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Accessibility Evaluation of E-government Mobile Apps Services in Pakistan

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Abstract: This study uses automated tools to evaluate Pakistani government services (websites, mobile apps, and mobile web versions) for users who are blind or visually impaired. The chosen services pertain to several departments of the Pakistani government that have websites, mobile applications, and mobile web versions. For assessment purposes, this study employs four automated tools (Wave, Achecker, Web Accessibility, and Accessibility Scanner), three of which are for websites and one of which is for mobile apps and their corresponding mobile web versions. While Wave, Achecker, and Web Accessibility Tool are used to evaluate websites, Accessibility Scanner is used to evaluate mobile apps and their corresponding mobile web versions. The WCAG 2.0 and 2.1 accessibility standards are being applied by these tools to websites, mobile apps, and the mobile web. The majority of the services breached the WCAG 2.0 and 2.1 rules, according to the evaluation results, which calls for quick attention from service departments and developers in order to prevent discrimination against users without disabilities.

Keywords: Web content Accessibility Guidelines (WCAG), Mobile Accessibility Framework (MAF), WAVE (Web Accessibility Versatile Evaluator), Accessibility Checker (Achecker), World Wide Web Consortium (W3C), Web Accessibility Initiative (WAI)

1. Introduction

The accessibility is the level to which everyone can use a system irrespective of their intellectual or physical abilities. Accessibility refers to the ability to utilize a website efficiently, including the ease through which it can be navigated and its structure fully understood regardless of any type of disability problem. Accessibility deals with the competence of clients to visit the web page while taking into account variances in their needs and the circumstances in which they find themselves.

There are several standards and guidelines which can be used for developing effective platforms that provide equal access to all citizens. Such standards and guidelines can enable the developers/programmers to develop a website or mobile applications accessible and make their applications whether web-based or android-based, available to persons with disabilities. The world known common guidelines are the Web Content Accessibility Guidelines version 1.0 and version 2.0 of W3C. The WAI of the W3C has produced guidelines of accessibility for web designers/developers and named as Web Content Accessibility Guidelines (WCAG). Software developers could use such standards to render their sites/websites reachable to the persons with impairments. The first edition of these standards was launched/introduced in 1999 named as WCAG 1.0. The revised edition launched/introduced on 2008 named as WCAG 2.0. The current edition is WCAG 2.1, launched/introduced on 2018. It's simpler to apply and learn, and it can be thoroughly tested using machine driven tools and living beings' manual assessment [1].

The WCAG 2.0 is composed of four principles: POUR, which are perceivable, operable, understandable, robust, having 12 standards with 61 SC, 3 stages of conformance (Level A, Level AA, Level AAA) [1].

Next recent/current edition is WCAG 2.1 which consists of four principles POUR like WCAG 2.0, 13 guidelines with 78 SC, 3 aforementioned stages of conformance [1]. The three levels of conformance/accessibility recommendations categories as follows in Table 1:

Table 1. WCAG conformance levels description

Category	Description	Symbol
1	The first level ensures that the designer/programmer must apply/adopt these standards to make all of a website's information available to all users, including specialized persons	A
2	The second level ensures that the designer/programmer must apply/adopt these standards in order to get rid of the significant accessibility hurdles to get website's information	AA
3	The third level ensures that the designer/programmer can apply/adopt these standards at their current state, it is not that significant, however it makes the website quite accessible to impaired users	AAA

The focus of this research is on the accessibility assessment of Pakistani public services available through mobile for visually impaired persons considering different categories using the aforementioned set of standards defined by W3C. As per United Nations, 15% of the global total population have impairments [2] that's why accessibility evaluation of services has become very important nowadays. The purpose of evaluation of accessibility is to find out whether the selected applications are developed in accordance with Web Content Accessibility guidelines or not and fully accessible to people with visual disabilities. So, that in future developers may bring their attention towards adopting/applying such guidelines in the designing and development process of applications ensuring equal access to visually impaired persons/low vision users.

2. Literature Review

Computer systems with different kinds of interfaces, such as Web-based systems or mobile devices, are now one of the most widely used tools for giving access to social media services/assistance, and other kinds of essential information that individuals need in everyday lives So, it is essential that all people including those with disabilities, have access to these services.

Majority of researches have been carried out in this area in many organizations regarding web accessibility evaluation using different evaluation techniques, automated tools and methods in response to the significance of web accessibility, including libraries by D. Comeaux and A. Schmetzke [14] in 2013; M. Providenti and R. Zai III [15] in 2011, hotels by R. Williams and R. Rattray [16] in 2005, accounting firms by R. Williams and R. Rattray [17] in 2003, and government sectors (Aidi-Ahmi & Rosli-Mohamad, 2016; Serra, Carvalho, Ferreira, Vaz, and Friere, 2015; Lujan-Mora, Navarrete & Penafiel, 2014; Kamoun & Almourad, 2014; Baowaly & Bhuiyan, 2012; M. Bakhsh and A. Mehmood [1] in 2012). A couple of researches also have been carried out to assess the accessibility of smart phones by assessing the level of accessibility in mob apps using WCAG's rules.

Four government mob apps of Brazilian government available for both android and iOS were assessed by using WCAG 2.0 and applying audit method. These apps were selected from diverse categories: banking, economy, security and tourism. The results obtained uncovered many elementary accessibility problems (Lack of accessible labels and description, meaningful sequence, colour contrast, navigation, help, links and buttons) in the evaluation of applications using WCAG 2.0 and were not in compliance with these principles at any level [3]. Ten android-based mob apps were evaluated by using "Accessibility Scanner" tool and WCAG2.1. These apps were randomly selected from well-known apps across the world, reported by PCMAG. Mob apps were installed from Google Play Store on mobile phones based android OS version 7.0. The evaluation results of the selected mob apps showed that they were inaccessible by not complying with the WCAG 2.1 lowest needed level [4].

Ten android-based mob apps were evaluated by using "Accessibility Scanner" tool and applying WCAG2.1. These apps were particularly related to air quality monitoring means to detect the amount of air we inhale. Apps were selected from Google Play Store and installed on smartphones having android OS version 7.0. In order to assess these apps, activation of mob device location was necessary for the detection of location to monitor the quality of air. The evaluation results of the selected mob apps showed violation of WCAG 2.1 and "text contrast" is the far more prevalent reason for failing to comply these standards, while second is "touch target" [5]. 479 apps considering different 23 business related apps were evaluated by using automated tool-Mobile Accessibility Checker and following accessibility standards by W3C. These app were selected and installed from Google play store on the basis of popularity. Using MAC, these apps were assessed by looking at their graphical user interface (GUI) designs and compliance with accessibility criteria. As a result, 30 percent of the GUI elements were unavailable to all users means it was challenging or nearly hard for impaired persons in order to gain access to it [6]. Four mob apps and 4 websites considering 2 governmental and 2 commercials, evaluated by conducting usability tests involving 10 participants. The participants included 6 blind persons and 4 mainstream users and they were guided about test and method. The usability test took place at usability testing lab. At least three members out of each user group assessed all websites and apps, generating roughly 26 hours of live recording. The evaluation results obtained showed that approximately 79 percent of the difficulties identified in this study were caused by specialized persons [7].

