Evaluating the Web Accessibility of IIT Libraries: A Study of Web Content Accessibility Guidelines

Subhajit Panda
University Library, Chandigarh University, Punjab, India, and
Rupak Chakravarty
DLIS, Panjab University, Chandigarh, India

Abstract

Purpose:

The purpose of this paper is to investigate and identify the status of Web Content Accessibility Guidelines (WCAG) Conformance levels (A, AA, AAA) and accessibility status in terms of Severity (Error, Warning and Review) and Responsibility (Editor, Webmaster and Developer) of Indian Institutes of Technology (IIT) Library websites based on Siteimprove Software-as-a-Service (SaaS) platform.

Design/methodology/approach:

The library websites of IITs were tested using Siteimprove web-tool to gather details pertaining to W3C's WCAG 2.1 standards. The data thus obtained were then visualized using spreadsheet software for greater insight. A partial correlation test was also done to **assess** the relationship between the three conformance levels.

Findings:

The study could identify significant accessibility-related limitations of the IIT library websites concerning the three WCAG 2.1 Conformance Levels A (max IIT Bombay), AA (max IIT Dhanbad (ISM)) and AAA (max IIT Gandhinagar and IIT Varanashi (BHU)), Severity and Responsibility. A positive linear relationship exists among these conformance levels. The mean value of conformance levels were found to be 18.3 (A), 2.2 (AA) & 3.1 (AAA); Severity scores were found to be 14.4 (Error), 3.9 (Warning) & 5.2 (Review); and Responsibility scores were found to be 6 (Editor), 9.3 (Webmaster) & 8.3 (Developer) respectively.

Practical implications:

The study highlights the comparative picture of accessibility issues and conformance levels of the IITs' library website homepage with the help of results derived/based on Siteimprove Accessibility Checker (SAC). The findings of the study reveal that though the library website of IITs' in India possess a well-designed and easily navigable website homepage as far as their accessibility for VIPs is concerned, there are several issues that are still to be resolved.

Social implications:

WIPO's Marrakesh VIP Treaty (MVT) and the W3C's WCAG cater to the requirements and rights of the persons with vision-related disability of accessing information and knowledge building a steeper and deeper knowledge divide. Identifying and rectifying the shortcomings in the library websites will bridge the accessibility-divide and make the society more inclusive.

Originality/value:

No previous study could be identified evaluating the accessibility issues of library website of Indian IITs focused on vision-disabled persons using Siteimprove. The methodology and approach of this paper have value in terms of reusability and reproducibility facilitating future studies.

Keywords: Marrakesh VIP Treaty (MVT), Web Content Accessibility Guidelines (WCAG), WCAG 2.1, Conformance Levels, Siteimprove, Accessibility of Technological Institutions Library Website, Accessible Format Copy (AFC), Alternate Format Material (AFM), Accessible Books Consortium (ABC), Global Book Famine.

Paper Type: Research Paper

1. Introduction:

Globally, it is estimated that at least 2.2 billion people have a vision impairment or blindness, of whom at least 1 billion have a vision impairment that could have been prevented or has yet to be addressed. But more than 90% of the world's books are not accessible. This is what is known as the Global Book Famine. The "famine" refers to the fact that less than 10% of published works, such as books and educational materials, in developed countries and less than 1% in developing countries are ever made into accessible formats, such as Braille, large print or audio[44]. This also enlarges the fact that persons who are blind in developing countries have only a one in ten chance of going to school or of getting a job. They are in danger of being caught in an unfortunate and vicious cycle of illiteracy and resulting unemployment. The lack of accessible books is a very real barrier to getting an education and leading an independent, productive life. Web Accessibility, access issues with visually impaired or print disabled people and Marrakesh Treaty are not new concepts but are certainly relevant issues for the society. In India studies emphasizing the accessibility problems of the library websites of technical institutions and technology-driven intervention are scarce and needs attention.

2. Literature Review:

To understand the importance of web accessibility and to create awareness here some prominent scholarly researches are discussed. It also correlates the present study among existing literature and visualizes its need for equal access to information.

Angkananon, Wald and Ploadaksorn[3] (2020) in their paper dealt with the accessibility evaluations of Thailand's web using WebThai2Access, which was developed from Web2Access with Thai Evaluation Criteria for the Thai guidelines and evaluation tools to be used to evaluate Thai websites for those with disabilities. Teixeira, Eusebio and Silveiro[39] (2019) aimed to analyse the website accessibility of travel agents (TA) located in the Central Region of Portugal, taking a sample of 182 websites and using the AccessMonitor and TAW automatic evaluation tools based on Level AAA conformance level of WCAG 2.0. Ismail and Kuppusamy[20] (2019) presented the accessibility analysis of higher education websites with the case study of college websites (N=44) affiliated with the University of Kashmir and Cluster University Srinagar in India with the use of two major accessibility evaluation tools, TAW and aXe. In their another study, Ismail and Kuppusamy[21] (2016) provided insights into the current state of web accessibility in 40 websites of North East Region of India by adapting web accessibility evaluation tools namely EvalAccess and WAVE, where the study result emphasized the need for enhancing the accessibility of these websites further. Noh et al.[34] (2015) in their study examined the actual situation of the compliance by conducting web accessibility assessment among 25 websites of the Korean public institutions in the science and technology field according to KWCAG 2.0 web accessibility tool. Adepoju and Shehu[2] (2014) conducted research to evaluate know the usability level via accessibility evaluation of the federal universities in Nigeria using Web Accessibility checker, HERA and WAVE as automated accessibility checking tool according to WCAG (1.0 & 2.0) and the recommendations for improvement on the websites were also included. Lujan-Mora, Navarrete, and Penafiel[31] (2014) analyzed the accessibility of a group of e-government websites of all South American countries and Spain using WAVE, ACheker, Total validator and TAW, tools for accessibility evaluation. Hayafa et al.[8] (2013) have evaluated the increase in accessibility of 20 public educational universities of Malaysia, from 2012 to 2013 and ACheker and TAW was used as a tool for this evaluation. Bakhsh and Mehmood[4] (2012) evaluated the websites of the central government in Pakistan including all ministries and divisions using Functional accessibility evaluator and Total validator accessibility evaluation tools based on World Wide Web Consortium's (W3C) web accessibility standards. Abdul Aziz, Wan Mohd Isa, and Nordin[1] (2010) studied the accessibility and usability level of Malaysia Higher Education Website using 120 samples of higher education institution websites from the online portal of the Ministry of Higher Education according to WCAG 1.0 guideline with the help of EvalAccess 2.0 accessibility checker tool.

Table 1: Application of web accessibility checker(s) in web accessibility research			
S N	Relevant Works		Web Accessibility Checker(s)
	Paper Title	Author(s)	
1.	Development and testing of a thai website accessibility evaluation tool[3]	Angkananon, Wald and Ploadaksorn (2020)	WebThai2Access
2.	Website accessibility of Portuguese travel agents: A view using web diagnostic tools[39]	Teixeira, Eusebio and Silveiro (2019)	AccessMonitor, TAW

3.	Web accessibility investigation and identification of major issues of higher education websites with statistical measures: A case study of college websites[20]	Ismail and Kuppusamy (2019)	TAW, aXe
4.	Accessibility analysis of North Eastern India Region websites for persons with disabilities[21]	Ismail and Kuppusamy (2016)	EvalAccess 2.0, WAVE
5.	A study on the current status and strategies for improvement of web accessibility compliance of public institutions[34]	Noh, Jeong, You, Moon and Kang (2015)	KWCAG 1.0
6.	Usability Evaluation of Academic Websites Using Automated Tools[2]	Adepoju and Shehu (2014)	WAVE, HERA, ACheker
7.	eGovernment and Web Accessibility in South America[31]	Lujan-Mora, Navarrete and Penafiel (2014)	WAVE, ACheker, Total validator, TAW
8.	Study of the accessibility diagnosis on the public higher institutions websites in Malaysia[8]	Hayafa, Abuaddous, Jali and Basir (2013)	ACheker, TAW
9.	Web Accessibility for Disabled: A Case Study of Government Websites in Pakistan[4]	Bakhsh and Mehmood (2012)	Functional accessibility evaluator, Total validator
10.	Assessing the accessibility and usability of Malaysia Higher Education Website[1]	Abdul Aziz, Wan Mohd Isa and Nordin (2010)	EvalAccess 2.0

Table 1 displayed the bibliographical details and the tools used in web accessibility research. The present study is a further extension of the previous works, attempting to evaluate the current state of web accessibility compliance of Indian IITs' library website homepage with the help of *Siteimprove Accessibility Checker* as outlined by WCAG 2.1 guidelines.

3. The Marrakesh VIP Treaty (MVT):

Marrakesh VIP Treaty (MVT) is a treaty on copyright to ensure access to published copyrighted work to the Visually Impaired Persons and Persons with Print Disabilities (MVT) adopted in Marrakesh, Morocco, on 27th June 2013 after it was ratified by 20 countries. It also includes persons as beneficiaries who are otherwise disabled to written works. The foundations to the Marrakesh Treaty was laid in in 1981 when a joint working group was created between the WIPO (World Intellectual Property Organization) and UNESCO. MVT was enacted on 30th September 2016. The treaty has 22 articles dealing with various recommendations. The Treaty imposes two main restrictions/limitations on copyright:

Table 2: MVT - Permissions & Solutions			
SN	Access & Exchange	Permissions	Exception/Solutions
1.	Accessible Copies of Copyrighted Works	1. Print-disabled persons can make themselves OR 2. Done by the Authorized Entities (AEs)	1. Copyright holders'/ publishers' permission not required 2. No need to pay royalties.
2.	Cross-Border Exchange of 'Accessible Format Copies'(AFC) OR Alternate Format Materials (AFM)	Allows AEs to facilitate cross-border exchange of AFC/AFM.	Enable VIPs to access copyrighted works published world-wide thus neutralizing the affect of 'Global Book Famine'.

MVT facilitates the access of books, magazines and other printed materials for the visually impaired/print disabled persons. It creates a positive influence among them and accepted globally including both developing and least developed countries (LDCs). It improves awareness of the challenges faced by the print-disabled community and persons with disabilities, policies making, implement additional provisions in context with other laws, greater access to education. MVT empowers VIPs through Accessible Format Copies (AFC)/Alternate Format Material (AFM) to contribute to cultural developments both as consumers or creators. By adopting AFCs, educational institutions can serve the visually impaired persons ensuring equal access to education, social and cultural inclusion. It has far-reaching implications by reducing poverty and building a more equal society. MVT makes the VIPs economically self-sufficient by providing access to learning materials in accessible formats, which generates opportunities for professional growth, allowing beneficiaries to contribute to their local economies[45].

