 Accepted: 15-11-2019

**How to quote:** Montes-Gil, José; Londoño-Rojas, Luis; Tabares-Morales, Valentina (2019). Proceso metodológico para el análisis comparativo de validadores automáticos de accesibilidad Web. *Informador Técnico*, 84(1), 35-47.  
<https://doi.org/10.23850/22565035.2303>

## Resumen

La accesibilidad web es aquella característica que permite que cualquier persona sin importar sus condiciones pueda acceder a los contenidos de los sitios web. El uso de validadores automáticos permite realizar un primer análisis acerca del nivel de accesibilidad de un sitio web. Sin embargo, la selección de estas herramientas tiende a no ser trivial, debido a las diferencias técnicas que presenta cada validador. El objetivo de este trabajo fue realizar un análisis comparativo entre validadores automáticos de accesibilidad, buscando establecer criterios de selección a la hora de elegir un validador para realizar una evaluación de accesibilidad. Se propuso una metodología basada en tres etapas que permitieron seleccionar 14 validadores que fueron analizados bajo diferentes criterios. Además, permitió concluir que ninguno de los validadores analizados cumple con todas las características, por lo que no sería suficiente seleccionar solo uno para realizar un proceso de evaluación de accesibilidad. Por lo tanto, este proceso metodológico se constituye como una herramienta de gran utilidad para la selección de validadores de accesibilidad.

**Palabras clave:** validadores de accesibilidad; validadores automáticos; accesibilidad; herramientas de evaluación de accesibilidad web; evaluación automática.

## Abstract

Web accessibility is that feature that allows anyone, regardless of their conditions, to access the contents of websites. The use of automatic validators allows a first analysis to be made about the level of accessibility of a website. However, the selection of these tools tends not to be trivial due to the technical differences presented by each validator. The objective of this work was to carry out a comparative analysis between automatic accessibility validators, seeking to establish selection criteria when choosing a validator to carry out an accessibility evaluation. A methodology was proposed based on three stages that allowed the selection of 14 validators that were analyzed under different criteria. Also, it allowed us to conclude that none of the analyzed validators fulfills all the characteristics, the reason why it would not be enough to select only one to carry out an accessibility evaluation process. Therefore, this methodological process constitutes a very useful tool for the selection of accessibility validators.

**Keywords:** accessibility validators; automatic validators; accessibility; web accessibility evaluation tools; automatic evaluation.

## 1. Introduction

With the continuous growth of the number of websites found on the Internet, it is important to have tools to verify if these sites meet web accessibility guidelines that allow access to all people (Shawn-Lawton, 2005), which They are defined within the Web Content Accessibility Guidelines (WCAG) established by the international consortium of a generation of recommendations and standards World Wide Web Consortium (W3C) and in Section 508 that is part of the Rehabilitation Act of 1973 in the United States. For this reason, web accessibility validators are created as tools that developers, designers, experts, and users have to carry out the automatic accessibility evaluation of a website.

Currently, there are a large number of accessibility validators on the web, of which 128 are tools that have the endorsement of the Web Accessibility Initiative (WAI). However, automatic accessibility validators present different problems; One of them is that they evaluate a small proportion of the criteria defined in the standards (Abuaddous; Zalisham-Jali; Basir, 2016). Another problem is the way the results are presented, which can be confusing for the user, as evidenced by Brajnik; Vigo; Yesilada; Harper (2016) whose experiment consisted of evaluating individually and in groups the level of accessibility of various websites, concluding that the interpretation of the results is better when several users cooperate, due to the level of difficulty that this process can have.

Based on the above, and taking into account the work of Akram and Sulaiman (2017), who conducted a review of articles to assess accessibility on different websites worldwide, it was shown that 87 % of these documents use automatic tools for the accessibility assessment, and the selection of accessibility validators is identified as problematic, according to the way the results are presented.

For the present work, a systematic process of evaluation and comparison of web accessibility validators is applied, focused on the analysis of how the results of the evaluations are delivered and displayed, both in the validators that are commonly used in the literature and the emerging validators of the last two years.

The results of this work can serve as a support tool in the selection of automatic web accessibility validators for both expert accessibility evaluators and for developers, designers, and institutions that wish to determine the level of accessibility of their websites.