Due to massive growth in web and mob apps usage, Governments are also focusing to use websites and mob apps for public information. Governments prefer to convey their information through electronic means, and a large population retrieves that information through web-based portals and their respective mobile apps. Present electronic era is supposed to facilitate all users in equitable manner. But the problem arises when the available web-based content and mob apps do not follow the accessibility standards, which causes accessibility issues, and a large population remains deprived to retrieve information from government websites There is a need to evaluate these services and mobile applications to highlight the accessibility issues for the improvement of the services for visually impaired users. Furthermore, in Pakistan limited research studies were conducted on web accessibility evaluation.

This research study/case study, expanding upon previous work/early studies assesses Pakistani mobile android applications accessibility for visually impaired persons, considering different categories in accordance to WCAG 2.0 and 2.1. The study particularly focuses on government services available through mobile for visually impaired persons and categorizes as: general services (KP Government, ePay Punjab), specialized services (Kamyab Jawan Program, Pharmapedia Pakistan) and public services (Foreign Minister's Portal App, Pakistan Citizen Portal App, Covid-19 Gov PK, HEC eServices, Pak-Identity/NADRA App).

The proposed framework is mob accessibility framework (MAF) for people with visual disabilities.

The Mobile Accessibility Evaluation Framework consists of four major components: Distinguishable, Adoptable, Navigation & Input Modalities and 7 sub-components: Color contrast/Text contrast, Item Description, Image Contrast, Item Label, Orientation, responsiveness/mobile friendliness, Touch Target. These Parameters (major and sub-components) of the framework are most related to the standards and SC of the WCAG2.1 i.e., Adoptable (SC 1.3), Distinguishable (SC 1.4), Navigation & interaction (SC 2.4) and Input Modalities (SC 2.5).

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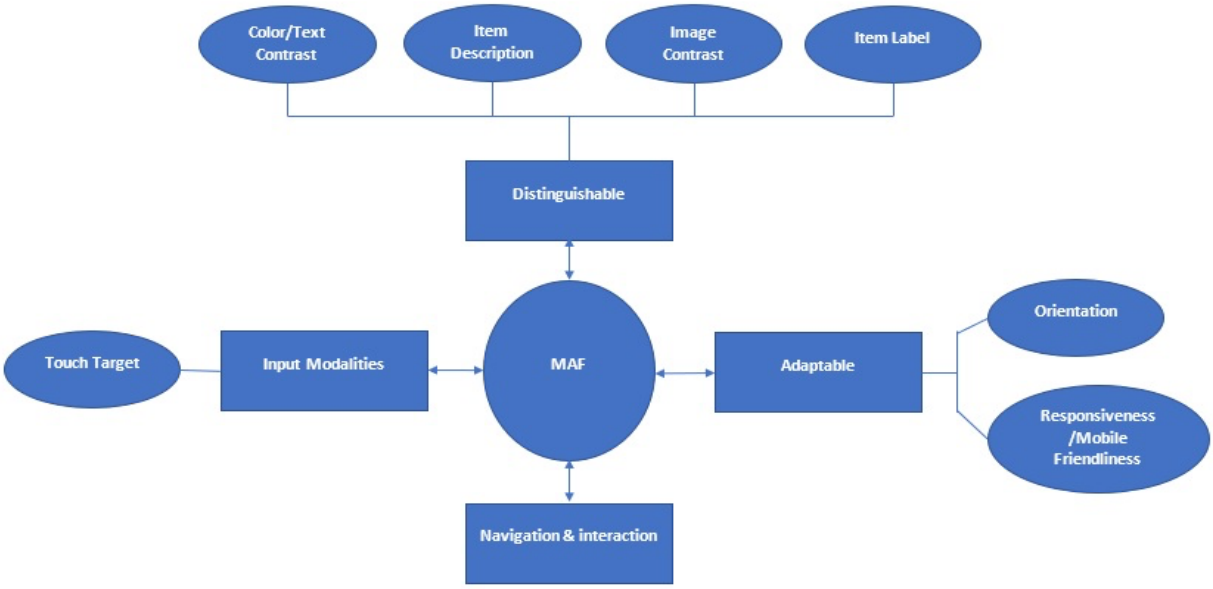

Figure 1. Mobile Accessibility Evaluation Framework

3. Methodology

This study evaluated/assessed Pakistani government services available in web version, mob version and their respective mobile applications (android version) for visually impaired users, considering their popularity and most widely used services. Automated tools used in this research work were Achecker, Wave, Mobile-Friendly, and Accessibility Scanner Tool. According to the WCAG 2.0 guideline, websites must meet Level A standards in order for impaired persons to easily visit them. Achecker, Wave and Webaccessibility tool used for websites evaluation/assessment as these tools assesses/evaluates WCAG 2.0 and 2.1. Acheckder, Wave tool is freely online available tool that evaluate guidelines from WCAG 2.0 while Webaccessibility tool is also freely available online tool which evaluate guidelines from WCAG 2.1 which is the lates version of WCAG. As assessment of the mobile version of websites was also carried out, so for checking the responsiveness/mobile friendliness of the selected website "Mobile-Friendly" tool was used, either these services available in mobile using browser.

3.1. Population of the Study

The author selected Pakistani government services available through mobile having mob and web version as well on the basis of their popularity and most widely used services criteria. The selected apps were as: Pakistan Citizen Portal App, Foreign Minister's app, Pak-Identity app (NADRA), Tigers Force App, HEC eServices, ePay Punjab app, NADRA app, Covid-19 app, Kamyab Jawan Program App, KP Government app, Pharmapedia Pakistan app and their respective mobile and web versions. Except Pakistan Citizen Portal App, all the selected applications available in web version and mob web version as Pakistan Citizen Portal App is only available on Play store.

3.2 Evaluation Tools

Tool selection was based on parameters of the proposed framework (MAF). The selected apps were free of cost and was assessed on android version 11. Android device was selected for assessment of these applications as Android is widely used, with 85.9% of the worldwide sales in 2017 [12], and therefore believed that such a corresponding number of impaired persons worldwide use Android smartphone. The selected apps for android version and mobile version were assessed using "Accessibility Scanner Tool" and their respective web version were assessed using tools: "Mobile-Friendly", "WAVE", "AChecker" and "Webaccessibility tool". The "Mobile-Friendly" is online available tool which is recommended to test the responsiveness of web services. As assessment of the mobile version of websites was also carried out, so for checking the responsiveness/mobile friendliness of the selected website "Mobile-Friendly" tool was used, either these services available in mobile using browser.

The "WAVE" is also online free tool used to identify contrast error, error and alerts of the web services. The online testing tool "AChecker" is recommended for assessment of accessibility effectiveness of overall website to standards available from WCAG. AChecker identify web accessibility problems categorize as: known problems, likely problems, potential problems.

Accessibility Scanner tool is a suggestion provider tool used for enhancement of the accessibility of apps and websites (web services that can be accessible through using mobile though browser). It provides recommendations about how to make an app more accessible. This tool supports many of the WCAG 2.1 standards.

Different tools were selected for assessment of the parameters of the proposed framework as tool selection was based on parameters of the proposed framework (MAF). Image contrast, color/text contrast, item description and item label (sub-components of distinguishable) were the parameters of my proposed framework. So, for the evaluation of these parameters Accessibility Scanner tool was used. As evaluation of mobile version using browser was carried out and mobile friendliness/responsiveness was one of my framework's components. In order to check either selected web services were available through mobile or not, Mobile-Friendly tool was used. WAVE tool was used to evaluate Color contrast as it was one of my framework's components and this tool is used to identify error, contrast error and alerts.