4. Web Content Accessibility Guidelines (WCAG):

Web Content Accessibility Guidelines (WCAG) is a set of single shared standard for accessibility of web content to make the web more available to disabled people. It is the initiative of the World Wide Web Consortium (W3C) Web Accessibility Initiative (WAI) with the cooperation of individuals and other organizations. The WCAG standards are testable with a combination of automated testing and human evaluation. The "Web Content" contained in a web page includes information such as text, images, sounds and code or markup languages that define the structure, presentation, etc. WCAG 1.0 (published May 5, 1999) had 14 guidelines, ranging from the need for comparable text to web-based clarification and simplicity. Every guideline was backed by one to 10 checkpoints. Content that conforms to WCAG 2.1 (published 5 June 2018) also conforms to WCAG 2.0 (published 11 December 2008)[5]. (This is often called "backwards compatible").

4.1. WCAG Layers of Guidance:

WCAG 2.0 and WCAG 2.1 are stable technical standards that can be referenced. They have 13 guidelines, organized according to four principles, commonly known as **POUR**[42]: **P**erceivable, **O**perable, **U**nderstandable, and **R**obust. There are testable performance metrics at 3 stages for each guideline: **A, AA, and AAA**. WCAG 2.1 covers a wide range of guidelines to improve the usability of Web content. Under these guidelines, websites will be made more accessible to people including having vision-disabilities and how online material (web content) can be made more accessible to disabled persons. These guidelines address web content accessibility on desktops, laptops, tablets, and mobile devices.

Table 3: WCAG Layers of Guidance[33][38]			
Layer	**No.**	***Testable***	***Description***
Principles	4	no	The four principles, POUR[42]: *Perceivable, Operable, Understandable, and Robust*, are the foundation for Web accessibility.
		P	• *Perceivable*: Components of information and user interface must be communicated to users in ways that they can interpret.
		O	• *Operable*: Components of the user interface and navigation must be operational.
		U	• *Understandable*: Information and user interface operation must be comprehensible.
		R	• *Robust*: Content must be robust enough for a wide range of user agents, including assistive technologies, to understand it effectively.
Guidelines (Under the principles)	13	no	Provide the basic goals that authors should work toward in order to make content more accessible to users with different disabilities. Provide the framework and overall objectives to help authors understand the success criteria and better implement the techniques.
Success Criteria	3	yes	Used where requirements and conformance testing are necessary such as in design specification, purchasing, regulation, and contractual agreements. Three levels of conformance are defined: *A (lowest), AA, and AAA (highest)*.
Sufficient and Advisory Techniques	2	partially	For each of the guidelines and success criteria in the WCAG 2.0 document itself, the working group has also documented a wide variety of technique which fall into two categories: those that are *sufficient* for meeting the success criteria and those that are *advisory*.

			Beyond formal requirements allow authors to better address the guidelines. Some advisory techniques address accessibility barriers that are not covered by the testable success criteria.

All of these layers of guidance (principles, guidelines, success criteria, and sufficient and advisory techniques) work together to provide guidance on how to make content more accessible. Authors are encouraged to view and apply all layers that they are able to, including the advisory techniques, in order to best address the needs of the widest possible range of users.

5. Scope of the Study:

The scope of the study consists of the evaluation of Conformance level, Severity and Responsibility of the 23 The Indian Institutes of Technology (IITs). IITs are the autonomous public institutes of the national importance of higher education, governed by the Institutes of Technology Act, 1961. There are currently 23 IITs having a common council (IIT Council), which oversees their administration. The Minister of Human Resource Development (MHRD, GoI) is the ex-officio Chairperson of the IIT Council. The Indian Institutes of Technology (IITs) are prestigious and premier engineering and technology-oriented institutes of higher education established to train scientists and engineers, with the aim of developing a skilled workforce to support the economic and social development of India after independence in 1947. Most of the IITs offer B.Tech. and M.Tech. degrees and research programmes leading to PhD and Post Doctorate degree.

Union Budget 2020-21, Government of India (GoI) allocated a total of Rs.7332 Cr (73.32 billion US $) to the Indian Institutes of Technology (IITs), which is 14.38% more than the last year, i.e. the financial year 2019-20[36].

SN	Table 4: IITs and their locations, sorted by date of establishment			
	Name	Abbreviation	Founded	Indian States/UTs
1	IIT Kharagpur	IITKGP	1951	West Bengal
2	IIT Bombay	IITB	1958	Maharashtra
3	IIT Madras	IITM	1959	Tamil Nadu
4	IIT Kanpur	IITK	1959	Uttar Pradesh
5	IIT Delhi	IITD	1961	Delhi
6	IIT Guwahati	IITG	1994	Assam
7	IIT Roorkee	IITR	1847	Uttarakhand
8	IIT Ropar	IITRPR	2008	Punjab
9	IIT Bhubaneswar	IITBBS	2008	Odisha
10	IIT Gandhinagar	IITGN	2008	Gujarat
11	IIT Hyderabad	IITH	2008	Telangana
12	IIT Jodhpur	IITJ	2008	Rajasthan
13	IIT Patna	IITP	2008	Bihar
14	IIT Indore	IITI	2009	Madhya Pradesh

15	IIT Mandi	IITMandi	2009	Himachal Pradesh
16	IIT (BHU) Varanasi	IIT (BHU)	1919	Uttar Pradesh
17	IIT Palakkad	IITPKD	2015	Kerala
18	IIT Tirupati	IITTP	2015	Andhra Pradesh
19	IIT (ISM) Dhanbad	IIT (ISM)	1926	Jharkhand
20	IIT Bhilai	IITBH	2016	Chhattisgarh
21	IIT Goa	IITGOA	2016	Goa
22	IIT Jammu	IITJM	2016	Jammu and Kashmir
23	IIT Dharwad	IITDH	2016	Karnataka

6. Study Objectives:

i. To highlight briefly the concept and role of Marrakesh VIP Treaty (MVT), Accessible Format Copies'(AFC) and WCAG 2.1 in enabling and empowering the VIPs.

ii. To investigate the status of WCAG 2.1 Conformance levels (A, AA, AAA).

iii. To determine co-relation among the three WCAG 2.1 Conformance levels (A, AA, AAA).

iv. To investigate the status of IIT websites according to Siteimprove parameter Severity (Error, Warning and Review) as manifested in the WCAG 2.1 Guidelines

v. To investigate the status of IIT websites according the Siteimprove parameter Responsibility (Editor, Webmaster and Developer) as manifested in the WCAG 2.1 Guidelines.

7. Research Methodology

The study evaluates the IITs library websites in terms of their accessibility and MVT, WCAG compliance. To examine these websites two tools have been used. The tool which has been used to test and evaluate IIT websites is a Web-Browser plug-in/extension, called *Siteimprove Accessibility Checker **(SAC)*** compatible with both Mozilla FireFox and Google Chrome web browsers. *Siteimprove* is a cloud-based software which enhances the content quality, work towards accessibility compliance, drives search engine traffic, meets data privacy requirements, and measures website performance and ROI of the website to make it proper visible by evaluating every aspect of the website - all in a single platform. *Siteimprove* follow WCAG 2.1 Principle and Guidelines of accessibility criteria and its Accessibility Metrics provide detailed statistical data comprising Conformance Levels (A, AA, AAA), Severity (Error, Warning and Review) and Responsibility (Editor, Webmaster and Developer). However, Siteimprove supports the WCAG 2.1 success criteria either partially, fully or it may not support at all.

8. Results and Discussion:

Here, the statistical value generated by the Siteimprove Accessibility Checker (SAC) after thoroughly evaluate the IITs' library website homepage with the different kinds of accessibility parameter, e.g. conformance level, severity and responsibility; are discussed briefly and try to find any trend present or not.

8.1. Siteimprove Accessibility Metrics Statistics:

The table below represents the overall status of Accessibility Metrics of Indian IIT Libraries' Homepage as measured by Siteimprove through a matrix comprising Conformance Level, Severity and Responsibility. WCAG 2.1 Conformance is broken down into three levels A, AA and AAA. Severity has Error, Warning and Review as its three components while Editor, Webmaster and Developer are the three constituents of the broader matrix Responsibility.

		Accessibility Metrics								
SN	**Name of IIT**	**Conformance level**			**Severity**			**Responsibility**		
		A	**AA**	**AAA**	**Error**	**Warning**	**Review**	**Editor**	**Webmaster**	**Developer**
1	IIT Varanasi, BHU[11]	21	3	5	21	3	5	12	6	11
2	IIT Dhanbad, (ISM)[17]	20	4	4	16	7	5	8	8	12
3	IIT Bhubaneswar[23]	21	3	3	17	5	5	3	11	13
4	IIT Bombay[22]	28	3	4	23	4	8	6	10	19
5	IIT Delhi[24]	27	2	4	17	6	10	11	17	5
6	IIT Dharwad[12]	21	1	2	15	4	5	5	13	6
7	IIT Gandhinagar[14]	14	2	5	14	3	4	6	6	9
8	IIT Goa[15]	13	2	2	10	4	3	3	10	4
9	IIT Guwahati[13]	27	3	3	24	5	4	3	12	18
10	IIT Hyderabad[16]	19	3	2	16	4	4	6	7	11
11	IIT Indore[25]	14	2	3	11	4	4	6	7	6
12	IIT Jammu[9]	12	1	3	6	4	6	6	8	2
13	IIT Jodhpur[26]	24	2	3	19	5	5	6	10	13
14	IIT Kanpur[37]	23	2	4	21	1	7	10	10	9
15	IIT Kharagpur[27]	17	1	2	9	3	8	8	11	1
16	IIT Madras[6]	14	2	4	10	5	5	6	8	6
17	IIT Mandi[28]	10	2	2	10	1	3	2	6	6

Table 5: Siteimprove Accessibility Metrics Statistics

18	IIT Patna[29]	15	2	2	15	1	3	4	4	11
19	IIT Roorkee[32]	14	2	1	10	3	4	5	7	5
20	IIT Ropar[30]	22	3	4	20	3	6	8	15	6
21	IIT Bhilai[10]	14	2	3	9	5	5	5	4	10
22	IIT Palakkad[17]	20	2	2	13	5	6	5	16	3
23	IIT Tirupati[19]	10	2	4	5	6	5	4	7	5
	Σ	420	51	71	331	91	120	138	213	191
	Mean	18.3	2.2	3.1	14.4	3.9	5.2	6	9.3	8.3

A. WCAG 2.1 Conformance Levels[40]:

WCAG 2.1 is a reliable, referenceable technical standard. It has 13 rules, structured according to four criteria, commonly known as POUR: Perceivable, Operable, Understandable, and Robust. For each guideline, there are testable performance levels at 3 stages: A, AA, and AAA. These are also known as WCAG 2.1 Conformance Levels.