## 2. Theoretical framework

### 2.1. Web accessibility

Accessibility is understood as the set of characteristics that allow a person, regardless of their physical, cognitive, or psychological conditions, to easily access a product or service. Therefore, web accessibility refers to the characteristics that websites have to allow access to anyone regardless of their conditions (Shawn-Lawton, 2005).

According to the W3C, web accessibility implies that anyone, regardless of their conditions, can perceive, understand, navigate, and interact with the web (Ismailova; Kimsanova, 2017). Section 508 defines accessibility as the degree to which a product, device, service, or environment is available to as many people as possible (Krepp, 2014).

## 2.2. Web accessibility standards

Accessibility standards are the norms, guides, and guidelines created by government entities or consortium initiatives, to give guidelines on how to build a website so that it can be accessed by as many people as possible, in such a way so that no type of user is excluded because they have some type of disability (Varela *et al.*, 2012). Below are some international standards and web accessibility initiatives.

- **Accessible Rich Internet Applications (ARIA):** This is a project of the W3C Web Accessibility Initiative (WAI) that aims to improve the accessibility of dynamic elements of interfaces developed in AJAX, HTML, Javascript and other technologies (Watanabe; Fortes; Dias, 2017).

- **Web Content Accessibility Guidelines (WCAG):** They are the guidelines that the W3C designed for the creation of accessible websites. Currently, it is in version 2.1, which is the beta test of version 3.0 (Alonso-Virgós; Rodríguez-Baena; Pascual-Espada; González-Crespo, 2018; Kirkpatrick; Connor; Campbell; Cooper, 2018).

- **Section 508:** It is the United States standard that defines that all products must meet functional requirements that allow access to anyone regardless of their conditions, it also includes guidelines that must be taken into account when creating accessible products, including web pages (Jaeger, 2004; Krepp, 2014; United States Access Board, 2000).

- **Authoring Tool Accessibility Guidelines (ATAG) and User Agent Accessibility Guidelines (UAAG):** These are two guides that the W3C created to support the WCAG regarding emerging technologies, such as multi-agent systems and authoring tools (Agüero; Perea, 2009; Richards; Spellman; Treviranus, 2015; Spellman; Allan; Shawn- Lawton, 2016).

## 2.3. Accessibility assessment

The accessibility evaluation consists of the validation of some characteristics of a website based on an accessibility standard. Accessibility evaluations have two approaches; The first is the manual evaluation, carried out by an expert user in the subject of accessibility, and uses as a validation tool an instrument with a series of defined criteria to review whether or not they are met on the website. The second approach is automatic evaluation, which can be applied by any user, to do this, one or more web accessibility validators are used as a tool, which, through the website address, access it and based on accessibility standards, they evaluate the code of the page.

Currently, most of the works found in the literature on accessibility assessment focus on government websites (Ismailova; Kimsanova, 2017; King; Youngblood, 2016; Power, Pimenta-Freire; Petrie, 2009) and university institutions (Akram; Sulaiman, 2017; Ismailova; Inal, 2018; Ismailova; Kimsanova, 2017; Kurt, 2017; Laufer-Nir; Rimmerman, 2018). This makes a lot of sense since it is up to these institutions to be pioneers in the construction of accessible websites, taking into account that they are portals that are accessed by a large number of people with different characteristics.

## 2.3. Web accessibility validators

As mentioned above, web accessibility validators are tools that allow accessibility assessment to be performed automatically. Currently, there are a large number of accessibility validators that can be of the web type, desktop applications, or browser extensions. Some of these validators focus more on evaluating accessibility in terms of page contrasts, others on responsive website design on different types of devices, and generally, most validators evaluate the criteria for accessibility standards like WCAG and Section 508, although some new validators evaluate based on adaptations of WCAG criteria to specific needs.

### 3. Related works

A search was carried out for works related to the comparison of web accessibility validators and methodologies of evaluation of accessibility validators.

López-Zambrano, Moreira-Pico; Alava-Cagua (2018) presented a methodological model to assess and classify automatic web accessibility assessment tools. Within the case study of this work, the accessibility validators TAW, Ecuador Web Analyzer, Functional Accessibility Evaluator, Achecker, Ainspector, Access Monitor, Examinator, Vamolá, Tingtun Accessibility Checker, aXe, Total Validator, SortSite, Tenon Wave, Cynthia Says, WCAG Contrast Checker and Judgment Studio Toolbar were compared, based on the three levels of conformity (A, AA, AAA) and the four principles of WCAG (operable, robust, understandable and perceivable), obtaining as a result several comparative tables with the best five validators, according to the levels of compliance. It is concluded that the automatic evaluation of accessibility must be complemented with the manual evaluation, in addition, it is recommended to use accessibility validator evaluation methodologies based on the standards defined by the W3C, to determine which validator should be used in each specific case of evaluation. of accessibility.