The main/major components/screens/interfaces of mobile apps and their respective mob web version were assessed using the Accessibility Scanner, which assessed the interfaces of mobile apps for content labels, touch target size, clickable elements, textual contrast, contrast in imagery and same for their respective mobile version though browser. The assessment of web version and mob version through automated tools used single entrance/homepage screen of the services for the evaluation.

3.3 Assessment Process Flow

3.3.1 For Mob Apps and Mob Web Versions

The method proposed for the evaluation/assessment of the Pakistani public services having both mobile app and mobile web version (accessible using mobile browser), consisted of seven phases. Phases of the proposed method were sequential and as shown in Figure 2:

- Select applications
- Install apps from Google Play Store
- Install Accessibility Scanner Tool
- Open and activate tool on Android device
- Open apps for assessment
- Record the results
- Analyze the results

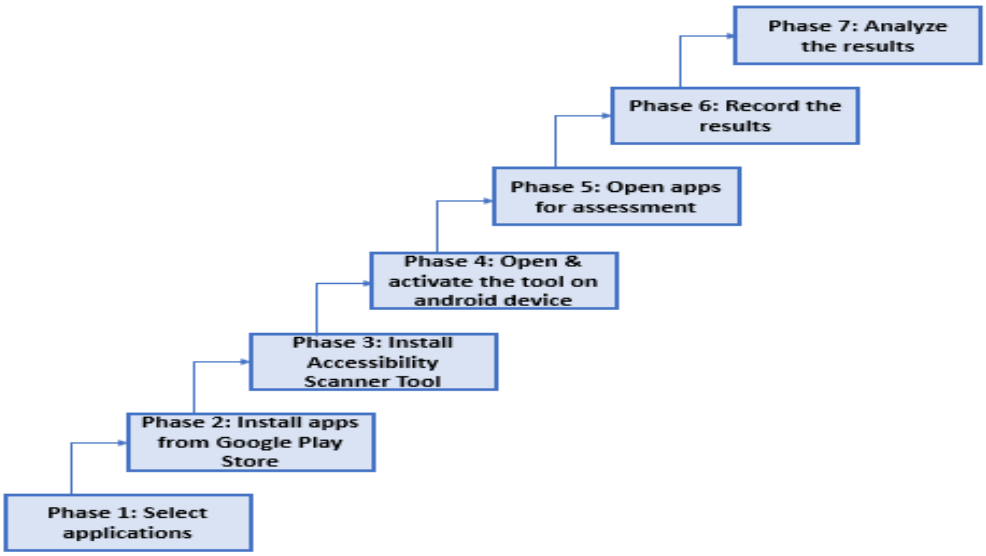

Figure 2. Accessibility Evaluation of Mobile Apps Flow (AMAF)

Phase-1 Select applications: In this phase, selection of mobile applications was carried out.
Phase-2 Install apps from Google Play Store: At this stage, the apps chosen in the previous phase were deployed from Google Play Store.
Phase-3 Install Accessibility Scanner Tool: At this stage, Accessibility Scanner tool was installed/deployed from Google Play Store for evaluation of mobile apps. This tool evaluates guidelines/standards from WCAG 2.1.
Phase-4 Open & Activate the tool on Android Device: At this stage, the installed tool of the previous phase was opened and activated from Accessibility settings of the mobile. After activation a blue button with a tick mark sign will always be visible on mobile screen to capture the screens of apps and mob version. This button is movable on the mobile screen.
Phase-5 Open Apps for Assessment: At this phase, the installed applications were opened and clicked the blue button of the tool for capturing of screens for the purpose of evaluation. To start evaluation of the chosen apps with installed tool, some steps were followed: open and run the applications to evaluate, then press the blue button that provides option for capturing screens. When the too is turned on, the blue button with tick mark icon would always be displayed on the screen.
Phase-6 Record the Results: After that, assessment result through the tool would generate a report of errors/faults in components found in the assessed mob app and data of the evaluated apps saved in Excel Sheet.
Phase-7 Analyse the Results: In last phase, recorded obtained data were analysed using statistical analysis in Excel Sheet. The same assessment process was applied to the mob web version for the assessment. For the assessment firstly activate the Accessibility scanner tool, then open the respective mob web version of the selected mob apps in browser then press on the button of the tool for assessment.

3.3.2 For Web Version (Websites)

The evaluation was mainly focused on the homepage of each service as this research limited the entry page's assessment. The criteria of evaluation of the selected services were the selection of their main pages/homepages for a quick analysis of accessibility assessment, as homepage/entry page is the first page and up-to-date page/section of any website. After selection of websites for evaluation three automated tools: Wave, Achecker and Webaccessibility were used for assessment. The evaluation process involved steps: First opened website in browser and copied its URL, then pasted URL into above mentioned three automated tools in browser one by one. Then automated tools generated results of the websites after evaluation and then the obtained results were recorded in the Excel Sheets individually for statistical analysis.

The next section provides detail and analysis of the results obtained of the evaluated websites using automated tool Wave, Achecker, Webaccessibility tool and results obtained of the evaluated mobile apps and mobile version using Accessibility Scanner tool.

4. Results and Discussion

There are so many tools available for the purpose of evaluation. But according to the need of the developed framework and keeping in view the dataset, population sample four different tools were used that fulfills the need of the proposed framework and described as under:

4.1 A Checker Findings for Web Accessibility

Achecker examined the websites using guidelines available from 2.0. The obtained data/findings indicated that except for two web portals (MOFA, HEC eServices Portal) that reported completely passed and two websites (ePay Punjab, Tigers Force) that reported Conditional passed, hardly any of the web portals examined passed the WCAG2.0 minimum accessibility test (LavelA), as shown in the Table-2. Furthermore, only the Online Payment Government Receipts of Pakistan (ePay Punjab) website received a conditional pass for the 3 levels of standards and Tigers Force Website received a conditional pass for the WCAG 2.0 LevelA only. Ultimately, the study found in the light of results obtained shown in Table-2, that the compliance of web accessibility guidelines/standards across the selected Pakistani government public websites is quite low. The findings appear to be in line with those of others research conducted around the world, such as Malaysia (Aidi Ahmi & Rosli Mohamad, 2016), Nigeria (Adepoju & shehu, 2014).

The criteria chosen for Pass, Fail or Conditional Pass a website is given: if K=0 , L=0, P=0 then Result will be considered passed (P), if K=0 , L> 0 (having some value other than zero), P>0 (having some value other than zero), then Result will be conditional passed (C), if K>0 (having some value other than zero), L>0 (having some value other than zero), P=0 (having some value other than zero), then Result will be Failed (F). Thus, result (R) status purely depends on Known Problem (K) because the indicated Known Problems are critical, demanding the website developer's instant attention.

Accessibility issues are categorized into three parts by AChecker. (a) known problems: to resolve these problems, the web page must be modified, (b) likely problems: to resolve these issues, the web page may need to be modified and (c) potential problems, that describe such issues that AChecker seems unable to identify and necessarily you won't need to change any web pages to address these issues.