Table 6: WCAG Conformance Level & Web page success criteria[40]		
Level	**Degree**	**Web Page Success Criteria**
A conformance	Minimum	Conforms Level A
AA conformance	Medium	Satisfies all the Level A and Level AA Success Criteria
AAA conformance	Highest*	Satisfies all the Level A, Level AA and Level AAA Success Criteria,

Level AAA conformance not recommended for entire sites because it is not possible to satisfy all Success Criteria for some content[41].

Accessibility of a website increases higher the conformance level it meets, i.e. from Level A to Level AA and Level AAA. These three levels of conformance are categorized in order to meet the needs of different groups and different situations: A (lowest), AA (mid-range), and AAA (highest).
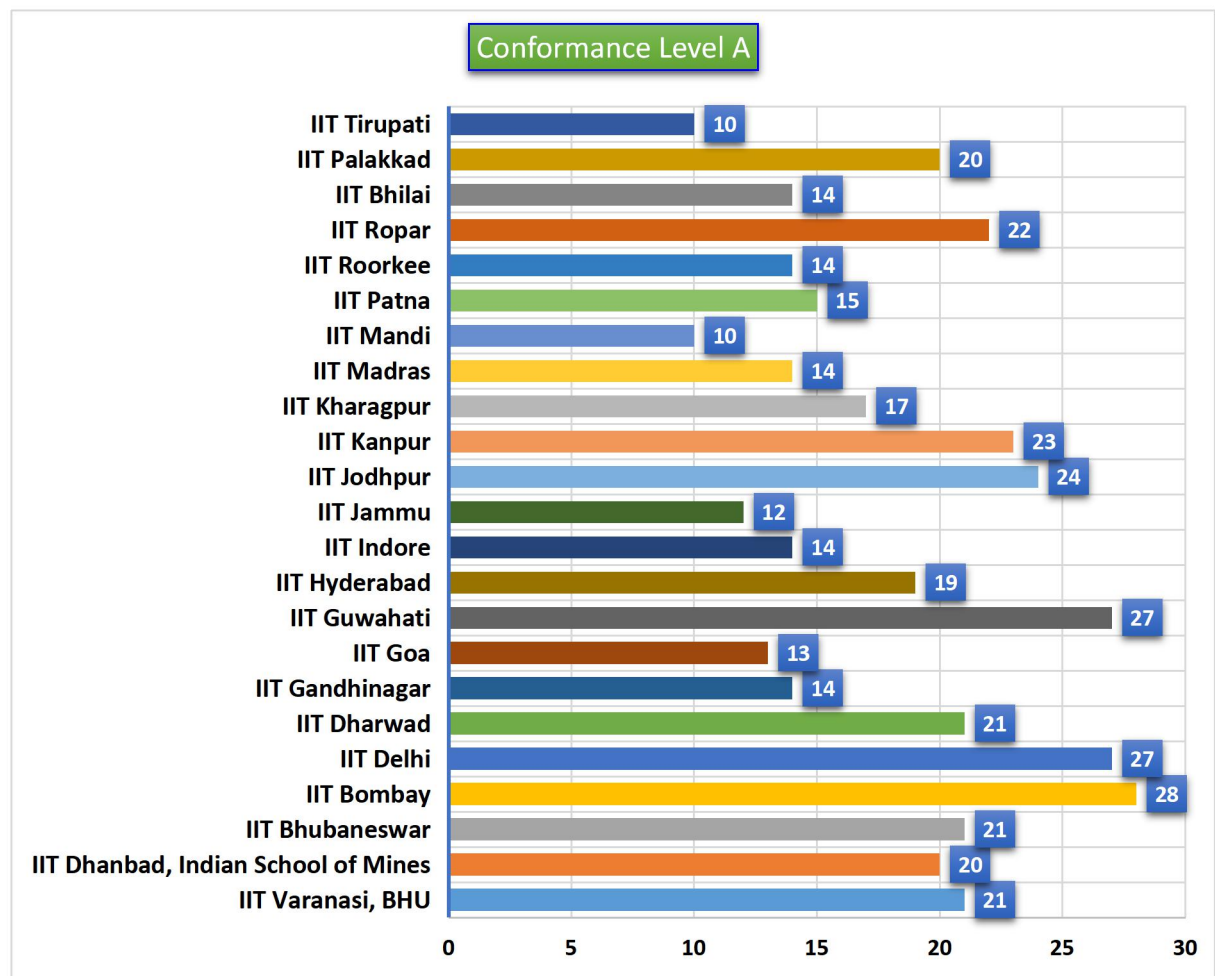
Figure 1: Conformance Level A Statistics

The above diagram shows the statistical values of Conformance Level A success criterion issues conformed by the different IIT Libraries' Website Homepage. IIT Bombay library website homepage meets the highest number of Level A success criterion (i.e. 28) followed by IIT Delhi & IIT Guwahati (2nd rank with score= 27 each). IIT Tirupati and IIT Mandi libraries' website homepage have ranked last with minimum score =10 each as reported by SAC. Websites which have a greater number of issues need to improve to transform their website into a more accessible library website for the disadvantaged users.
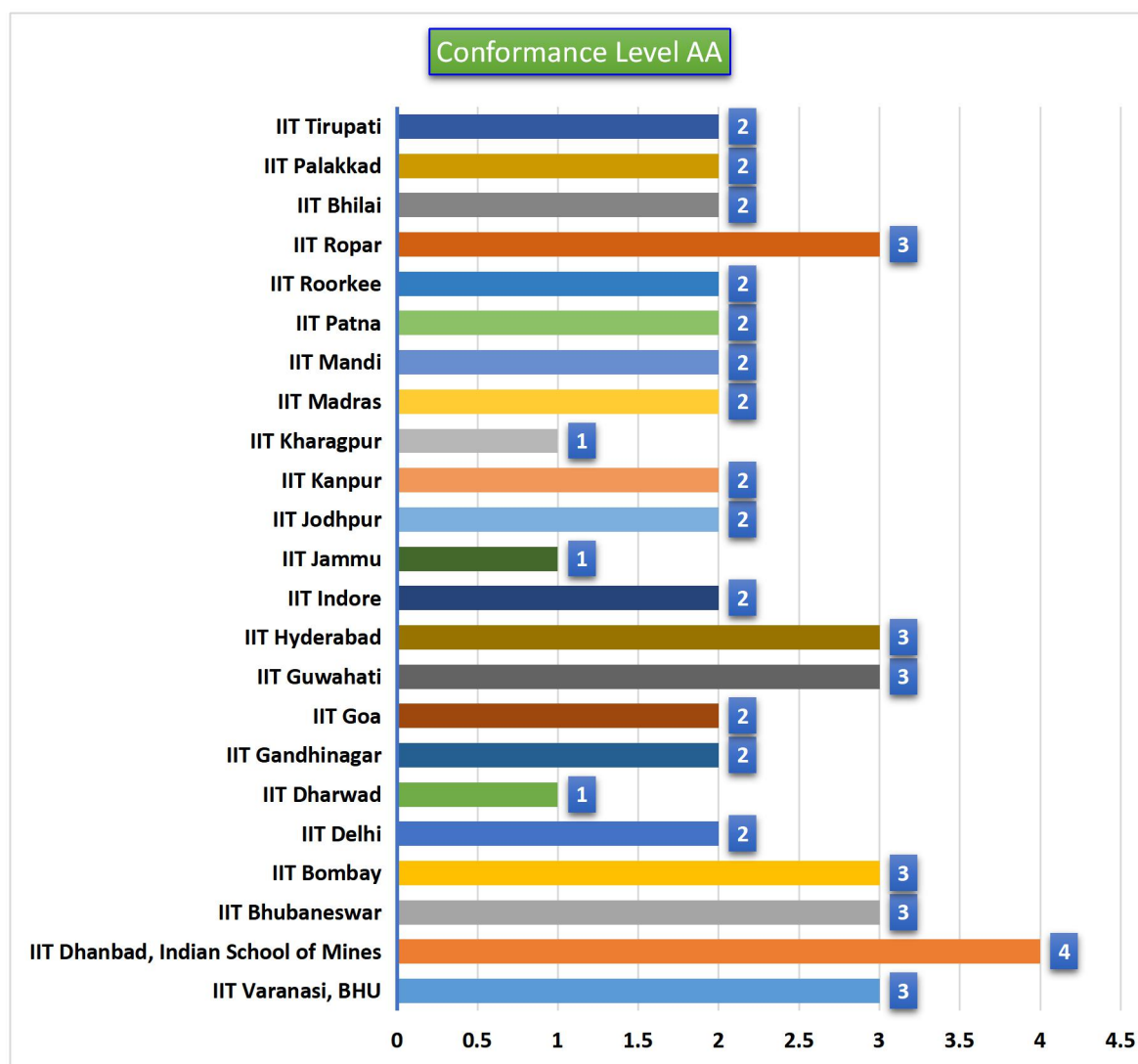
Figure 2: Conformance Level AA Statistics

