

Master in Technical Communication and Localization (TCLoc)

Architecting Design Systems for Web Accessibility

A Comparative Study of Web Accessibility Guidelines in Design Systems

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Abstract

The challenges of web accessibility have spanned decades since the inception of the Web and remain a relevant research topic in the current climate of accessibility laws, such as the Americans with Disabilities Act and the European Accessibility Act, being enforced. The World Wide Web Consortium (W3C), the organization responsible for drafting web standards, published several guidelines for building accessible web applications, one of which is the Web Content Authoring Guidelines (WCAG).

Design systems, a recent trend in software engineering, have become a popular way for teams to structure and align design and user experience guidelines, notably web accessibility. This study analyzes a sample of 5 design systems derived from the catalog published by Open UI, a chapter under the W3C, which aims to standardize design systems. A comparative analysis of the design systems on how they integrate accessibility guidelines was performed in 2 aspects: the 4 components of Information Architecture, and quality of alignment with the WCAG.

The results of the analysis could provide useful knowledge for software engineering teams looking to improve accessibility best practices in their teams or explore several benefits of design systems in aligning goals within an organization.

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List of Abbreviations

A11y	Accessibility
ADA	Americans with Disabilities Act
ARIA	Accessible Rich Internet Applications
ATAG	Authoring Tool Accessibility Guidelines
CMS	Content Management Systems
IA	Information Architecture
NPM	Node Package Manager
SSO	Single Sign-on
UI	User Interface
UX	User Experience
W3C	World Wide Web Consortium
WAI	Web Accessibility Initiative
WCAG	Web Content Authoring Guidelines

1. Introduction

In the past decade, design systems have become an essential tool for software companies in scaling their products while achieving a cohesive user experience (Churchill, 2019, p.1). Design systems provide a common visual language and help streamline processes between different stakeholders, such as designers, developers, and content writers (Vesselov & Davis, 2019, p.35). They are usually documented in the form of a centralized website for ease of access and iterative modification. Several large-scale software companies, such as Google, Microsoft, Apple, and IBM, have made their own design systems publicly available, encouraging many software companies to build their own. This move of publicizing guidelines is a response to the web becoming more global and requiring a more democratic and inclusive user experience (Barbareschi et al., 2021, p.1).

However, several studies show that web accessibility is still a current challenge. In 2022, WebAIM analyzed the top 1 million pages, reporting 50.8 accessibility failures per page on average (WebAIM, 2022). Factors, such as different business priorities, lack of awareness, and lack of robust development and testing environments for developers, are the main causes (Patel et al., 2020, p.6).

1.1 Problem Statement

To solve the web accessibility challenge, the Web Accessibility Initiative (WAI) created the Web Content Accessibility Guidelines (WCAG), a public repository of guidelines for web authors, such as developers, to build accessible websites (Web Accessibility Initiative [WAI], 2008). However, developers have expressed a lack of effective resources in understanding such guidelines and testing compliance (Paternò et al, 2020, p.6). Despite the availability of tools to measure WCAG compliance, they still report unreliable results, leading to a lack of trust in such tools (Manca et al., 2022, p.2).

The purpose of a design system in centralizing a business's user experience standards can be leveraged in setting accessibility guidelines in one place, increasing shared knowledge of building WCAG-compliant user interfaces within the team. The potential of design systems for automation may also help streamline WCAG compliance into several development process phases. The most widely adopted design systems have been built by software companies with a huge global user base and have the resources to invest in accessibility (Yew et al., 2020, p.7). By following best practices proposed by the most widely adopted design systems, software engineering teams may benefit from solutions that have been tried and tested. Those with limited time and budgets may save costs and focus on building their products (Häger, 2021, p.4).

While no official standards in design systems have yet been set, initiatives such as the Open UI have started proposing guidelines to solve the vast differences in information architecture (IA) in hundreds of public design systems (Open UI Community Group, 2023). Standards in design systems IA will provide developers with the resources to structure design systems that support accessibility.