Table 2. Detailed Results by Achecker

Website Title	WCAG2.0 (Level A)				WCAG2.0 (Level AA)				WCAG2.0 (Level AAA)			
	K	L	P	R	K	L	P	R	K	L	P	R
MOFA	0	0	0	P	0	0	0	P	0	0	0	P
Pak-Identity	31	0	89	F	10	0	98	F	10	3	106	F
Tigers Force	0	1	117	C	9	1	121	F	9	27	126	F
NADRA Pakistan	26	0	467	F	56	0	497	F	56	235	512	F
HEC-eServices Portal	0	0	0	P	0	0	0	P	0	0	0	P
Online Payment of Govt. Receipts	0	0	38	C	0	0	40	C	0	0	42	C
Covid-19 Health Advisory Platform	37	0	247	F	44	0	298	F	47	69	305	F
Kamyab Jawan	28	0	273	F	63	2	303	F	64	87	308	F
Pharmapedia Pakistan	4	0	778	F	3	0	808	F	3	559	814	F
Khyber Pakhtunkhwa Official Website	180	0	768	F	92	1	876	F	94	438	881	F
Total	**306**	**1**	**2777**		**277**	**4**	**3041**		**283**	**1418**	**3094**	

Table-3 shows the AChecker-generated known problems for all levels of the WCAG 2.0 standard as Known Problems are critical that require immediate attention of developers.

Table 3. Result Summary based on WCAG 2.0

Known Problems	WCAG2.0 (Level A)		WCAG2.0 (Level AA)		WCAG2.0 (Level AAA)	
	Total	%	Total	%	Total	%
1.1 Text alternatives: Provide text alternatives for any non-text content.	239	78.10	35	12.64	35	12.37
1.2 Time-based media: Provide alternatives for time-based media.	NA	NA	NA	NA	NA	NA

1.3 Adaptable: Create content that can be presented in different ways (for example simpler lay-out) without losing information or structure.	3	0.98	10	3.61	10	3.53
1.4 Distinguishable: Make it easier for users to see and hear content including separating foreground from background.	0	0	161	58.12	167	59.01
2.1 Keyboard accessible: Make all functionalities available from a keyboard.	2	0.65	2	0.72	2	0.71
2.2 Enough time: Provide users enough time to read and use content.	1	0.33	1	0.36	1	0.35
2.3 Seizures: Do not design content in a way that is known to cause seizures.	NA	NA	NA	NA	NA	NA
2.4 Navigable: Provide ways to help users navigate, find content, and determine where they are.	37	12.09	51	18.41	51	18.02
3.1 Readable: Make text content readable and understandable.	5	1.63	5	1.81	5	1.77
3.2 Predictable: Make web pages appear and operate in predictable ways.	NA	NA	NA	NA	NA	NA
3.3 Input Assistance: Help users avoid and correct mistakes.	14	4.58	7	2.53	7	2.47
4.1 Compatible: Maximize compatibility with current and future user agents, including assistive technologies.	5	1.63	5	1.81	5	1.77
TOTAL	306	100	277	100	283	100

As per table-3, errors identified at Level A are the highest among the assessment at three Levels. According to Level A requirements, one of the concerns that has to be addressed further is Text Alternatives, which has 239 errors with 78.10% across all evaluated websites. According toa the results obtained shown in the table below, as per second and third level of WCAG, one of the main concerns that needs to be addressed further is Distinguishable in both Level's requirements, which has 161 errors with 58.12 % in Level AA and 167 errors with 59.01% in Level AAA across all evaluated websites. Consistent with Aidi Ahmi & Rosli Mohamad (2016), Level A suggests the provision of Text Alternatives which is also known as "alt attributes" providing text replacement for other non-textual components, e.g., graphics, areas, embeds, buttons and form elements. As the availability of a text alternative allows users to see the content like its original content intended to see by the user. Therefore, the web developer must pay extra attention to this error identified in the evaluated websites because if the non-text element is related to a page, then its availability is much more essential.

Second highest error identified at Level AA and Level AAA is Distinguishable (Text contrast, Item Description, Image Contrast, Item Label) which was one of my proposed framework's components. Color contrast is the most important component providing usability and screen readability to users. It refers to how well one color stands out from another color. The selection of color contrast is very important of developing a web page specifically the color scheme for the text and foreground, hyperlink text and foreground, current/active hyperlink text and foreground, and accessed hyperlink text and foreground. The WCAG 2.1 recommended minimum contrast ratio for small text must is 4.5:1 and minimum contrast ration for lar text must is 3:1. Thus the evaluated websites violate standard criteria of color contrast and reported as the second highest identified error from Level AA and Level AAA with 58.12% and 59.01% as in figure 3.

Other problems that need more developer's attention are as: Navigability, Adaptability, Readability, Input Assistance, Compatibility etc. Adaptability refers to a degree to which view and operation of content is not limited to a single screen direction, like portrait or landscape. Navigation (links, titled page, scrolling etc.) refers to going from one web page to other web pages within the website. The navigation of websites and apps are called to be accessible if they provide ease for fully access to any application system (web and mobile) to the persons with impairments. The issues/errors listed as not applicable (NA) are those which have not been identified as known issues. Alternatively, AChecker categorises these problems as either likely or potential issues.

Figure 3. Total errors of the three levels (A, AA, AAA)

4.2 Wave Findings for Web Accessibility

Wave examined/assessed the websites using WCAG 2.0 and the evaluation was carried out in browser by following the same process mentioned above. Wave displays feedback concerning the availability of webpages with the help of inserting symbols/icons and signs on to the evaluated webpage. This tool examined the errors as: features, alerts, contrast error, HTML5, Accessible Rich Internet Application (ARIA), based on WCAG 2.0. The websites were accessed dated: 31 January, 2022 for assessment. The evaluation results by Wave shown in Table-4. As the minimum contrast ratio for small text is 4.5:1 according to WCAG 2.0 then in Table-4 the contrast ration above 4.5:1 considered as passed of the respective websites while contrast ratio below 4.5:1 considered as failed.

Table 4: Detailed Results by Wave

Main	Errors													
Sub-categories	Linked image missing alt. text	Missing alternative text	Empty/ Missing Label	Empty Heading	Empty Button	Empty link	Broken aria	Total Errors	Alerts	Structural elements	Large text Contrast Errors	fea-tures	HTML & aria	Small text Contrast Ratio
MOFA	6	0	0	0	0	4	2	12	40	55	19	33	180	8.59:1
Pak-Identity	0	3	0	0	0	1	1	5	3	2	2	0	0	8.59:1
Tigers Force	0	0	0	0	3	1	1	5	11	13	39	3	8	8.59:1
NADRA Pakistan	6	2	0	0	0	3	1	12	194	82	16	51	17	3.35:1
HEC-eServices Portal	0	0	0	0	0	0	0	0	2	0	0	1	0	8.59:1
e-Pay Punjab	0	0	0	0	0	0	0	0	3	0	0	1	2	8.59:1
Covid-19 Health Advisory Platform	0	8	1	0	0	4	0	13	37	83	24	23	779	3.13:1
Kamyab Jawan	2	3	0	0	0	29	0	34	36	48	11	31	141	3.13:1
Pharmapedia Pakistan	1	0	1	0	0	2	0	4	77	56	18	31	33	3.13:1
KP Official Website	0	17	4	12	7	3	6	49	319	149	42	64	10	8.59:1
Total	**15**	**33**	**6**	**12**	**10**	**47**	**11**	**134**	**722**	**488**	**171**	**238**	**1170**	

The results obtained by WAVE showed that every website reported errors except two websites (HEC eServices Portal, ePay Punjab). Figure-4 shows the summary of the errors reported in all evaluated websites.