In case of WCAG 2.1 Conformance Level AA (medium), meeting both the success criterion issues Level A and Level AA, IIT Dhanbad (ISM) library website homepage secured the highest rank (score= 4). The 2nd position is occupied simultaneously by six libraries including libraries websites of IIT Ropar, IIT Hyderabad, IIT Guwahati, IIT Bombay, IIT Varanasi (BHU) etc., with each having score =3. Some library websites managed to obtain a meagre score value of 1 including that of e.g. IIT Kharagpur, IIT Jammu, IIT Dharwad etc. because both the success criterion issues A and AA are not conformed simultaneously by these library websites. To meet the WCAG 2.1 guidelines and to make the library websites more accessible, it is necessary for these websites to adequately meet the Conformance Level AA so that visually challenged persons can also gain information from their web-content easily.
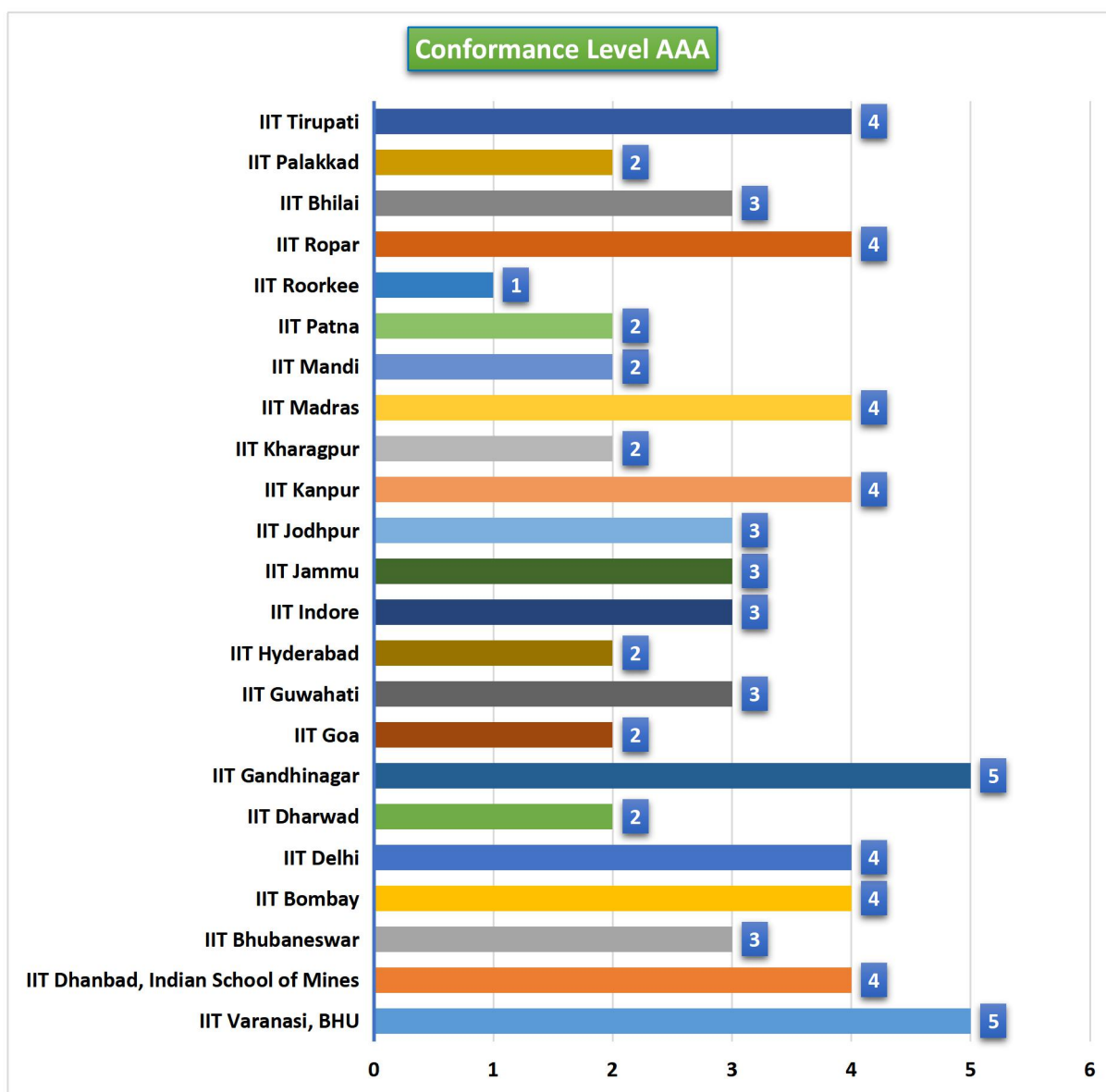
Figure 3: Conformance Level AAA Statistics

Conformance Level AAA is the highest and hardest level of conformance to adhere to. Harder compliance can be attributed to the fact that, in order to obtain this conformance level, Success Criterion Level A, AA and AAA (all of the three) should be simultaneously met. In case of IIT libraries' website homepage, IIT Gandhinagar and IIT Varanashi (BHU) obtained the highest value (i.e. 5) and in second position there are IIT Tirupati, IIT Ropar, IIT Madras, IIT Kanpur, IIT Delhi, IIT Bombay etc (each with 4 value). Library website homepage of IIT Roorkee has the least value (i.e. 1) among the all IITs.
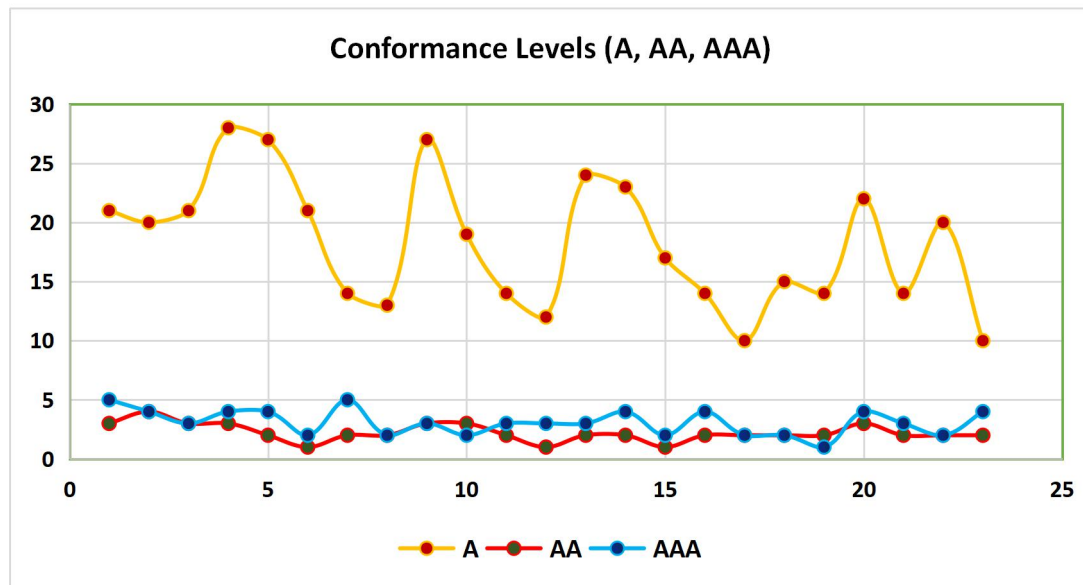
Figure 4(a): Comparative line-graph (Conference Level A, AA, & AAA)
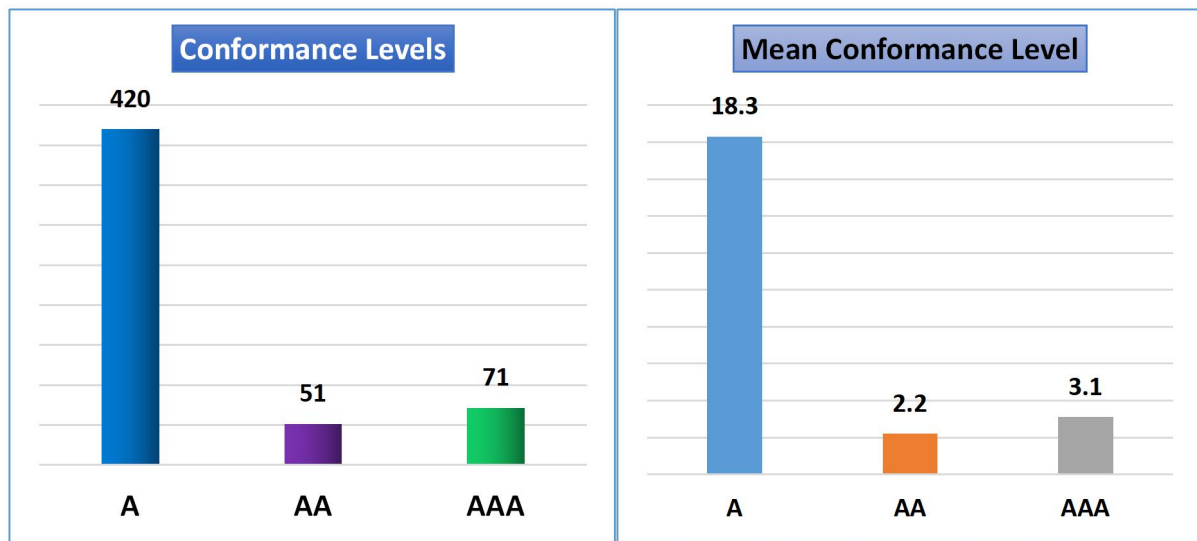
Figure 4(b): Total score of WCAG 2.1 Conference Levels
Figure 4(c): Mean score of WCAG 2.1 Conformance Levels

Fig. 4(a) above depicts the status of the three WCAG 2.1 Conformance Levels - A, AA & AAA. It is evident from the above plot that at the conformance level A, which is easiest of the three, has much higher values (max $_{score}$ = 28) than the levels AA (max $_{score}$ = 4) and AAA (max $_{score}$ = 5). Also, it can be noted that the Conformance Levels AA and AAA issues have similar scores. It is pertinent to note that conformance level AAA is hardest level of conformance to comply with/adhere to. Conformance level score of websites depends upon the structure and content quality of the websites. Fig. 4(b) reflects the aggregated conformance level scores of all the IITs. It can be gathered that the overall score of conformance level A is much higher (Σ score = 420) than in comparison to the levels AA (Σ

score = 51) and AAA (Σ score=71). According to fig. 4(c), the average value of the conformance levels A, AA & AAA were found to be, 18.3, 2.2 & 3.1 respectively.

Correlation coefficients:

Table 7: Corresponding Correlation Coefficients Table of A, AA & AAA[6 43]

	X_1 (A)	X_2 (AA)	X_3 (AAA)	X_1^2	X_2^2	X_3^2	$X_1 x X_2$	$X_1 x X_3$	$X_2 x X_3$
	21	3	5	441	9	25	63	105	15
	20	4	4	400	16	16	80	80	16
	21	3	3	441	9	9	63	63	9
	28	3	4	784	9	16	84	112	12
	27	2	4	729	4	16	54	108	8
	21	1	2	441	1	4	21	42	2
	14	2	5	196	4	25	28	70	10
	13	2	2	169	4	4	26	26	4
	27	3	3	729	9	9	81	81	9
	19	3	2	361	9	4	57	38	6
	14	2	3	196	4	9	28	42	6
	12	1	3	144	1	9	12	36	3
	24	2	3	576	4	9	48	72	6
	23	2	4	529	4	16	46	92	8
	17	1	2	289	1	4	17	34	2
	14	2	4	196	4	16	28	56	8
	10	2	2	100	4	4	20	20	4
	15	2	2	225	4	4	30	30	4
	14	2	1	196	4	1	28	14	2
	22	3	4	484	9	16	66	88	12
	14	2	3	196	4	9	28	42	6
	20	2	2	400	4	4	40	40	4
	10	2	4	100	4	16	20	40	8
Sum	**420**	**51**	**71**	**8322**	**125**	**245**	**968**	**1331**	**164**