1.2 Research Question and Objectives

What are the differences in the information architecture of leading design systems in how they document WCAG compliance?

Objectives:

1. Determine the different ways design systems are structured to incorporate web accessibility guidelines.

2. Evaluate the different design systems based on how they align their guidelines with WCAG criteria.

The results of this research will offer valuable insights to software engineering teams wishing to architect their design systems to include web accessibility.

1.3 Scope and Limitations

The sample was based on the catalog provided by the Open UI Community Group (2023b) and does not include other sources. The sample design systems were only analyzed on the accessibility guidelines: WCAG 2.1 Success Criteria and Sufficient Techniques. Due to time constraints, the methodology employed only manual techniques and used only the search keyword “accessibility”.

2. Review of Related Literature

This literature review will examine the current state of knowledge on web accessibility and the challenges software practitioners face, notably during authoring and testing. This review will also explore the role of design systems and the current state in which web accessibility is articulated in design systems. All related literature has been compiled from peer-reviewed journals, published books, official government websites, and the WAI website, except for four sources (Deque Systems, Inc. 2023; Google, 2023; Penamora, 2023; Sparkbox, 2022). By synthesizing existing research and identifying key themes and trends, this review aims to provide an overview of the opportunities for design systems to solve some of the current web accessibility challenges.

2.1 History of Web Accessibility

Web Accessibility aims to assist users with disabilities with ease of access to the web, which means websites, tools, and technologies should be designed with them in mind (WAI, 2008).

Tim Berners-Lee, the founder of the Internet, during his keynote speech at the 1994 Second International World Wide Web conference, mentioned that "the power of the web is in its universality. Access by everyone regardless of disability is an essential aspect" (*Tim Berners-Lee: The Future of the Web (WWW94)*, 1994). This paved the way for defining accessibility guidelines that later became the Web Content Accessibility Guidelines. 9 years later, in 2008, WCAG 2.0 was released, which went beyond HTML standards, but all digital content. Several minor versions have been released (WCAG 2.1 in 2018 and WCAG 2.2 in 2022) and version 3.0 is in progress (Penamora, 2023).

The Web Accessibility Initiative (WAI), an initiative of the World Wide Web Consortium (W3C), is responsible for defining web accessibility standards and supporting and educating people on them (WAI, 2008). WCAG is one of several components of web accessibility. As opposed to WCAG which are guidelines for consumer content, such as websites, Authoring Tool Accessibility Guidelines (ATAG) cater to tools, such as Content Management Systems (CMS), word processors, photo editors, and video editors (WAI, 2022b).

Several initiatives have also been formalized to address the need for web accessibility. In 1990, the Americans with Disabilities Act (ADA) was signed into law (ADA.gov, 2023), with Section 508 specifically containing accessibility guidelines relevant to electronic and information technology (Section 508.gov, 2022). The EU's Web Accessibility Directive of 2016, which has been derived from the United Nations (UN) Convention on Persons with Disabilities (The Office of the High Commissioner for Human Rights, 2006), covers digital products and services such as computers,

operating systems, and smartphones (European Accessibility Act, 2019). In 2019, the complementary European Accessibility Act took effect, which requires companies to implement the guidelines by 2025.

However, several studies show that web accessibility is still a current challenge. The issue of web accessibility has been raised in several studies in the past (Kelly et al., 2007; Rosson et al., 2005), but remains a relevant topic. During AxeCon 2023, Kumar (2023) mentioned that 37% of lawsuits in the year 2022 were comprised of American Disability Act-related lawsuits. In the same year, WebAIM has done an analysis of the top 1 million pages which reported 50.8 accessibility failures per page on average (WebAIM, 2022).

2.2 Challenges in Web Accessibility

2.2.1 Authoring Challenges in Web Accessibility

A study explored the possible factors influencing the lack of accessibility in websites, and one area of focus is the challenges software practitioners face.