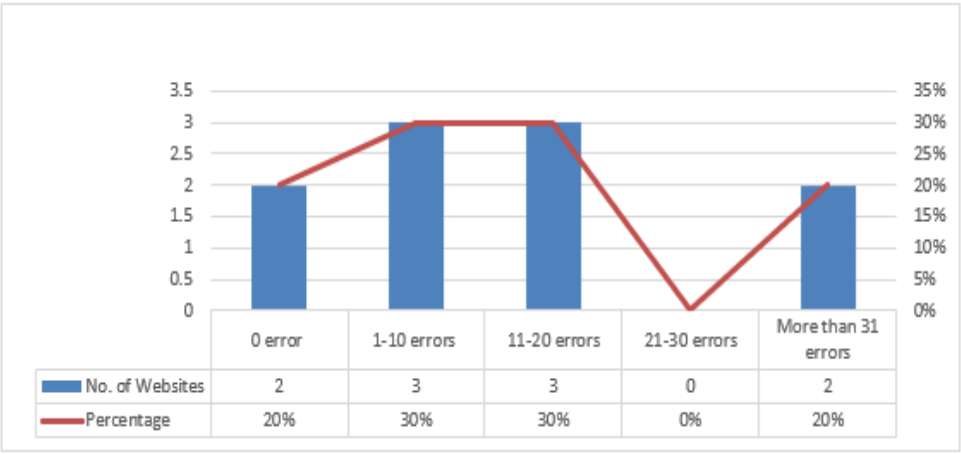

Figure 4. Websites errors summary with percentages

Figure-5 shows the details of the WAVE errors that require immediate attention of the web developers. An "empty link" was the most usually discovered error across the evaluated websites. An "empty link" describes that there is no text in the Hyperlink given on the website. This error found in several studies (Aidi Ahmi & Rosli Mohamad, 2016). To fix this problem, the web developers should include meaningful text within the hyperlink that specifies its functionality. The second highest identified error is" missing text alternatives". Text alternative means there is no text for image. Text alternative is very important for screen-readers when there is an image with no substitute text and due to some reason, the image is unavailable then the screen reader user may not get access to the image. The third highest identified error is "empty heading" which refers to a heading that has no textual content. So, this is another important component and developers must provide a meaningful content for a heading. Its unavailability may cause confusion to the users, as per WAVE certain users like keyboard and screen-reader interact a website on the basis of heading elements. Figure-5 summarizes the other errors reported by WAVE with its significance.

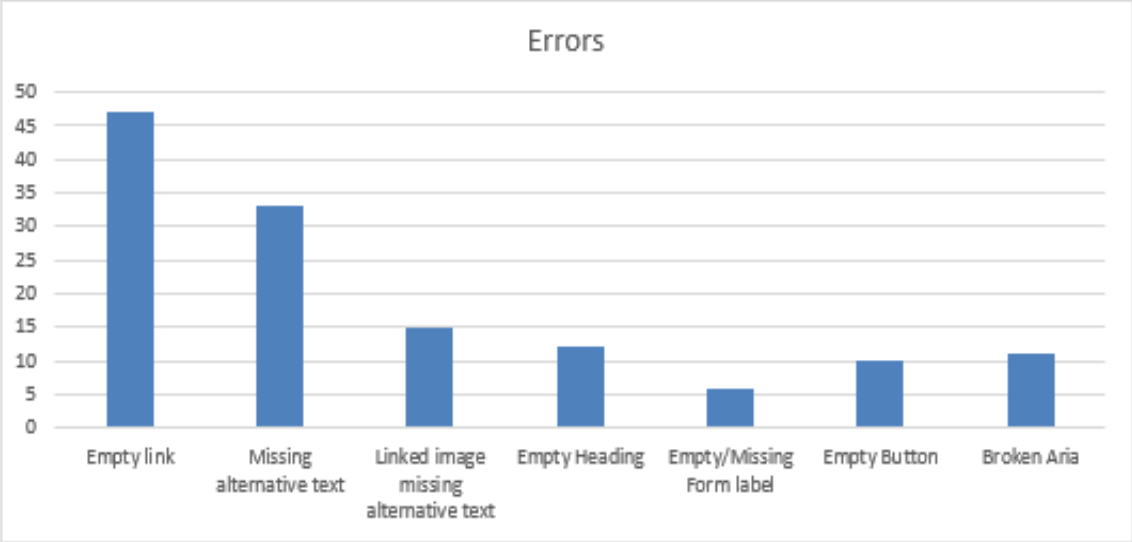

Figure 5. Errors summary with Wave

As navigation and interaction was one of the proposed framework's components so the statistical analysis of the navigation and interaction errors found by Wave and Achecker is shown in Figure-6. According to the analysis of the results obtained from Wave and Achecker, it has been examined that Achecker found 139 errors of navigation and interaction, across all evaluated websites while Wave found 65 errors of navigation and interaction, across all evaluated websites.

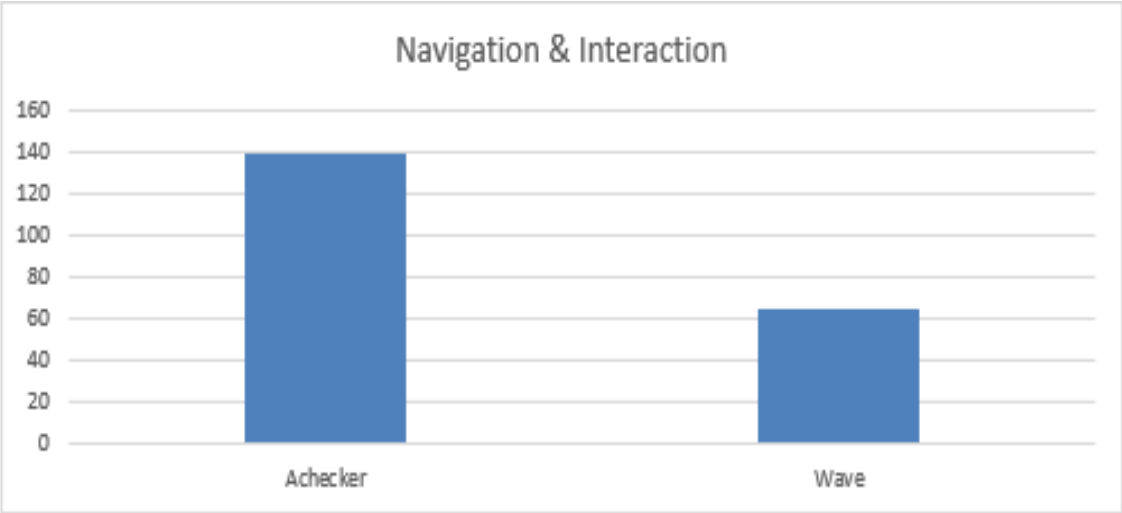

Figure 6. Navigation & Interaction errors by Achecker & Wave

4.3 Web accessibility Tool Findings for Web Accessibility

The webaccessibility tool evaluated websites according to guidelines from WCAG 2.1. This tool checks and analysis the websites accessibility for people with impairments and to check either websites meet the standards/guidelines WCAG 2.1 or not. It evaluated the websites and gave the results included number of violations found and Conformance score in percentage form. Generally, Conformance refers to how well something adheres to a set of guidelines. The term Conformance is one of the guidelines of WCAG 2.1 as Conformance 5, which describes that a website must meet all the requirements of the three levels (A, AA, AAA). The obtained results by webaccessibility tool showed that except for two websites (ePay Punjab, Covid-19) that could not be tested by this tool, none of the websites tested passed completely. Highly violated reported websites were four with low conformance score as: MOFA, Kamyab Jawan, Pharmapedia Pakistan, Khyber Pakhtunkhwa official website, shown in below Figure-7.