Table 7: Corresponding Correlation Coefficients Table of A, AA & AAA

The correlation coefficients r_{12}, r_{13} and r_{23} are computed using[6][43] following expressions:

$$r_{12} = \frac{SS_{X_1 X_2}}{\sqrt{SS_{X_1 X_1} SS_{X_2 X_2}}}$$

$$r_{13} = \frac{SS_{X_1 X_3}}{\sqrt{SS_{X_1 X_1} SS_{X_3 X_3}}}$$

$$r_{23} = \frac{SS_{X_2 X_3}}{\sqrt{SS_{X_2 X_2} SS_{X_3 X_3}}}$$

In this case, based on the data provided, and the calculations made in the table above, we get that

$$SS_{X_1 X_1} = \sum_{i=1}^{n} X_{1,i}^2 - \frac{1}{n}\left(\sum_{i=1}^{n} X_{1,i}\right)^2 = 8322 - \frac{1}{23}(420)^2 = 652.435$$

$$SS_{X_2 X_2} = \sum_{i=1}^{n} X_{2,i}^2 - \frac{1}{n}\left(\sum_{i=1}^{n} X_{2,i}\right)^2 = 125 - \frac{1}{23}(51)^2 = 11.913$$

$$SS_{X_3 X_3} = \sum_{i=1}^{n} X_{3,i}^2 - \frac{1}{n}\left(\sum_{i=1}^{n} X_{3,i}\right)^2 = 245 - \frac{1}{23}(71)^2 = 25.826$$

$$SS_{X_1 X_2} = \sum_{i=1}^{n} X_{1,i} X_{2,i} - \frac{1}{n}\left(\sum_{i=1}^{n} X_{1,i}\right)\left(\sum_{i=1}^{n} X_{2,i}\right) = 968 - \frac{1}{23}(420 \times 51) = 36.696$$

$$SS_{X_1 X_3} = \sum_{i=1}^{n} X_{1,i} X_{3,i} - \frac{1}{n}\left(\sum_{i=1}^{n} X_{1,i}\right)\left(\sum_{i=1}^{n} X_{3,i}\right) = 1331 - \frac{1}{23}(420 \times 71) = 34.478$$

$$SS_{X_2 X_3} = \sum_{i=1}^{n} X_{2,i} X_{3,i} - \frac{1}{n}\left(\sum_{i=1}^{n} X_{2,i}\right)\left(\sum_{i=1}^{n} X_{3,i}\right) = 164 - \frac{1}{23}(51 \times 71) = 6.565$$

Therefore, based on this information about the square sums, as calculated above, the Person's correlation coefficients r_{12}, r_{13} and r_{23} are computed as follows:

$$r_{12} = \frac{SS_{X_1 X_2}}{\sqrt{SS_{X_1 X_1} SS_{X_2 X_2}}} = \frac{36.696}{\sqrt{652.435 \times 11.913}} = 0.416$$

$$r_{13} = \frac{SS_{X_1 X_3}}{\sqrt{SS_{X_1 X_1} SS_{X_3 X_3}}} = \frac{34.478}{\sqrt{652.435 \times 25.826}} = 0.266$$

$$r_{23} = \frac{SS_{X_2 X_3}}{\sqrt{SS_{X_2 X_2} SS_{X_3 X_3}}} = \frac{6.565}{\sqrt{11.913 \times 25.826}} = 0.374$$

Finally, we can compute all the possible partial correlations:

$$r_{12.3} = \frac{r_{12} - r_{13}r_{23}}{\sqrt{1 - r_{13}^2}\sqrt{1 - r_{23}^2}} = \frac{0.416 - 0.266 \times 0.374}{\sqrt{1 - 0.266^2}\sqrt{1 - 0.374^2}} = 0.354$$

$$r_{13.2} = \frac{r_{13} - r_{12}r_{32}}{\sqrt{1 - r_{12}^2}\sqrt{1 - r_{32}^2}} = \frac{0.266 - 0.416 \times 0.374}{\sqrt{1 - 0.416^2}\sqrt{1 - 0.374^2}} = 0.13$$

$$r_{23.1} = \frac{r_{23} - r_{21}r_{31}}{\sqrt{1 - r_{21}^2}\sqrt{1 - r_{31}^2}} = \frac{0.374 - 0.416 \times 0.266}{\sqrt{1 - 0.416^2}\sqrt{1 - 0.266^2}} = 0.301$$

Table 8: Pearson Product Moment Partial Correlation: Ungrouped Data[6][43]	
Statistic	**Value**
Correlation r(xy)	0.416
Partial Correlation r(xy.z)	0.354
Correlation r(xz)	0.265
Partial Correlation r(xz.y)	0.130
Correlation r(yz)	0.374
Partial Correlation r(yz.x)	0.301

● **Results:**

Like the correlation coefficient, the partial correlation coefficient takes on a value in the range from –1 to 1. The value –1 conveys a perfect negative correlation controlling for some variables (that is, an exact linear relationship in which higher values of one variable are associated with lower values of the other); the value 1 conveys a perfect positive linear relationship, and the value 0 conveys that there is no linear relationship. From the table above, it can be easily inferred that a positive statistical value has been obtained for each probable relationship, i.e. either a correlation coefficient or a partial correlation coefficient, suggesting a positive linear relationship between the conformance level A, AA & AAA issues (obtained by SAC on the website homepage of the Indian IIT libraries).

B. Severity:

Siteimprove's severity categorization indicates the appropriate actions to be considered pertaining to the different accessibility findings. Severity is measured through three components namely Error, Warnings and Review. Error and Warning are counted for occurrences of an issue which have been automatically determined to be in contravention of the WCAG 2.1. Review captures issues that cannot be checked automatically but requires a manual inspection to determine if each item lives up to the success criteria.[38] If we consider

accessibility issues as a determination parameter than the Severity components can be described as follows:

SN	Severity Component	Description
	Table 9: Severity Components as a Determination Parameter[38]	
1.	Errors	Issues which have been automatically determined as failures to meet success criteria in the WCAG.
2.	Warnings	Issues which have been automatically determined as failures to meet best practices in the WCAG.
3.	Reviews	Potential failures to meet best practices or success criteria in the WCAG, which can only be confirmed by a manual inspection.
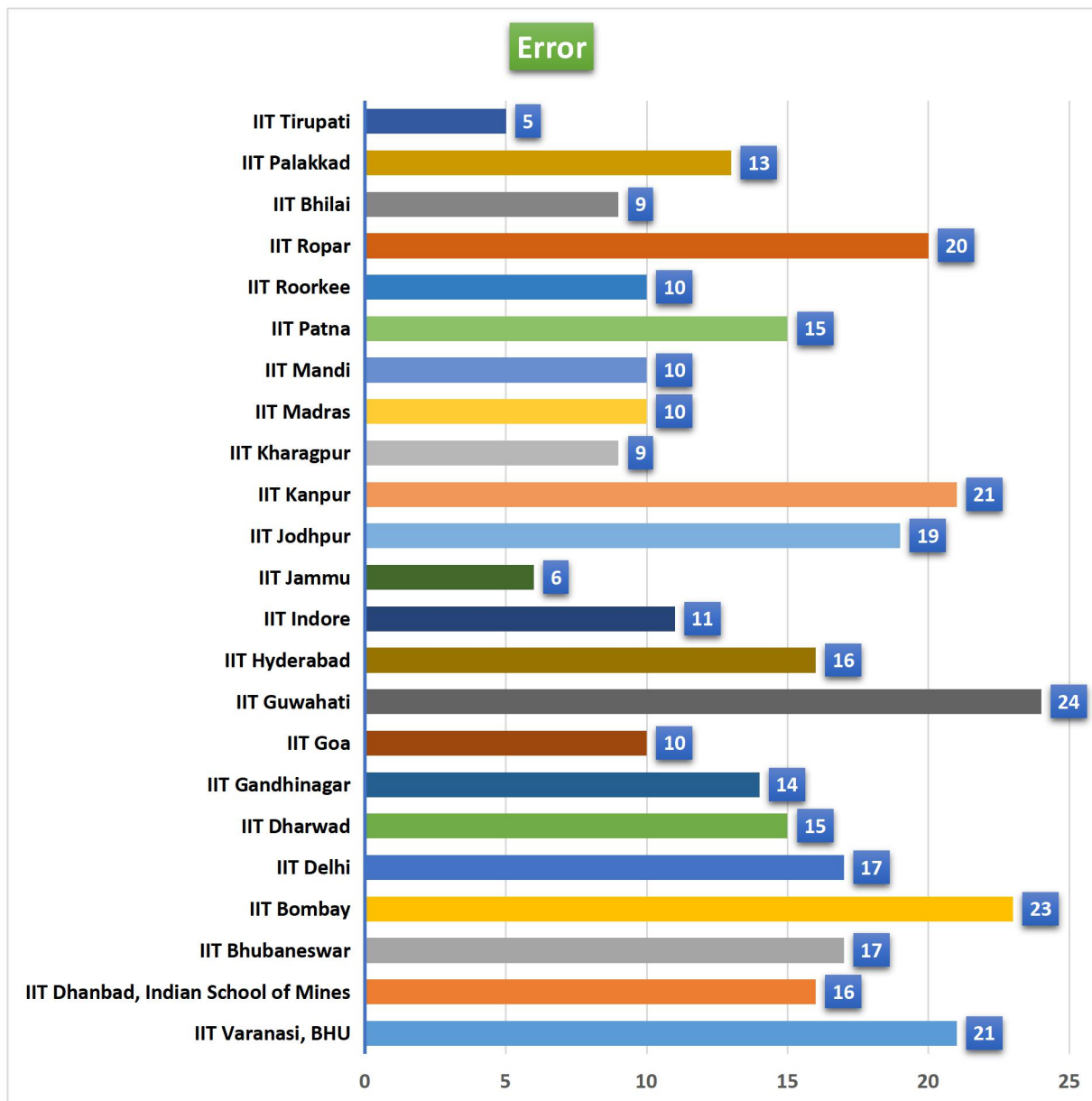
Figure 5: Error value chart