While the W3C provides official and publicly accessible documentation on standards (WCAG), containing an index of Success Criteria and different techniques to fulfilling them (WAI, 2022c).

The main causes are a lack of awareness of what accessibility means, different business priorities, and a lack of robust development and testing environments for developers (Patel et al., 2020, p.4). The authors expound that lacking training or hiring accessibility experts leads to a lack of knowledge in interpreting accessibility guidelines.

Rosson et al. (2005, p.531) also noted that firms are generally cautious in investing in accessible design, as this might not translate to a sizeable return on investments. Without support from businesses, accessibility becomes an afterthought, and software practitioners who value accessibility will feel disempowered.

Kumar (2023) confirms such causes by noting a lack of quality knowledge in software practitioners, inconsistent test results, and fragmented levels of automation for validation.

A consensus on the possible solutions is found in several papers, noting the inclusion of accessibility in university curricula, offering technical workshops on accessibility, and investing in developer tools catered to accessibility (Patel et al., 2020, p.6; Martin et al., 2022, p.5).

2.2.2 Testing Challenges in Web Accessibility

The second area of web accessibility issues that is worth exploring is testing, which serves to validate that the design and development phases comply with accessibility guidelines.

The WAI has made available a huge repertoire of accessibility evaluation tools allowing users to filter by device, accessibility guidelines, industry, or government standards (WAI, 2022b). However, despite the availability and abundance of resources, this still does not resolve the issue of lack of awareness among developers.

One reason is the usability of the accessibility evaluation tools themselves. In a survey conducted by IBM to observe web accessibility skills in their developer teams, developers found that "they are hampered by incomplete skills, new standards, incomplete browser implementations, and inconsistencies in assistive technologies. Tools that should help developers are often unclear, cumbersome, and incomplete when compared to the standards to be tested." (Trewin et al., 2010, p.10).

A recent study exploring the issue of lack of transparency in accessibility evaluation tools hypothesizes that the incoherent results confuse developers and dissuade them from adopting said tools (Manca et al., 2022, p.1). The researchers used a combination of comparative analysis, surveys, and user tests on a set of tools proposed by the WAI. They surveyed 139 users, with a significant number of accessibility experts (36.24%) and web developers (24.64%). The study concludes the following characteristics are what make an accessibility tool useful: providing concise and actionable instructions, accurately matching the needs of the different end-users, and limiting irrelevant details.

While some phases of testing can be automated using software evaluation programs, human testers are required for part of or the entire test in other cases. It is essential to the goals of the WAI, stating that accessibility is about people (WAI, 2023). However, the small sample size and diverse array of disabilities pose challenges in recruiting real human testers, whose feedback is essential for building accurate adaptive technologies (Petrie et al., 2006, p.1134).

Even the effectiveness of WCAG is subject to evaluation, whether it is sufficient and clear for software practitioners to carry out accessibility implementation. Many studies confirm that the guidelines themselves can be regarded as a barrier and must be improved (Hayfa et al., 2016), with differing interpretations of WCAG even among expert testers and developers with web accessibility knowledge. One study considered it complex and ambiguity in some of its passing criteria can be subject to misinterpretation (Alonso et al., 2010, p.8). Another study shows that even experts can be

subject to the Evaluator Effect, where for experts, half of the success criteria fail to meet the 80% agreement threshold, produce 26% incorrect ratings and 20% false positives, and miss 32% of the true problems (Brajnik et al., 2012, p.8). Test results for inexperienced testers and developers produce higher false positives.

Cooper (2016, pp.1-2), a member of W3C, suggested a needs-based approach to addressing web accessibility issues of the 2020s. In his paper, he wrote that comprehensive documentation of accessibility is essential to advancing the guidelines, whose first step is collating all the known needs.

2.3 The Role of Design Systems

Design Systems have recently become an emerging concept in the software industry.