In the work of Ismail, Kuppusamy, and Nengroo (2018), the accessibility assessment was carried out with multiple tools from the websites of government departments. Before starting this evaluation, a comparative analysis of the automatic accessibility validators that would be used (Achecker, Cynthia Says, Tenon, WAVE, Mauve, and Hera) was prepared, using as a guide comparison mechanism, automatic checks, online services, accessibility checked by parameter, API, browser extension, language, supported formats, testing by levels (A, AA, AAA), testing by priorities (P1, P2, P3), accessibility review reports, the format of reports, software license and assistance for report generation, obtaining within the conclusions that each validator detects different accessibility characteristics, so that, to have a better evaluation, more than one validator must be used.

For their part, Kaur and Dani (2017) carried out the comparative analysis of the automatic mobile web accessibility validators MobileOK Checker, TAW, EvalAccess Mobile, and MobiReady. The comparison of these is made based on three parameters, correctness, integrity, and coverage. As a result, it was found that the best validators for automatic evaluation of accessibility on mobile devices are EvalAccess and MobileOK.

In Al-Ahmad's investigation; Ahmaro; Mustafa (2015) made a comparative analysis of the automatic web accessibility validators WAVE, Adesigner, A-Prompt, Web Accessibility Inspector and ATRC Accessibility Checker. In this study, tests were carried out on each tool for each criterion and it was concluded that none of the validators evaluates all the accessibility guidelines defined by the W3C, therefore they suggest using more than one validator for the automatic evaluation of accessibility and applying manual accessibility evaluation to guarantee the evaluation of all the criteria of the accessibility standards.

Pacheco, Amorim; Barbosa; Ferreira (2017) carried out a comparative analysis of accessibility assessment tools, to assess the accessibility validators AccessMonitor, ASES, and TAW. Within the conclusions of this work, the authors suggest the use of more than one accessibility validator to guarantee a better evaluation and also mention that for this particular case, the AccessMonitor validator presents both false negatives and false positives in the results.

Martín, Amado-Salvatierra; Hilera (2016) carried out the accessibility evaluation of MOOC platforms using the Examinator, Functional Accessibility Evaluator, and Tingtun validators, where they obtained as a result, an accessibility ranking of these eight MOOCs, recommending the use of the accessibility validators used in the study.

On the other hand, Al-Khalifa; Baazeem; Alamer (2017) carried out the accessibility review of the web portals of the Government of Saudi Arabia to raise awareness regarding the accessibility of e-government

services, as well as validate whether new policies to improve the accessibility of these sites have they been effective or not. To do this, the Achecker, Total Validator, and WAVE validators were used as tools and concluded that the accessibility of these portals has been considerably improved in recent years.

In the work of Akram and Sulaiman (2017) a systematic literature review was carried out to determine web accessibility problems in the portals of universities and the Government of Saudi Arabia for people with disabilities. Among the findings of this work, it is highlighted that, from the summary of existing research studies on web accessibility that they carry out, 87% of the articles reviewed use automatic web accessibility assessment tools and the most used accessibility validator is TAW, followed Achecker and EvalAccess.

## 4. Methodology

To carry out a comparative analysis of accessibility validators, an integrated methodology was proposed in three stages, which are described below:

**Stage 1:** At this stage, an initial selection of 21 accessibility validators was made, after performing the literature review, taking into account only those that appear at least once referenced in the literature consulted. Two basic criteria were analyzed in the selected validators:

- **Type of application:** This criterion allowed determining if the validator is a web, desktop, and/or browser extension tool.
- **License:** This criterion allowed us to identify if the validator was free or if there was any cost for its use.

**Stage 2:** The validators that met the criteria of being web applications and free licenses were selected, taking into account the classification made in stage 1. The availability review of each of the selected validators and their description was also carried out.