An Error represents an accessibility violation that can be detected automatically. For example, an image tag that is missing the alt attribute. Figure above indicates that Library website homepage of IIT Guwahati and IIT Bombay demonstrated a highest error value (i.e. 24 and 23 respectively) accounting for greater number of accessibility violation in context with WCAG 2.1 principles as evaluated by SAC. Again, some of the IIT Libraries' website scored very low including IIT Tirupati (error value 5) and IIT Jammu (error value 6), which indicates their library websites are easily accessible.
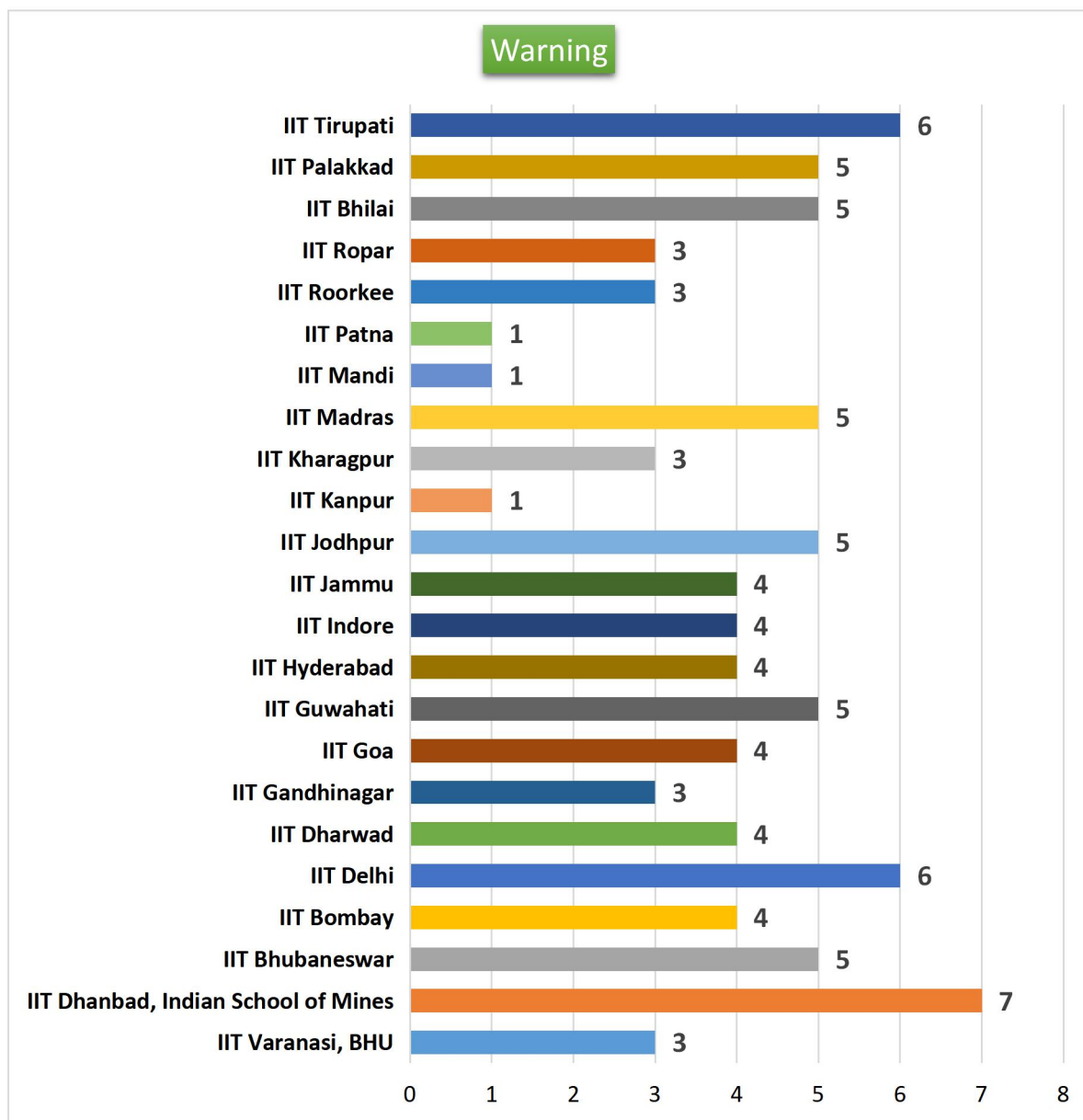
Figure 6: Warning issue chart

A Warning represents content that does not follow best practices and can be detected automatically. For example, having a top-level heading on each page is a best practice. If a page does not have one, the Siteimprove scan flags this as a warning. The above figure indicates that Library website homepage of IIT Dhanbad, IIT Tirupati and IIT Delhi obtained significant number of warning values (i.e. 7, 6 & 6 respectively) that needs to be addressed along with reorganizing website content in a more usable and accessible manner as envisaged by the WCAG 2.1. Library website homepage of IIT Patna, IIT Mandi and IIT Kanpur received the least warning value (i.e.1 each) reflecting positive compliance. Again, warning value 4 and 5 were found to be the most common value for most of the IIT libraries' homepage evaluation.
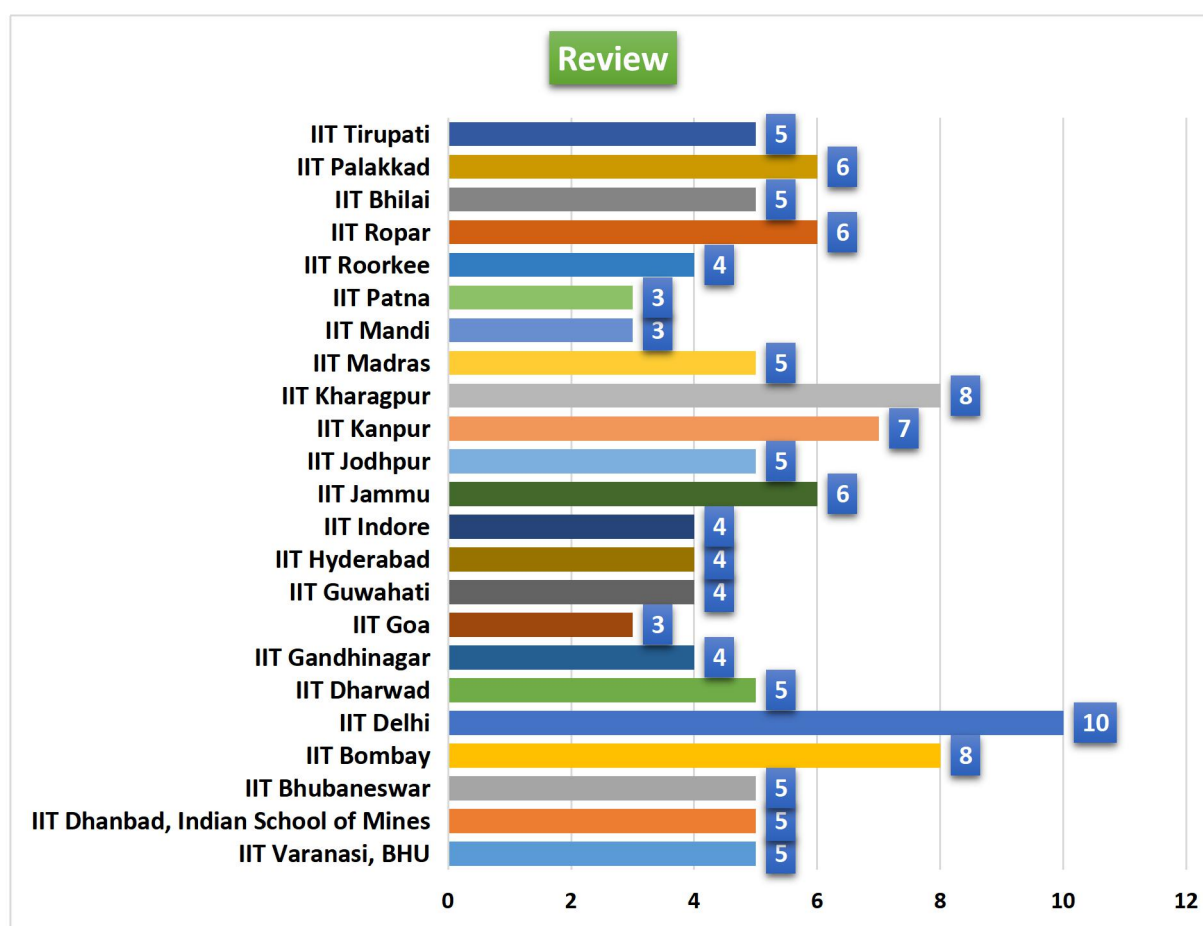

Figure 7: Review issue chart

A Review represents a possible problem that can't be verified automatically and needs to be looked at. For example, verifying that an image has appropriate alt text. Figure above indicates that IIT Delhi library website homepage with a Review value 10 is in highest position among all IITs' and IIT Kharagpur & IIT Bombay is in second position with Review

value 8 each. IIT Patna, IIT Mandi and IIT Goa were found to have lowest Review value (i.e. 3). Again, from the above figure above, it can be noted that Review values 4 and 5 are most common.
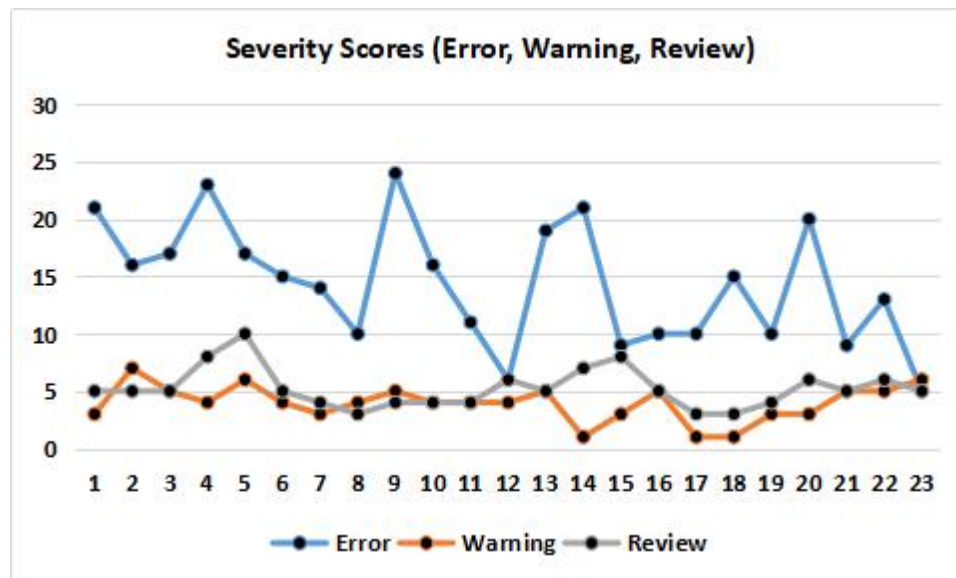
Figure 8(a): Comparative line graph of Severity Scores

Figure 8(b): Total Severity scores of component Error, Warning & Review
Figure 8(c): Mean Severity scores of component Error, Warning & Review

Fig. 8(a) above depicts the status of the three WCAG 2.1 Severity Scores - Error, Warning & Review. It is evident from the above plot that Error has much higher values (max score = 24) than the Warning (max score = 7) and Review (max score = 10). Fig. 8(b) reflects the aggregated Severity scores of all the IITs. It can be gathered that the overall score of Severity

issue Error is much higher (Σ score = 331) than in comparison to the Review (Σ score = 120) and Warning (Σ score=91). According to fig. 8(c), the average value of the Severity issues of component Error, Review & Warning were found to be, 14.4, 5.2 & 3.9 respectively.