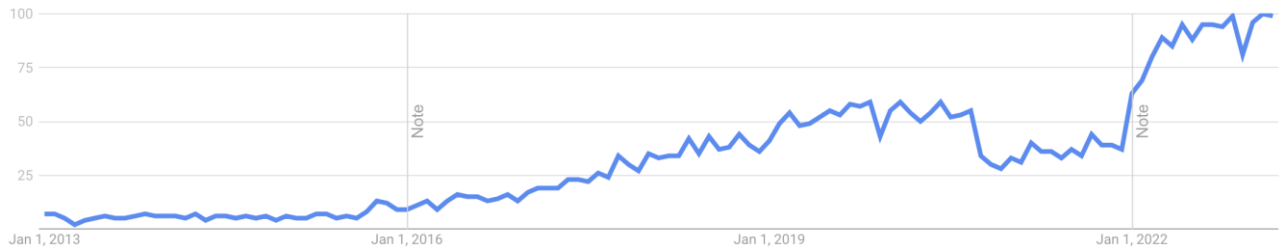


Figure 1. Google Trends on the keyword "Design System" (Google, 2023)

Searching on Google Trends for the keyword "Design System" (parameters: Worldwide, between January 1, 2013, and March 18, 2023, on all categories), we see a significant upward trend starting from the year 2018.

The constant growth of the web has invited more users to adopt it. The Web expanded to several platforms such as mobile phones and tablets and has become more international, catering to a more diverse set of users. This translates to the specialization of roles, where software companies are now comprised of dedicated teams or experts, each with a set of domain skills, such as design, development, content writing, translation, and testing (Yilmaz et al., 2012). This introduces the risk of company silos forming, where each team's own working methods could deviate from the others, a common phenomenon in large enterprises. Modern software needs to address a variety of use cases while remaining robust to deliver a cohesive user experience. Some of the solutions to mitigate company silos are centralizing domain knowledge and aligning teams to company values. All of these trends and requirements explain the recent and natural proliferation of Design Systems (Vesselov and Davis, 2019, p. 5; Lamine and Cheng, 2022, p.2).

However, based on related literature and research, Design Systems still carry some ambiguity in their definition despite several studies showing that the majority of the tech industry sees their importance (Đukic, 2020, p.8; Kilrain & Edelberg, 2020, p.1; Konaté, 2018, p.58; Yew et al., 2020, p.2). This interesting overlap reveals that companies are convinced from having observed the benefits reaped by other companies who have successfully adopted Design Systems, yet have a difficult time bootstrapping due to the lack of industry standards.

2.4 Components of Information Architecture

Along with web accessibility and design systems, information architecture (IA) emerged as a discipline during the growth of the World Wide Web, as explored in the book "Information Architecture" by Rosenfeld & Morville (2002, p.4). The authors relate IA to "the design of shared information environments and the support of usability and findability, in the face of multiple experiences and information overload in the digital era". These challenges are not only limited to end users but also to organizations, where several disciplines coexist and use the same channels for communicating. Their book explores several strategies for applying IA to achieve information coherence across an organization.

According to them, IA is made up of four components:

1. Organizing systems – Categorizing information
2. Labeling systems – Representing information with terminology
3. Navigation systems – Moving through information
4. Search systems – Methods for searching for information

As websites are ever evolving, the longevity of a website depends on the robustness of its IA, in its ability to accommodate and adapt to changes (Garrett, 2011, 91). The same ever-evolving nature can be said of design systems (Lamine & Cheng, 2022, p.18; Suarez et al., 2019), which allow flexibility and scalability but involves maintenance. Vesselov & Davis (2019, p. 68) state that creating a predictable architecture is crucial to the success of a design system. While the book does not explicitly mention IA, it employs the four components of IA through:

- "categorizing to improve discoverability (p. 69)" (Organizing Systems)
- "consistent usage of the terminology defined by the team" (p. 16)" (Labeling systems)

- “navigation that is easy for users to recall and that allows them to perform familiar actions” (p. 82)” (Navigation Systems)

- “vastly improving the usability of a design system by including a search functionality (p. 88)” (Searchability)

This makes a case for IA's role in relaying web accessibility guidelines in design systems.