**Stage 3:** Once the validators were described, they were compared, according to the evaluation criteria presented below:

- **Standards:** Low standards were identified, with which the validator carried out the accessibility analysis.
- **Evaluation categories:** The classification parameters of the results obtained by the validator were analyzed, these classifications could be specific to the tool or defined based on the principles of the WCAG or other standards.
- **Evaluation measures:** It was observed in the results of the accessibility evaluation obtained by the validator were shown in numerical and/or percentage form.
- **How the results are displayed:** The way the validator presented the results was observed. It was identified if it is done graphically if the criteria of the standards were listed if the source code was presented if errors were located in the interface, if the number of elements was analyzed against the number of approved elements or if indicated how to correct the error.
- **Download results:** It was determined if the results of the accessibility evaluation can be downloaded.
- **Number of citations:** Associated with the process of analysis of the characteristics of the accessibility validators, a systematic literature review process was carried out where scientific articles that respond to keywords related to accessibility assessments were selected. Also, searches were performed with the name of each of the selected validators. Finally, the number of citations they have had in scientific publications was established.

## 5. Results and discussion

This section presents the results obtained by applying the proposed methodology, with its respective analysis. When applying the first stage, 21 accessibility validators were selected after analyzing the 128 available through the W3C website. As mentioned, the selection of these validators was made taking into account their appearance in specialized literature where accessibility evaluations are carried out.

The selected validators and their description regarding the type of application and its licensing are presented in Table 1.

As a result of the second stage, 14 validators that met the application criteria of being web application with a free license were selected

**Table 1.**  
Pre-selection of automatic accessibility validators

Validators	Type of application			License	
	Web	Desk	Extension	Free	Payment
TAW	X			X	X
WAVE	X		X	X	X
Examinator	X			X	
Achecker	X			X	
Tenon	X		X	X	
Koa11y		X		X	
HTML CodeSniffer			X	X	
Adesigner		X		X	
Web Analyzer	X			X	
Functional Accessibility Evaluator 2.0	X			X	
Total Validator		X		X	X
SortSite	X	X		X	X
Mauve	X			X	
European Internet Inclusion Initiative	X			X	
Siteimprove			X	X	X
CynthiaSays	X			X	
HERA FFX			X	X	
AXE			X	X	
Tanaguru	X			X	
AccessMonitor	X			X	
Nibbler	X			X	X

Source: self-made.

The availability of each of them was reviewed and a short description was made, according to the information provided through their websites. Below are the selected validators:

- **TAW (<https://www.tawdis.net/>):** This tool allows analyzing the accessibility levels (A, AA, AAA) of a website. Supports HTML, CSS, and Javascript technologies. The evaluation is carried out by entering the URL of the website, and 3 categories are established, which are called Problems, Warnings, and Unverified. In each category, there is a total of elements distributed in the 4 principles of the WCAG (Operable, Robust, Understandable, Perceptible). In the particular case of the unverified ones, the validator recommends evaluating these criteria through a manual evaluation. The report can be sent via email.

- **WAVE (<https://wave.webaim.org/>):** Using this validator it is possible to determine the number of errors, alerts, characteristics, structural elements, HTML, ARIA, and contrast errors found on a website. Among the WAVE functionalities, it is possible to analyze the site by enabling or disabling the styles and contrast elements. It also has two tabs in which you can see a list with each identified element and documentation about its importance, meaning, and correction, if necessary. A particular feature in WAVE is that it allows you to see the location of each of the elements in the site interface.

- **Examinator (<http://examinator.ws/>):** Evaluates accessibility using WCAG 2.0 as a reference. Accessibility validation is done through a URL, loading the source code, or pasting a particular piece of code. The elements found on the site are classified into four categories (Excellent, Fair, Bad, very bad) and each one shows its name, purpose, and relationship with other criteria. Examinator displays a summary table with the total number of elements, their score, and the final weighting that will determine the level of accessibility of the site. The tool also performs an analysis-oriented by type of disability and a particular result for each limitation.

- **Achecker (<https://achecker.ca/checker/index.php>):** Using this tool determines through an accessibility assessment the number of known problems, probable problems, potential problems, HTML, and CSS validation found on a website. The evaluation of a page can be done from the selection of the guidelines BITV1.0 (Level 2), Section 508, Stanca Act, WCAG 1.0, and 2.0 (Levels A, AA, AAA). The validator does not determine a general level of accessibility, however, for each of the elements found, it shows the code portion and how it can be corrected. Another particular feature of the tool is that it allows you to download the evaluation in four formats (PDF, RDF, HTML, and CSV).