C. Responsibility:

In a website evaluation, responsibilities include appropriate job roles for fixing a particular issue type depending on the development, web management set up and other criteria of a particular organization. The Siteimprove Accessibility Service identifies and enables organizations to assign issues to different roles to resolve them in efficiently. In context of Siteimprove, the Responsibility consists of three components viz. Editor, Webmaster and Developer. The issues given in the Editor category are most often introduced through the content creation process using the organizational CMS. The issues given in the Webmaster category are most often coding tasks specific to a sub set of pages. Developer issues reported are most often global issues associated with website templates or CSS. Siteimprove Accessibility delegates issues to Editors, Developers or Webmasters depending on the issue criteria. Webmaster, Developer or Web Editor are the person(s) in charge of the website may choose to assign themselves as an administrator which means that they can go through the issues reported and assign them to lists. The webmaster can also choose to add issues to the list of ignored issues in decisions[38].

| Table 10: Accessibility Delegates and its content lists[38]		
SN	Accessibility Delegates	Content List Includes
1.	Webmaster	has a list in the tool that gives all the issues to be worked on for this role.
2.	Developer	has a list of issues in this category is displayed in the tool. These issues are typically related to style sheets and CSS. Often this list is for a website provider and not the website owner.
3.	Web Editor	has a lists issues that are introduced in the content creation process.
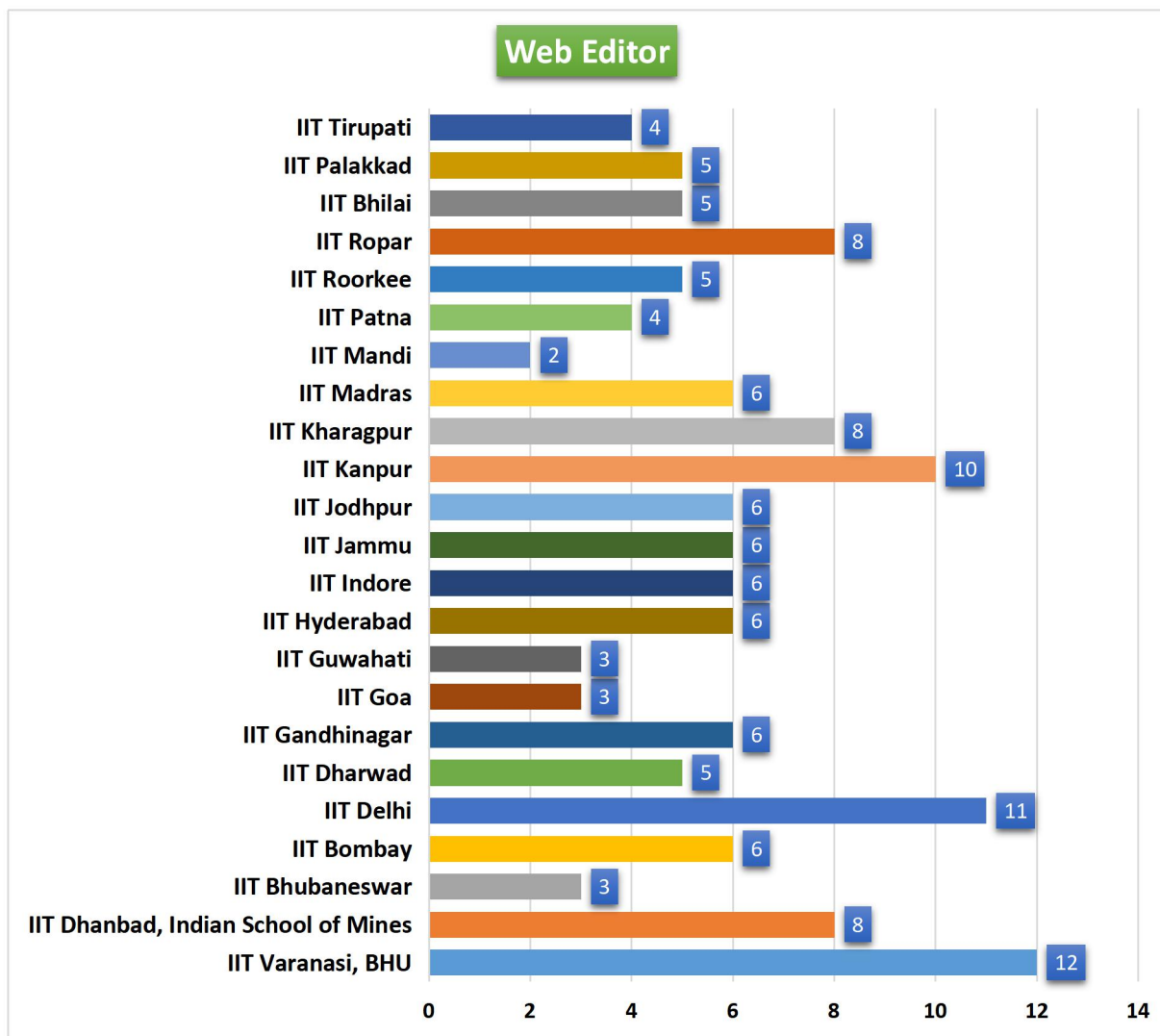
Figure 9: Chart of Web Editor list

A total of 12 issues, the highest, were reported related to Web Editor functionary improvement in case of IIT BHU library website followed by IIT Delhi and IIT Kanpur (with Web Editor related issues 11 & 10 respectively). In case of IIT Mandi only 2 issues were reported to be resolved by the Web Editor. Web editor value is one of the important issues which need to be fixed, and a lower value not always indicates that the website is a perfectly accessible one, it may also be due to insufficient web content present on the web page.
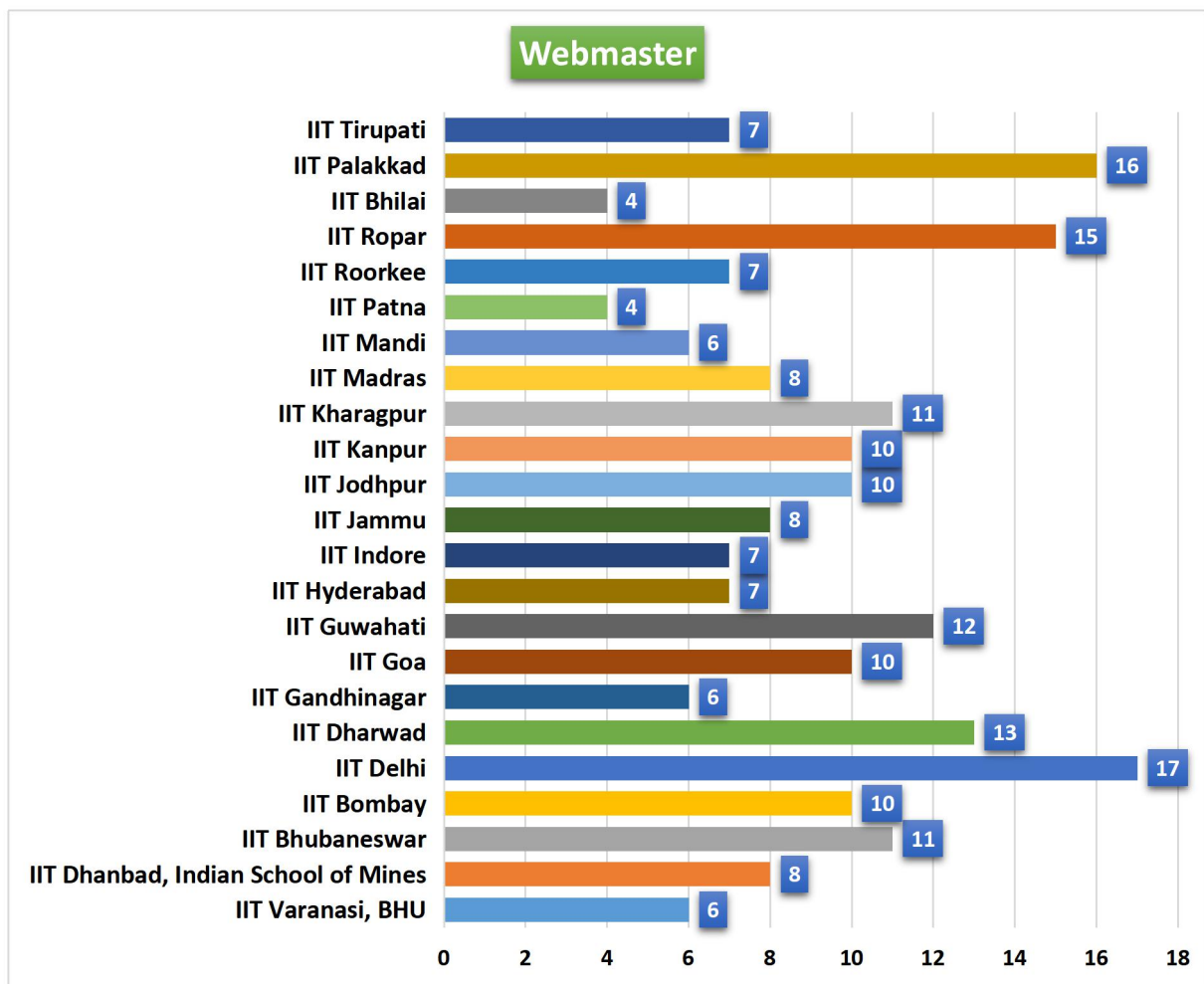
Figure 10: Chart of Webmaster list