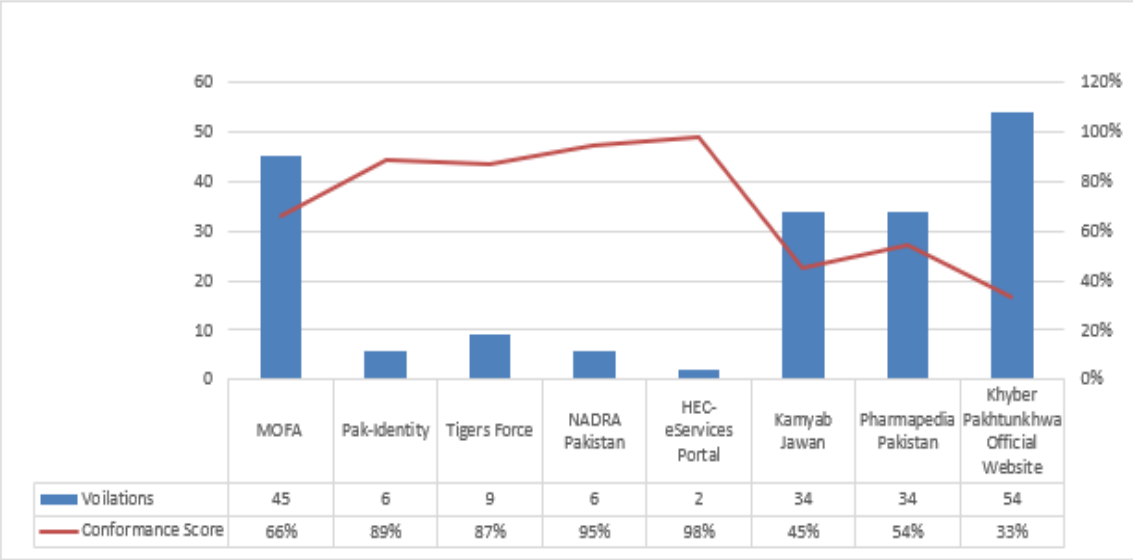

Figure 7: websites violation to WCAG 2.1 with percentages

4.4 Mob Apps Accessibility Results Based on Accessibility Scanner

The Accessibility Scanner tool was used for the assessment of Mob Apps (android version) and their respective mob web version (using browser). The assessment was carried out with android version 11. The mob apps were accessed and opened dated: 10 January, 2022 for assessment. This tool assessed the main screens of the mob apps and home page of their respective mob web version as this study limited the assessment of mob web version to home page and mob apps to main screens. This tool evaluated components: touch target, color contrast/text contrast, image contrast, item description and item label. All these components were my framework's components and defined in the proposed framework's Section (3.1). The threshold for Textual Contrast Ratio, Imagery Contrast Ratio, & Touch Target Size have already set out in the settings of Accessibility Scanner as; Text Contrast Ratio: 4.50, Image Contrast Ratio: 3.00, and Touch Target Size: 48dp. The selected mob apps were assessed and results were saved in Excel Sheet where each app assigned an ID started from character A and onwards, shown in Table-5.

Table 5. Apps with assigned IDs

ID	App Name
A	Prime Minister Citizen Portal PK

B	Foreign Minister's Portal
C	NADRA
D	Pak Identity (Nadra)
E	HEC eServices
F	ePay Punjab
G	Covid-19 Gov PK
H	KP Govt
I	Tigers Force
J	Kamyab Jawan
K	Pharmapedia Pakistan

Table-6 presents errors found in the main screens/interfaces of the mob apps by Accessibility Scanner. The highest identified errors were found in KP Govt. App followed by touch target and color contrast errors of this app. The second highest identified errors were found in Pharmapedia Pak App and app reported on third with errors was Prime Minister Citizen Portal PK. The evaluated apps having Orientation value: 0 means that no orientation issues were found in them vice versa. The results shows that nine applications were found with orientation errors.

Table 6. Mob Apps Accessibility Results by Accessibility Scanner

ID	Elements/ Errors	Touch Target	Colour contrast/ Text contrast	Item Description	Image Contrast	Item Label	Orientation
A	212	72	98	2	2	37	1
B	83	40	15	0	5	22	1
C	147	24	18	2	93	9	1
D	21	3	14	0	0	3	1
E	33	29	4	0	0	0	0
F	87	33	38	3	9	3	1
G	157	59	33	6	0	58	1
H	482	195	84	15	179	8	1
I	11	4	5	0	0	1	1
J	187	125	61	0	0	1	0
K	268	102	128	11	26	0	1
Total	**1688**	**686**	**498**	**39**	**314**	**142**	**9**

Fig-8 shows most recurrent errors found in accessibility assessment of mob apps. The most common recurrent errors are related to "Touch Target" which has 686 errors (40.63%), "text contrast/color contrast" which has 498 errors (29.5%), "Image Contrast" which has 314 errors (18.6%), "Item Label" which has 142 errors (8.4%), and "Item Description" which has 39 errors (2.3%). As a result, the touch target is the most repeated error, followed by the text contrast/color contrast which needs immediate attention of developers as the study main focus was on visually impaired users and these are the users that get more affected by such reported errors than the normal users.