- **Tenon (<https://tenon.io/>):** It determines the priority level of each of the elements on a website, classifying them in errors and warnings, showing the portion of code that relates them and a solution recommended by WCAG 2.0. This validator determines the time it took to perform the evaluation, the size of the screen and the page, in addition, the level of accessibility is shown to the user utilizing a graph and in percentage terms. The report generated by the application can be downloaded in CSV format.

- **Web Analyzer (<http://observatorioweb.ups.edu.ec>):** This validator establishes the accessibility level of a site based on the four principles established by the WCAG; Perceptible, Operable, Robust, and Understandable. Each item is categorized into four levels of measurement (Success, Error, Warning, and Not Applicable). The results show the code portion in case of Error and / or Warning, the level of criticality it represents to determine the level of accessibility of the site, and a description of how to apply an appropriate correction.

- **Functional Accessibility Evaluator 2.0 (<https://fae.disability.illinois.edu/>):** With the help of this tool, the elements belonging to a site are verified according to four categories (Violations, Warnings, Manual controls and Approved). Assessment can be done using HTML 5 and Aria or techniques inherited from HTML 4.

- **Tanaguru (<https://www.tanaguru.com/en/>):** This validator classifies the elements according to pass - not pass, Not applicable, Pre-classified, and Not evaluated, to determine the level of accessibility of the site. As an evaluation standard, it takes RGA 3.0 and its results are shown by graphs, in percentage, and numerical way. Some features of the tool allow the final result to be downloaded, the criteria of the regulations to be identified, the total number of elements implemented and a description of how the correction of failures can be addressed.

- **AccessMonitor (<http://www.acessibilidade.gov.pt/accessmonitor/>):** One of the main characteristics of this validator, is the possibility of loading a file with the source code, pasting only a portion of the code, or using the site's URL. The evaluation can be done using WCAG 1.0 or 2.0. The purpose of this tool is to quantify the level of accessibility of the site. The classification of results is done taking into account the HTML elements found and the total number of these elements with a suitable implementation. The tests carried out on the site are classified according to Errors, Warnings, and Approvals. Validator displays a numerical level of accessibility.

- **Nibbler (<https://nibbler.silktide.com/>):** Through this validator it is possible to assess the following five categories: General, Accessibility, Experience, Marketing, and Design. For each of the categories, the validator determines an overall score and recommendations for proper implementation.

- **CynthiaSays (<http://www.cynthiasays.com/>):** This validator evaluates a site, previously indicating the necessary accessibility guidelines (WCAG 1.0 and 2.0) and Section 508. Its report shows a list of the criteria and regulations, the number of elements, and the total number of elements implemented correctly, adding a description and help to correct the error.

- **SortSite (<https://www.powermapper.com/>):** The application determines the percentage problems that a website has, evaluating aspects such as accessibility, compatibility, regulations, usability, errors (such as broken links), and problems with search engines. SortSite performs its analysis taking into account Section 508 and WCAG 2.0. For each element, it shows a general description and in some cases the impact, according to an assistive tool.

- **Mauve (<https://mauve.isti.cnr.it/>):** This validator performs its analysis based on the WCAG 2.0, WCAG 2.1 guidelines. Visual deficiencies and Stanca Act, that can be selected by the user at the time of the evaluation. For the results of an evaluation, the categories used are called Errors and Warnings. Regarding the compliance criteria, this tool shows a description, its source code, and appends a link that redirects to the W3C website.

- **European Internet Inclusion Initiative (<http://checkers.eiii.eu/>):** This tool determines through a numerical value the level of accessibility on a page, classifying the elements of the site in Failures, Verifications, and Approvals. The tests carried out by the validator determine the total number of elements for each success criterion of WCAG 2.0, establish a description and technical aids for its correction, as well as show the code extract in which the error or the item is.

As presented, in the third stage the analysis of a set of defined criteria was made to evaluate the main characteristics of the accessibility validators. Table 2 presents the results associated with the first three criteria. According to Table 2, it was evident that twelve of the fourteen validators perform the accessibility assessment based on WCAG 2.0, only Nibbler and Tanaguru do not, since they do not apply any of the standards analyzed in this study. Four of the tools evaluate according to WCAG 2.1 and SortSite is the only one of the validators examined that offers the user the option of choosing one of the four standards to make the accessibility evaluation. On the other hand, only Tenon does not apply numerical evaluation measures and only four validators use percentage evaluation measures. Regarding the evaluation categories, the most common among the validators analyzed are Errors-Problems-Failures and Alerts-Warnings-Notices.