2.4.1 Information Architecture of Design Systems

Ongoing research strives to define design systems and the parts that constitute them, as supported by related literature in Lamine and Cheng’s paper (2022). Sparkbox (2022) surveyed 219 respondents who work with design systems on what elements constitute their design systems. Those that scored beyond 80% were typefaces, colors, and styles (98%), components (95%), and component documentation (85%). In a study by Werle (2020, p.41), where one of the main objectives is to define the parts of a design system, he sent out a survey asking respondents to list the elements of a Design System and score them by importance. Each element was grouped into categories, each with an average score. Although the element “Buttons” was rated as the most important (98.5%), a broader look at the categories resulted in “Principles" and “Patterns" scoring the highest. Design systems should not be limited to style guides or component libraries. Still, they should represent principles and be a collaboration tool that drives efficiency and better user experience (Vesselov & Davis, 2019, p.xvi).

Currently, a lot of reviewed research can only synthesize the consensus of industry practitioners, while no official standards have yet been made.

Aside from the challenges of naming and structuring, there are also challenges behind the logistics of building design systems.

2.5 Challenges in Building Design Systems

Building design systems is challenging and requires a lot of resources. In startups or small teams, it may not be viable due to time, cost, and resource constraints (Häger, 2021, p.10). This was confirmed by research conducted by Stepanova, where she interviewed 20 UI/UX practitioners from different companies on the impact of design systems in aligning work between interface designers and developers (Stepanova, 2021, p.40). Organizational maturity and stakeholder buy-in decide when it is appropriate to invest in design systems (Vesselov & Davis, 2019, p.47). The authors state the importance of solving the initial issues of getting buy-in from stakeholders (employees, the organization, and users), before starting work with design systems.

Due to the constantly evolving nature of design systems, Lamine & Cheng (2022, p.18) suggest that successful design systems involve a dedicated team, with responsibilities separate from developers and designers that work on other parts of the product.

For companies with fewer resources, one solution is to remove the overhead of establishing design systems by looking at existing design systems. This has been mentioned by several academic papers that include prototyping design systems in their methodologies (Abdi & Marouen, 2021; Aspinall, 2021; Đukic, 2020; Linder & Nilsson, 2022). This was also observed as a common response in a survey carried out during CHI 2020, where “companies increasingly want to develop their own design systems, but will use Material Design as a reference and an influence” (Yew et al., 2020, p.7). In Häger’s thesis (2021, p.4), he suggests startups and small companies use or take inspiration from open-source libraries.

2.5.1 Design Systems and Accessibility

Design systems and their role in addressing usability, centralizing information, and reducing ambiguity could fill the gaps in web accessibility challenges (Vesselov & Davis, 2019, p.83). In the studies previously mentioned, a significant number note the importance, or at least the presence of accessibility in the elements that make up design systems. Häger (2021, p.36) notes that by using a design system, designers and developers can more easily follow web accessibility principles. Vendramini et al. (2021, p.8) observe that one of the main reasons for adopting design systems is to “create alignment with teams”, “create a library of components to improve usability" and “implement built-in accessibility”. Lamine & Cheng (2022, p.2) promote that design systems "ensure that the desired system characteristics concerning usability (such as efficiency, accessibility, and performance) are consistently met”. They also argue that design systems play a vital role in elevating important discussions on UI behavior that require special expertise, such as accessibility and safety. Aspinall (2021) shares during the refactoring of the University of Minnesota’s Health Sciences Library website that the inclusion of an accessibility-focused design system resulted in faster load times due to lower memory footprint, successful site navigation, and increased task completion.