Figure above displays a comparative chart of webmaster-related issues of IIT library website under the study tested with SAC. IIT Delhi had 17 issues concerning the webmaster (highest). It was closely followed by IIT Palakkad and IIT Ropar library website with 16 & 15 webmaster related issues respectively. Least number of issues were reported for IIT Bhilai & IIT Patna library websites (only 4) to be addressed by the webmasters of the respective libraries.
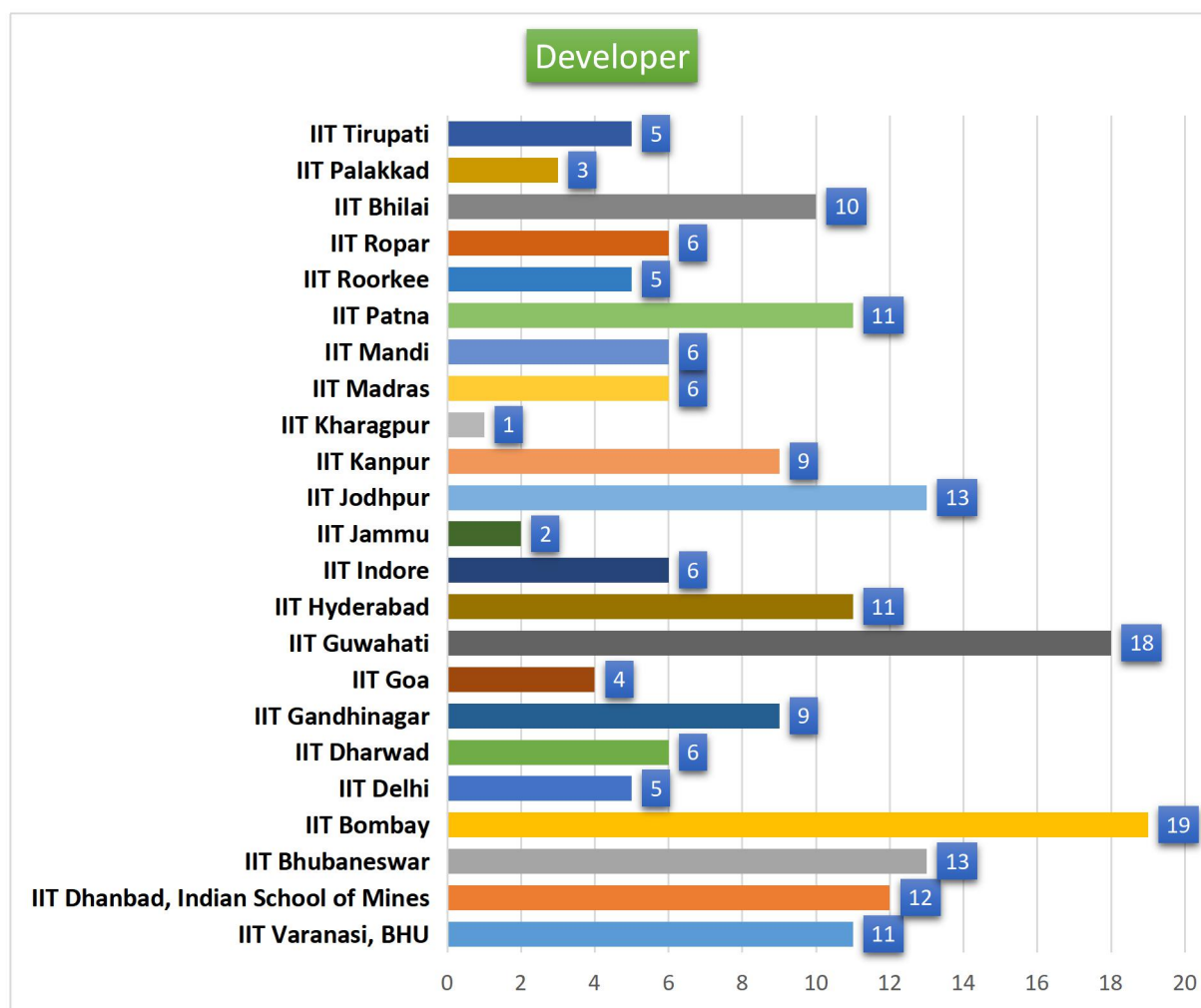
Figure 11: Chart of Developer list

Above figure indicates that IIT Bombay library website homepage were flagged for obtained 19 Developer related which is maximum amongst all the IITs. It was followed by IIT Guwahati with 18 developer-centric issues. Siteimprove could find only one developer related issue for IIT Kharagpur library website which is minimum of the all.
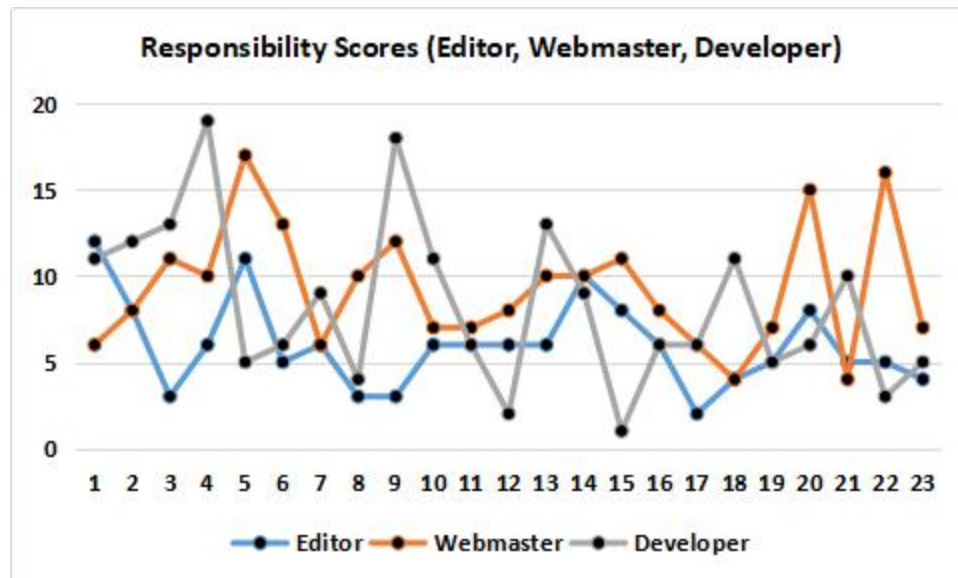
Figure 12(a): Comparative line graph of Responsibility Scores

Figure 12(b): Total Responsibility scores of Editor, Webmaster & Developer
Figure 12(c): Mean Responsibility scores of Editor, Webmaster & Developer

Fig. 12(a) above depicts the status of the three WCAG 2.1 Responsibility Scores - Editor, Webmaster & Developer. It is evident from the above plot that the Responsibility list of Developer has higher values (max $_{score}$ = 19) than the Webmaster (max $_{score}$ = 17) and Editor (max $_{score}$ = 12). Fig. 12(b) reflects the aggregated Responsibility scores of all the IITs. It can be gathered that the overall score of Webmaster list is much higher (Σ score = 213) than in comparison to the Developer list (Σ score = 191) and Editor list (Σ score=138). According to fig. 12(c), the average value of the Responsibility lists of Webmaster, Developer & Editor were found to be, 9.3, 8.3 & 6 respectively.

9. Summary of Major Findings:

The major findings of the study are summarized below:

- Siteimprove Accessibility Checker (SAC) was able to test and evaluate library websites from the perspective of WCAG 2.1 Principle and Success Criteria quite satisfactorily while providing a quantitative score for the three Conformance Levels A, AA and AAA.

- It also calculated values concerning Severity comprising of three parameters Error, Warning and Review.

- The select library websites could also be tested by Siteimprove for Responsibility roles/issues for Editors, Webmasters and Developers.

- In the case of Level A success criterion issue, IIT Bombay library website homepage showed highest compliance while IIT Tirupati and IIT Mandi libraries' website homepage were found to be least effective for this conformance level.
- IIT Dhanbad (ISM) library website homepage obtained the highest value (i.e. 4) for Conformance Level AA while IIT Kharagpur, IIT Jammu, IIT Dharwad was found to be the lowest with score = 1.

- Conformance Level AAA issues are the highest level which includes all the success criterion level A, level AA and level AAA. IIT Gandhinagar and IIT Varanashi (BHU) libraries' website homepage obtained the highest value (i.e. 5) for AAA. The minimum score 1 was reported for IIT Roorkee.

- Statistical tests reveal a positive linear relationship among the three WCAG 2.1 conformance levels A, AA and AAA respectively.

- Highest Error reflecting accessibility violations was reported for the library websites of IIT Guwahati and IIT Bombay while IIT Tirupati and IIT Jammu tested for a low error rates bearing a positive reflection towards accessibility.

- Web content that does not follow best practices and can be detected automatically are represented as Warning. Library website homepage of IIT Dhanbad, IIT Tirupati and IIT Delhi obtained the highest number of warning values (i.e. 7, 6 & 6 respectively). Library website homepage of IIT Patna, IIT Mandi and IIT Kanpur obtained least warning value (i.e.1 each) showing higher compliance with WCAG 2.1.

- Problems in a web page that can't be verified automatically and needs to be looked at are represented as Review. IIT Delhi library website was having 10 issues (maximum) to be reviewed. Library websites of IIT Patna, IIT Mandi and IIT Goa obtained the lowest

Review value (i.e. 3). Again, Review value 4 and 5 are the most common among the Indian IITs' library website homepage.

− Web editor issues are one of the important problems in a website that need to be tackled. A list of 12 issues (maximum) needing web-editor's intervention were noted in the library website homepage of IIT Varanasi (BHU). Least number of issues (2) requiring web-editor's attention were observed for IIT Mandi library website.

− The webmaster also has a list of tools to be worked on to build a well accessible website. IIT Delhi is in the highest position (with value 17) in this list. The lowest webmaster related aspects (4 each) were found for the library websites of IIT Bhilai & IIT Patna.

− Web developer list of issues were maximum (i.e. 19) for IIT Bombay library website while it was minimum (1 only) for the IIT Kharagpur library website.

− A significant variation without any uniform pattern was noted in various Accessibility Metrics obtained for the Indian IIT libraries' website homepage.

10. Conclusion:

"Access to Published Works for Persons Who Are Blind, Visually Impaired, or Otherwise Print Disabled" has been successfully accomplished through the Marrakesh VIP Treaty a.k.a. MVT administered by WIPO. MVT mandates the Authorized Entities (AEs) ("recognized" by the government) located in Contracting Parties (CEs) to facilitate reproduction, dissemination and availability of published works in accessible formats by means of a collection of restrictions and exceptions in their national copyright laws. Currently there are 100 signatories to the *ABC Charter for Accessible Publishing* comprising of 8 high-level principles pertaining to digital publications in accessible formats. ABC also organizes the *ABC International Excellence Award for Accessible Publishing.*

The three important aspects to make the Internet a unbiased and equitable access point are inclusive design, better UX and compliance. The inclusive design ensures website effectiveness for all users, all the time, without adaptation. Regular accessibility checks are suggested to obtain information needed to create and maintain an inclusive web presence. Better UX ensures usage of website by the people of all abilities. With special attention to navigation, ease of use, text clarity, and more, accessibility best practices benefit all users. Compliance helps the organizations in compliance and adherence to global legislation regarding a unified set of Web Content Accessibility Guidelines (WCAG 2.1). Siteimprove and tools like it can be used by libraries to make their website more inclusive and usable leading to utilization of the e-resources to vision-disables clienteles.

Libraries are the epitome of knowledge and are known for serving humanity without any prejudice and discrimination. As more and more user are accessing library websites for fulfilling their information need, it becomes imperative for them to extend the scope of

equitable access to the user community who are less equal owing to their vision-related disabilities. Libraries can use advance tools for assessing their websites' current status regarding Web Content Accessibility and take appropriate initiatives to make them available and accessible for those who have vision defects. The scores received by such tools can be compared with the Web Content Accessibility Guidelines (WCAG) developed by the World Wide Web Consortium (W3C), the current being WCAG 2.1 and upcoming WCAG 2.2 (scheduled to be published in early 2021). Libraries should adopt schedule-based checking their website for any issues flagged by web accessibility checker to adhere to and comply with WCAG 2.1 recommendations. There is no reason, why people with disabilities should be devoid of accessing the scholarly e-resources when technologies are available for the libraries to enrich, improve and align their websites thus bridging the knowledge divide in true sense. This will enable them to take appropriate steps in reshape and redefine library websites for serving their vision disabled patrons with equality and indiscrimination.

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