**Table 2.**  
Criteria evaluated in the third stage - Part 1

Validators	Standards					Evaluation categories	Measure	
	WCAG 1.0	WCAG 2.0	WCAG 2.1	Section 508	Others Which ones?		Numerical	Percentage
T.A.W		X				Problems, Warnings, No verified	X	
WAVE		X	X	X		Errors, Alerts, Features, Structural Elements, HTML 5 and Contrast with Aria	X	
Examinator		X				Excellent, Fair, Bad, Very bad	X	
Achecker	X	X		X	Acta Stanca, BITV 1.0	Problems, Known, Probable problems, Potential problems, HTML validation, CSS validation	X	
Tenon		X	X	X		Errors, Warnings		X
Web Analyzer		X			ISO 40500	Understandable, operable, Perceptible, Robust, Criteria analyzed, Criteria not applied	X	X
Functional Accesibility Evaluator 2.0		X				Violations, Warnings, Manual checkups, Pass	X	
Tanaguru					RGAA 3.0	Pass, Fail, Does not apply, Prequalified, Not Evaluated	X	X
Access Monitor	X	X				OK, Errors, Notices	X	
Nibbler					unidentified	Global accessibility, Experience, Marketing, Technology	X	
CynthiaSays	X	X				WCAG compliance levels	X	

Continued on next page

Continued from the previous page

SortSite	X	X	X	X	Total quality, Errors, Accessibility, Compatibility, Search, Standards, Usability	X	X
Mauve		X		Stanca Act, visual impairments	Errors and Warnings	X	
European Internet Inclusion Initiative		X			Failures, to be verified, Approved	X	

Source: self-made.

The second part of the evaluation criteria defined in the third stage is presented in Table 3, which are associated with the presentation of results, the possibility of their download, and the citations found for each validator. It was evident that only five of the fourteen validators allowed the download of the results of the automatic accessibility evaluation. The WAVE and Access Monitor tools are the only ones that allow accessibility errors to be viewed in the website interface. On the other hand, all the validators examined to show the criteria of the regulations that are being breached. Only six of the tools display graphs to represent the results, and nine provide the user with ways in which they can correct detected accessibility errors.

**Table 3.**  
Criteria evaluated in the third stage - Part 2

Validators	Results presentation					Download results		Number of citations	
	Graphics	Criteria of rules	Source code	Location error in interface	Quantity elements/ Quantity elements approved	¿ How correct the error?	Yes		No
T.A.W		X			X		X		28
WAVE		X	X	X		X		X	29
Examinator		X	X		X			X	8
Achecker		X	X				X		20
Tenon	X	X	X				X		2
Web Analyzer	X	X	X		X	X		X	1
Functional Accesibility Evaluator 2.0	X	X			X	X	X		5
Tanaguru	X	X			X	X	X		1
Access Monitor		X	X	X	X	X		X	3

Continued on next page

Continued from the previous page

Nibbler	X	X	X	X	X	X	0
CynthiaSays		X		X	X	X	10
SortSite	X	X		X	X	X	11
Mauve		X	X			X	4
European Internet Inclusion Initiative		X	X	X	X	X	3

Source: self-made.

Regarding the citation of each one of the analyzed validators, the following ranking is obtained, which is presented below in Table 4. The analysis of the citations allowed us to identify which validators are being used the most to perform accessibility evaluations in different contexts. The results showed that WAVE and TAW have been the most frequently referenced in research-level work, which could indicate in general terms that they best support this type of process.

**Table 4.**  
*More referenced accessibility validators*

Accessibility validator	Number of citations
WAVE	29
TAW	28
Achecker	20
SortSite	11
CynthiaSays	10
Examinator	8

Source: self-made.

## 6. Conclusions and future work

A methodological process was presented that allowed a comparative analysis of available tools to automatically validate the accessibility of websites. Different criteria from fourteen selected validators were analyzed to offer support in the accessibility evaluation process. Accessibility validators are essential tools in the process of improving web accessibility. However, of the validators analyzed in this work, none fulfilled all the criteria examined regarding how they delivered the results, which is a problem for users in interpreting the information obtained in the accessibility analysis.