The closest study to the objectives this research wants to carry out is Janetchke’s (2021) research on the Siemens Healthineers Design System, whose focus was improving the accessibility guidelines in the design system. Two sections (Janetschke, 2021, p.41, p.125) briefly compared the information architecture of 4 large-scale design systems (IBM's Carbon, Google’s Material Design, SAP’s Fiori, GE Healthcare’s Edison), which confirms the methodology of my study. However, the

study’s focus was building on improving specifically one design system, whereas my study’s focus will be comparing large-scale, publicly available design systems as a baseline for companies.

2.6 Summary

While there is an abundance of research and literature on web accessibility, there is not enough research on design systems as it is a more recent concept. Literature that deals with the overlap in design systems and web accessibility is further limited. This study aims to bridge the current gaps in web accessibility knowledge and industry standards in structuring design systems, to support software teams in including web accessibility guidelines in their design systems.

3. Methodology

This study will use a quantitative method using primary sources from available public data. There will be two phases. During the first phase, I will focus on defining constraints for selecting design systems. I will then model each of their IA in the different ways they integrate web accessibility. In the second phase, I will then compare the IA of each design system in how they align with WCAG criteria. I will extract the variables that are common in the IA of these design systems and analyze the similarities and differences.

3.1 Sampling

The data is derived from a non-probability purposive sampling of the list in the Open UI Design System Catalog (Open UI Community Group, 2023b), which I further refined with my own criteria (see Table 1, p. 15, below). Out of the 19 design systems listed in the catalog, 5 have been selected for my study.

The following table lists each criterion by order of selection. Performing each step in the following order allowed me to immediately skip a non-matching design system without needing to go through the rest of the criteria.

	Group	**Criteria**	
1	Is a design system	1	Contains design and development guidelines on building components
2	Publicly accessible and open source	2.1	No login or sign up required
		2.2	Developer kit downloadable on NPM or available on GitHub
3	In English	3	Is written in English or offers an English version
4	Values Accessibility	4.1	At least 70% of its component guidelines contain a section with the keyword “accessibility”
		4.2	Has a dedicated page on Accessibility

Table 1. Sampling Criteria

Criterion 1: Is a design system

Some of the items in the list are not actual design systems, but tools related to web development in general and had been included by Open UI in its catalog. For this study, we only select items that include design and development guidelines for building user interfaces. One such exclusion is Chromium, which is an open-source browser on which the Chrome browser is based but does not include any design guidelines.

Criterion 2: Publicly accessible and open-source

A design system is publicly accessible if the design system and source code are available to the public, without signing up for an account or logging in using company credentials (Criterion 2.1). In the list, the Auth0 design system is an internal document reserved only for Auth0 employees requiring Single Sign-on (SSO), so it was excluded from the sample.

Most design systems provide downloadable toolkits or packages containing the necessary elements developers can use to build user interfaces that adhere to the design systems' guidelines. While several public package repositories exist, design systems were selected if their packages are downloadable from Node Package Manager (NPM) or if the source code is available from version control repositories, such as GitHub (see Table 1, p. 15, Criterion 2.2).

Criterion 3: Actively maintained

The NPM website provides package information, such as the list of versions and the number of weekly downloads. For this study, a package is actively maintained if the number of weekly downloads >= 1000.

Criterion 4: In English

This study is conducted in English and to reach a broader audience, only design systems that offer an English version were chosen.

Criterion 5: Values accessibility

Among all the selection criteria, this one holds the most weight for this study and is the main determining factor for selection. Evaluating the inclusion of accessibility in a design system's architecture is an effective way of measuring a design system's investment in accessibility. Information findability is a critical factor of usability and information that is hard to find means the system fails to meet the needs of the user (Rosenfeld & Morville, 2002, p. 25).

Providing accessibility guidelines at a component level could be a beneficial factor in achieving WCAG Success Criteria especially if they relay WCAG Sufficient Techniques. One of these techniques is ARIA, which stands for Accessible Rich Internet Applications, a set of roles and attributes applied when developing web applications (WAI, 2022a). The following table lists the percentage of components containing accessibility guidelines for the selected design systems. The design system is selected if at least 70% of its components include them.