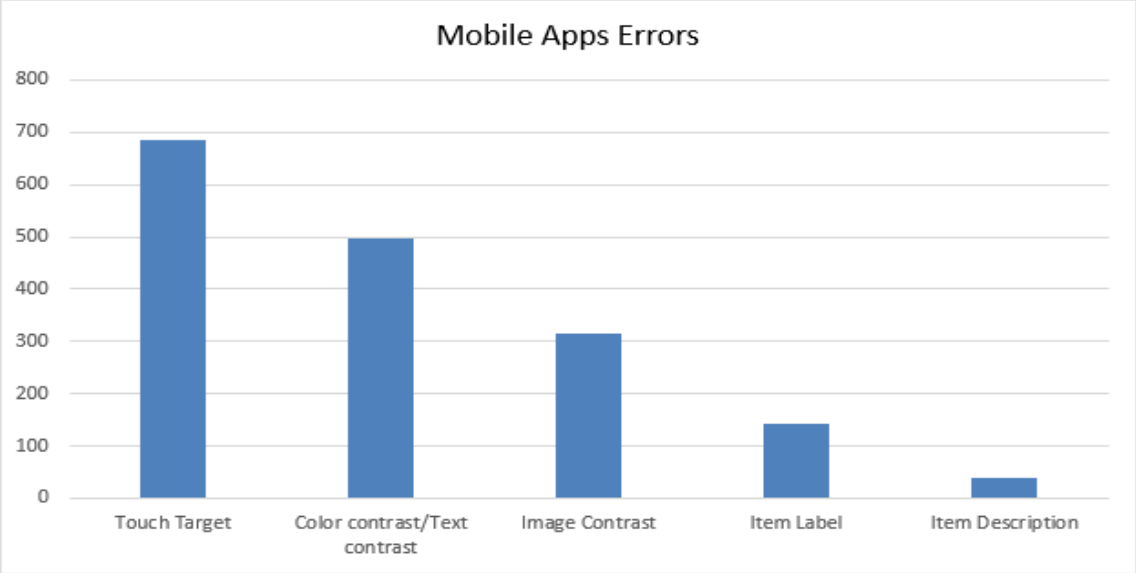

Figure 8: Mob Apps errors identified by Accessibility Scanner

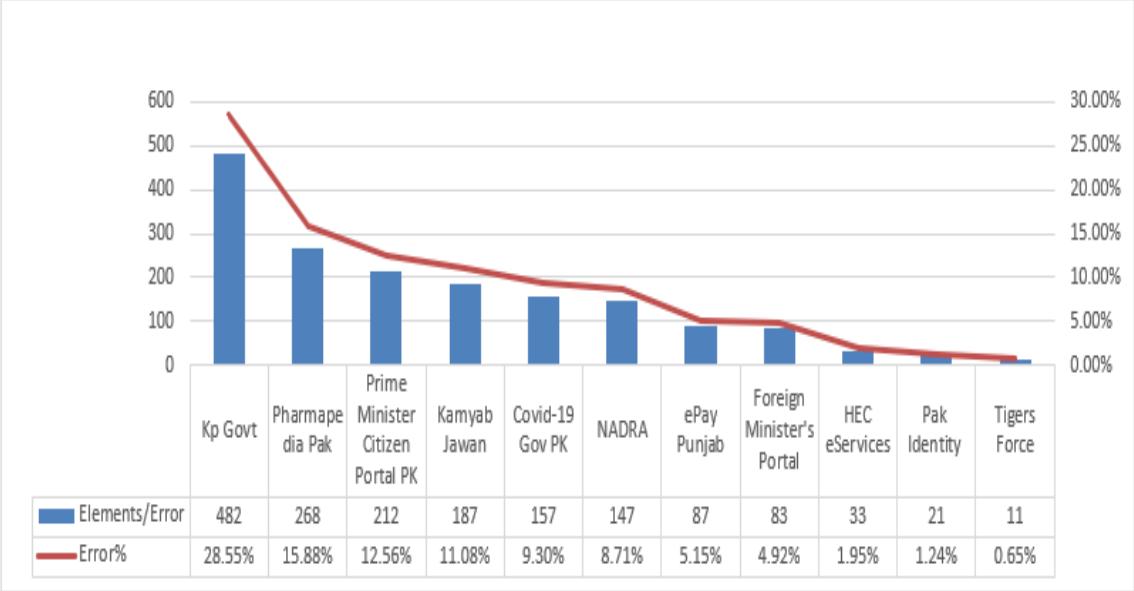

Figure 9: Apps with from highest to lowest errors and percentages

4.5 Mob Web Version Accessibility Results Based on Accessibility Scanner

The mob web versions of the selected apps except Prime Minister's Portal app because its mob web version is not available, by Accessibility Scanner following the assessment process for mob web versions mentioned in above sections. The mob web versions were accessed dated: 10 January, 2022 for assessment. The selected mob web versions were assessed and results were saved in Excel Sheet where each app assigned an ID started from character A and onwards, shown in Table-7.

Table 7. Mob-Web Version with assigned IDs

ID	Mob-Web Version
A	Prime Minister Citizen Portal PK
B	Foreign Minister's Portal

C	NADRA
D	Pak Identity (Nadra)
E	HEC eServices
F	ePay Punjab
G	Covid-19 Gov PK
H	KP Govt
I	Tigers Force
J	Kamyab Jawan
K	Pharmapedia Pakistan

Table-8 presents issues identified in the entry page of the mob web versions by Accessibility Scanner. The highest identified errors were found in KP Govt. followed by touch target and colour contrast errors of this mob web version. The second highest identified errors were found in Foreign Ministers Portal and mob web version reported on third with errors was NADRA. The evaluated mob web versions having Orientation value: 0 means that no orientation issues were found in them vice versa. As mob web version of the selected mob apps were opened though mob browser (Google Chrome), so Google Chrome is auto-rotatable.

Table 8. Mob Web Version Accessibility Results by Accessibility Scanner

ID	Elements/ Errors	Touch Target	Color contrast/Text contrast	Item Description	Image Contrast	Item Label	Orientation
A	156	118	23	0	0	15	0
B	44	40	4	0	0	0	0
C	4	1	2	0	0	1	0
D	9	6	2	0	0	1	0
E	1	1	0	0	0	0	0
F	28	15	1	0	0	12	0
G	166	109	49	0	0	8	0
H	26	19	1	0	0	6	0
I	5	3	2	0	0	0	0
J	5	3	2	0	0	0	0
Total	**444**	**315**	**86**	**0**	**0**	**43**	**0**

Fig-10 shows most recurrent errors found in accessibility assessment of mob web versions. The most common recurrent errors are related to “Touch Target” which has 315 errors (70.94%), “text contrast/colour contrast” which has 86 errors (19.36%), “Item Label” which has 43 errors (9.68%), “Image Contrast”, and “Item Description” which has 0 errors. As a result, the touch target is the most repeated error, followed by the text contrast/colour contrast which needs immediate attention of developers as the study main focus was on visually impaired users and these are the users that get more affected by such reported errors than the normal users.