After analyzing the obtained results, it can be concluded that in the accessibility evaluation process it is not enough to use a single validator, since none includes all the criteria, display mechanisms, and characteristics to make a complete accessibility analysis. This work can serve as a support tool for a user in the selection of validators to be used for the automatic accessibility evaluation of a website, according to their preferences on how the delivery of results can be more understandable.

As future work, we plan to analyze a big number of accessibility validators, including web validators, extensions, and desktop tools. Another future work will be to analyze the observations that real users have regarding how the existing validators deliver the results, to identify which are their preferences and the validators that best cover them. It is proposed to carry out an accessibility evaluation of a set of websites in the same field, using the accessibility validators analyzed, to compare their results in a specific case.

## 7. Acknowledgments

The work presented in this article is part of the project “Technologies to support learning processes at the Universidad Nacional de Colombia Sede Manizales” funded by the Universidad Nacional de Colombia.

## 8. References

- Agüero, Dante; Perea, Antonio (2009). *Diseño de Sitios Web Accesibles*. Universidad Nacional de la Rioja, Argentina. Recuperado de <http://www.virtualeduca.info/ponencias2010/8/AWUNLAR.pdf>
- Abuaddous, Hayfa; Zalisham-Jali, Mohd; Basir, Nurlida (2016). Web Accessibility Challenges. *International Journal of Advanced Computer Science and Applications (IJACSA)*, 7(10), 172–181. <https://doi.org/10.14569/IJACSA.2016.071023>
- Akram, Muhammad; Sulaiman, Rosnafisah (2017). A Systematic Literature Review to Determine the Web Accessibility Issues in Saudi Arabian University and Government Websites for Disabled People. *International Journal of Advanced Computer Science and Applications (IJACSA)*, 8(6), 321–329. <https://doi.org/10.14569/IJACSA.2017.080642>
- Al-Ahmad, Ahmad; Ahmaro, Ibraheem; Mustafa, Malik (2015). Comparison between web accessibility Evaluation tools. *Al-Madinah Technical Studies*, 1(4).
- Al-Khalifa, Hend; Baazeem, Ibtehal; Alamer, Reem (2017). Revisiting the accessibility of Saudi Arabia government websites. *Universal Access in the Information Society*, 16(4), 1027–1039. 09-016-0495-7 <https://doi.org/10.1007/s10209-016-0495-7>
- Alonso-Virgós, Lucía; Rodríguez-Baena, Luis; Pascual-Espada, Jordán; González-Crespo, Rubén (2018). Web page design recommendations for people with down syndrome based on users’ experiences. *Sensors (Switzerland)*, 18(11), 4047. <https://doi.org/10.3390/s18114047>
- Brajnik, Giorgio; Vigo, Markel; Yesilada, Yeliz; Harper, Simon. (2016). Group vs individual web accessibility evaluations: Effects with novice evaluators. *Interacting with Computers*, 28(6), 843–861. <https://doi.org/10.1093/iwc/iww006>
- Ismailova, Rita; Inal, Yavuz (2018). Accessibility evaluation of top university websites: a comparative study of Kyrgyzstan, Azerbaijan, Kazakhstan and Turkey. *Universal Access in the Information Society*, 17(2), 437–445. <https://doi.org/10.1007/s10209-017-0541-0>
- Ismailova, Rita; Kimsanova, Guilda (2017). Universities of the Kyrgyz Republic on the Web: accessibility and usability. *Universal Access in the Information Society*, 16(4), 1017–1025. <https://doi.org/10.1007/s10209-016-0481-0>
- Ismail, A.; Kuppusamy, K. S.; Nengroo, A. S. (2018). Multi-tool accessibility assessment of government department websites: a case-study with JKGAD. *Disability and Rehabilitation: Assistive Technology*, 13(6), 504–516. <https://doi.org/10.1080/17483107.2017.1344883>
- Jaeger, Paul (2004). Beyond Section 508: The spectrum of legal requirements for accessible e-government Web sites in the United States. *Journal of Government Information*, 30(4), 518–533. <https://doi.org/10.1016/j.jgi.2004.09.010>
- Kaur, Arvinder; Dani, Diksha (2017). Comparing and evaluating the effectiveness of mobile Web adequacy evaluation tools. *Universal Access in the Information Society*, 16(2), 411–424. <https://doi.org/10.1007/s10209-016-0466-z>