Name	**Maintainer**	**Components**	
		Percentage of components with a section on Accessibility	Total number of components
Bootstrap (2023)	Twitter	79.1%	24
Carbon Design System (2023)	IBM	97.5%	40
Lightning Design System (2023)	Salesforce	72.6%	84
Material Design (2023)	Google	97.1%	35
Spectrum (2022)	Adobe	100%	61

Table 2. List of selected design systems

See Appendix A (p. 40) for the complete list of design systems and their criteria evaluation.

Design systems that value Accessibility, at the very least, mention it as one of their values or principles and include a dedicated page on Accessibility (Lehner, 2023). This last criterion (see Table 1, p. 15, Criterion 4.2) holds lesser weight than Criterion 5.1, as providing contextual information related to the user's task of developing or testing components provides more impact (Rosenfeld & Morville, 2002, p. 175).

3.2 Keywords referring to Accessibility

On the aspect of Labeling Systems (Rosenfeld & Morville, 2002, p. 147), only the keywords "Accessibility" and "Accessible" were chosen for this study. While there are several terms related to accessibility (such as "assistive" or "ARIA"), a restricted list of keywords was used in modeling the IA due to time constraints. For future research, an improvement on this methodology would be to use automated tools (such as web scrapers) to perform a search on the list of keywords.

3.3 Modeling of the Design System IA

The design systems are documented as websites, and modeled using a hierarchical mapping, which shows ancestor-descendant relationships among elements (Nguyen et al., 2006). The hierarchy of pages in a website is commonly presented as a sitemap.

See Appendix B (p. 41) for the complete mapping of each design system.

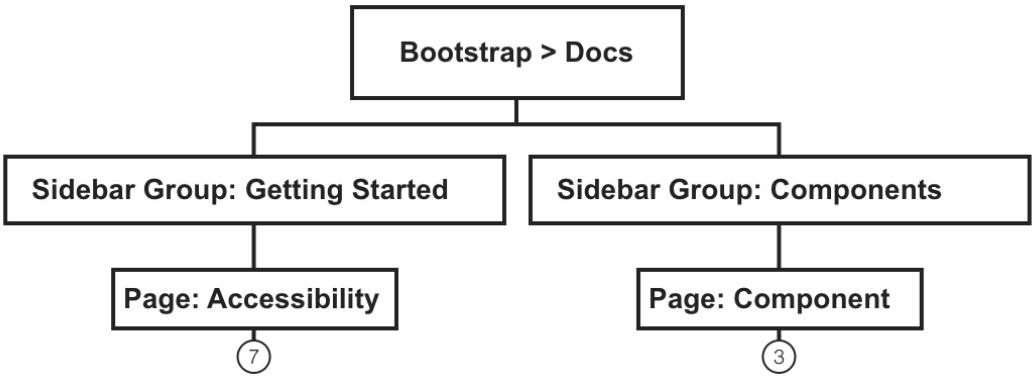


Figure 2. Example of a hierarchical mapping of the Bootstrap Docs, with some pages collapsed for brevity. (See Appendix B1, p. 41, for the complete diagram).

The starting points were derived from the URLs provided in the Open UI Design System Catalog. For brevity, only the highest level in which the design system documentation appears was used to model the sitemaps. Additionally, the URLs have been adjusted for this study to point to the latest version of the design system since some were outdated. For example, Bootstrap was listed as version 4 whereas the latest as of writing is 5.

The website was then manually crawled by clicking through the site's Navigation Systems, marking a page in the hierarchy if it has a descendant page that contains accessibility guidelines (see Table 1, p. 15, Criterion 4.2).

Each page is then categorized based on its navigation system level: Global, Local, and Context (Rosenfeld & Morville, 2002, p. 175).