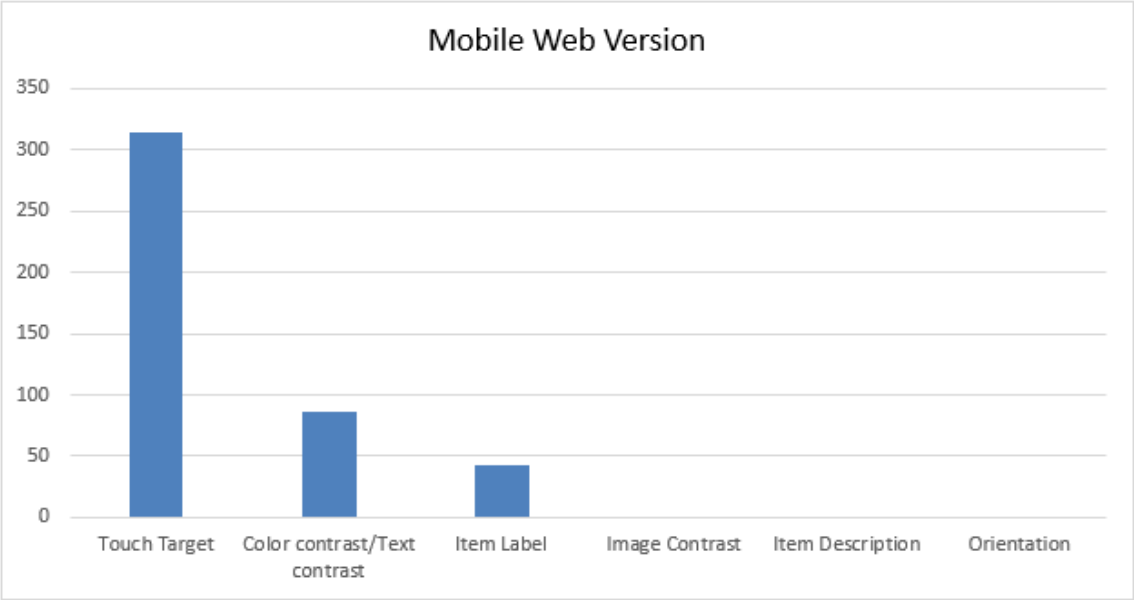

Figure 10: Mob web version errors identified by Accessibility Scanner

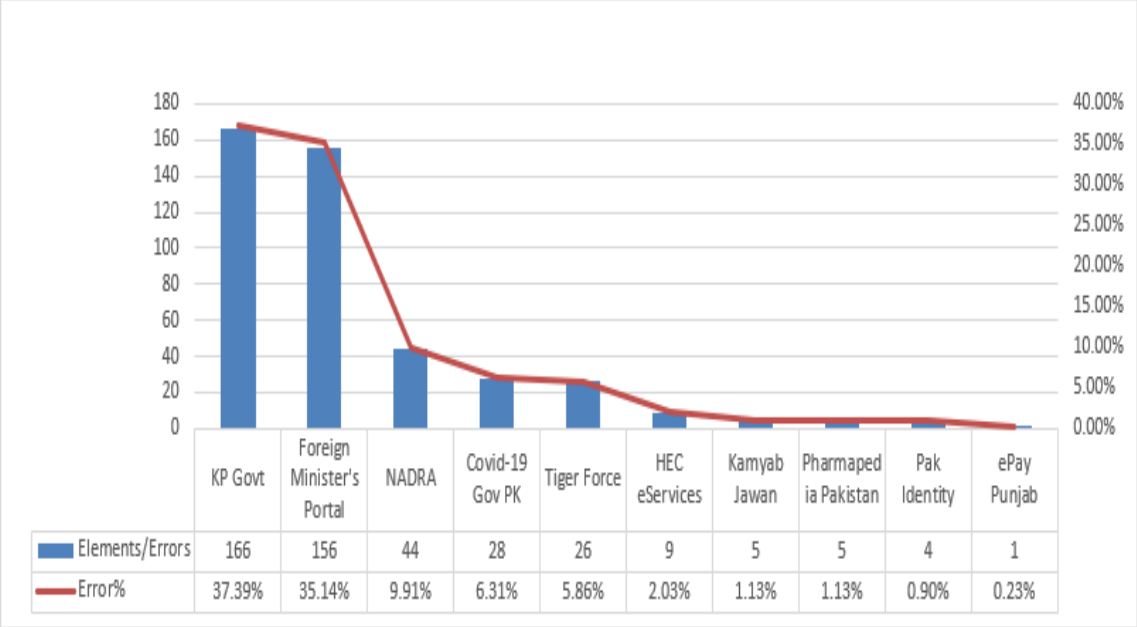

Figure 11: Mob Web Versions errors from highest to lowest with percentages

4.6 Comparative Analysis of Mob Apps and Mob Web Version Results

At the end, comparative analysis was carried out of the results obtained from accessibility scanner tool of the mobile version and mobile applications. So, the analyzed results showed that errors identified in mob apps are greater than errors identified in mob web version by Accessibility Scanner Tool shown in Fig-12. As people now a days prefer to use mob apps than websites and mob web version and the study found more errors in apps than their respective mob web version which indicates serious issues that affect many users specially people with visual impairments. So, developers must incorporate these such while developing services on government scale that will facilitate normal and visually impaired user.

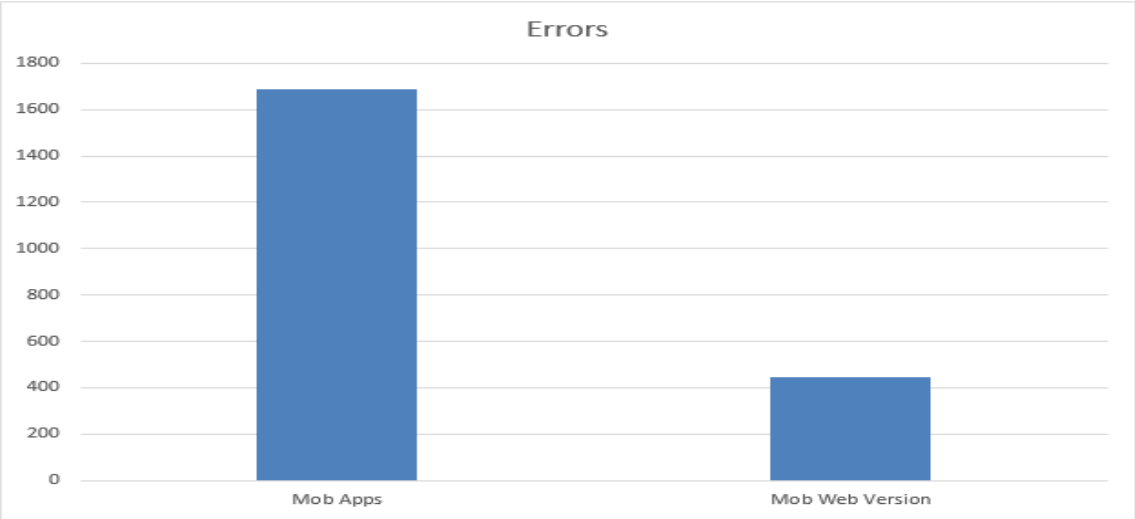

Figure 12: Comparative analysis of mob apps and mob web version

5. Conclusions

According to the findings/results the Pakistani websites, mob apps and mob web versions assessed did not achieve an acceptable level of accessibility by WCAG 2.0 and 2.1. As a result, it is important to correct the deficiencies to meet with the W3C's recommended levels of accessibility to provide full accessibility of services in order to avoid discrimination between normal users and users with visual impairments because the errors identified in three versions (websites, mob apps, mob web versions) of the selected services are the type of errors (color contrast ratio/ text contrast, touch targets, orientation etc.) by which visually impaired users would get more affected than the normal users and people with some sort of impairments need more attention to get fully facilitated by services. This study used three automated tools (online available) for websites assessment and one tool for mob apps assessment (available on play store). In websites assessment the highly identified errors reported: missing text alternatives, empty link, navigation errors while in mob apps and in their respective mob web version the highly identified errors reported: color contrast, touch target and orientation errors in mob apps specially by the selected automated tools. In light of the obtained results, it is nearly impossible for visually impaired users to get access to Pakistani Government services as these services are not built by adopting WCAG guidelines and that's why not satisfying these guidelines. Furthermore, these findings can be used to get recommendations for how to develop and enhance services in order to make them more accessible in equitable manner to all type of users.

Conflicts of Interest: Declare conflicts of interest or state "The authors declare no conflict of interest."

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