- King, Bridgett; Youngblood, Norman (2016). E-government in Alabama: An analysis of county voting and election website content, usability, accessibility, and mobile readiness. *Government Information Quarterly*, 33(4), 715–726. <https://doi.org/10.1016/j.giq.2016.09.001>
- Kirkpatrick, Andrew; Connor, Joshue; Campbell, Alastair; Cooper, Michael (5 de junio de 2018). *W3C Web Accessibility Initiative: Web Content Accessibility Guidelines (WCAG) 2.1*. Recuperado de <https://www.w3.org/TR/WCAG21/>
- Krepp, Benjamin (2014). Development of section 508-compliant document production protocols and websites. *Transportation Research Record*, 2469(1), 100–107. <https://doi.org/10.3141/2469-11>
- Kurt, Serhat (2017). Accessibility of Turkish university Web sites. *Universal Access in the Information Society*, 16(2), 505–515. <https://doi.org/10.1007/s10209-016-0468-x>
- Laufer-Nir, Hila; Rimmerman, Arie (2018). Evaluation of Web content accessibility in an Israeli institution of higher education. *Universal Access in the Information Society*, 17(3), 663–673. <https://doi.org/10.1007/s10209-018-0615-7>
- López-Zambrano, Javier; Moreira-Pico, Ramón; Alava-Cagua, Nathaly (2018). Metodología para valorar y clasificar herramientas de evaluación de accesibilidad web. *E-Ciencias de la información* 8(1), 1-18. <https://doi.org/10.15517/eci.v8i1.30012>
- Martín, José; Amado-Salvatierra, Héctor; Hilera, José (2016). MOOCs for all. Evaluating the accessibility of top MOOC platforms. *International Journal of Engineering Education*, 32(Extra 5), 2274-2283.
- Pacheco, Humberto; Amorim, Patricia; Barbosa, Priscyla; Ferreira, Simone (2017). Comparative Analysis of Web Accessibility Evaluation Tools. En *IHC '16 Proceedings of the 15th Brazilian Symposium on Human Factors in Computing Systems*. Sao Paulo, Brazil. <https://doi.org/10.1145/3033701.3033747>
- Power, Christopher; Pimenta-Freire, André; Petrie, Helen (2009). Integrating accessibility evaluation into web engineering processes. *International Journal of Information Technology and Web Engineering*, 4(4), 54–77. <https://doi.org/10.4018/jitwe.2009100104>
- Richards, Jan; Spellman, Jeanne; Treviranus, Jutta (24 de septiembre de 2015). *W3C Web Accessibility Initiative: Authoring Tool Accessibility Guidelines (ATAG) 2.0*. Recuperado de <https://www.w3.org/TR/ATAG20/>
- Shawn-Lawton, Henry (Febrero de 2005). *W3C Web Accessibility Initiative: Introduction to Web Accessibility*. Recuperado de <https://www.w3.org/WAI/fundamentals/accessibility-intro/>
- Spellman, Jeanne; Allan, Jim; Shawn-Lawton, Henry (2016). *W3C Web Accessibility Initiative: User Agent Accessibility Guidelines (UAAG)*. Recuperado de <https://www.w3.org/WAI/standards-guidelines/uaag/>
- United States Access Board (21 de diciembre de 2000). United States Access Board: Section 508 Standards for Electronic and Information Technology. Recuperado de <https://www.access-board.gov/guidelines-and-standards/communications-and-it/about-thesection-508-standards/section-508-standards>
- Varela, C., Miñán, A., Hilera, J., Restrepo, F., Amado, H., Córdova, M. y Villaverde, A. (2012). Estándares y legislación sobre accesibilidad web. En *IV Congreso Internacional ATICA 2012*. Loja, Ecuador (pp. 46–53). Recuperado de [http://www.esvial.org/wp-content/files/Atica2012\\_pp47-54.pdf](http://www.esvial.org/wp-content/files/Atica2012_pp47-54.pdf)
- Watanabe, Willian; Fortes, Renata; Dias, Ana (2017). Acceptance tests for validating ARIA requirements in widgets. *Universal Access in the Information Society*, 16(1), 3–27. <https://doi.org/10.1007/s10209-015-0437-9>
- Web Accessibility Initiative (W3C) (Marzo de 2006). *W3C Web Accessibility Initiative: Web Accessibility Evaluation Tools List*. Recuperado de <https://www.w3.org/WAI/ER/tools/>