While there might be other pages within a design system that mention “accessibility”, for this study, please note that I chose to focus on:

1. **Components**, as they are considered by most users an integral part of design systems (Sparkbox, 2022).

2. **Pages on Accessibility,** dedicated pages on web accessibility guidelines.

3.4 Analysis

3.4.1 Four Components of IA

Each design system IA model is classified according to the 4 components of IA: Organization Systems, Navigation Systems, Labeling Systems, and Search Systems (Rosenfeld & Morville, 2002), followed by a comparative analysis.

3.4.2 Alignment to the WCAG

Each section on Accessibility is assessed on the following levels:

1. No alignment – No links to WCAG Success Criteria or Sufficient Techniques.

2. Fair – Mentions implementation details, but no mentions of WCAG Success Criteria or Sufficient Techniques.

3. Good – Links to the corresponding WCAG Success Criteria or Sufficient Techniques.

4. Very Good – All criteria of Good, additionally warning whether a component is not accessible, and what steps to solve accessibility problems.

4. Results

4.1 Four Components of IA

The first step is to analyze the overall visual structure of each design system. All design systems use the sidebar layout, a page split vertically into two parts. It consists of a sidebar (usually on the left) and the main content on the other side.

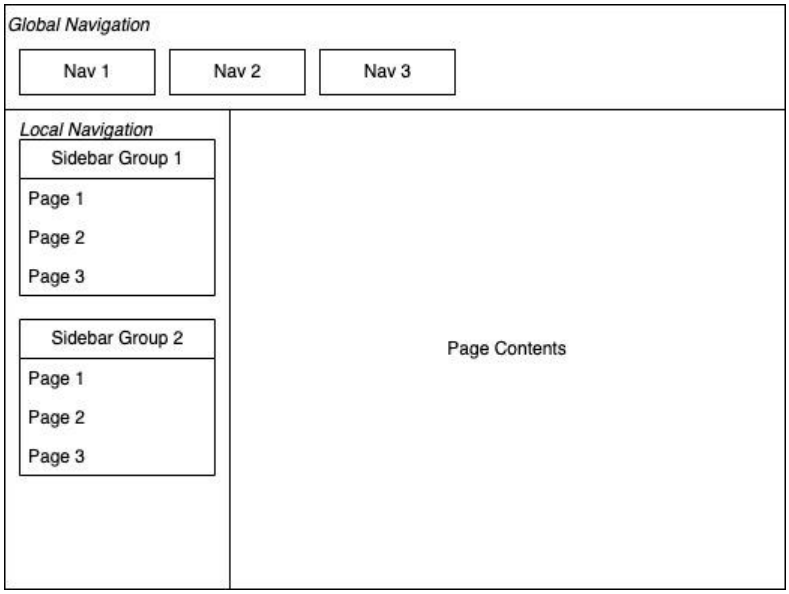


Figure 3. Wireframe of the Sidebar Layout

The sidebar consists of a Global or Local navigation menu, often showing the first few top levels of the sitemap hierarchy. When the user clicks on the navigational links in the sidebar, the content is shown on the main content. The main content then usually contains Local or Context navigations, depending on the complexity of the design system, although it is not always the case.

The hierarchy and classification of elements are highly similar across the sample, which led to the following element categories:

- Nav – For cases with the Global context on the top menu bar, a menu link is classified as so.
- Sidebar Group – All of the sidebars contain numerous links and hierarchies of links, so to increase findability, the links are grouped by topic.
- Page – This is both a link found in the sidebar and the actual page shown in the main content, which is divided into either sections or tabs.

- Section – Part of a page that is usually denoted by a heading or widget, or anything that is repetitive and recognizable across all pages of the same category. It is usually included in the Context navigation.

- Tab – Can be considered a subclass of a Section but is considered a Local navigation as opposed to a Context navigation due to changing tabs losing the previous context. To better organize detailed information, a page can be divided into tabs, and each tab can be considered a Page itself with its own sections.

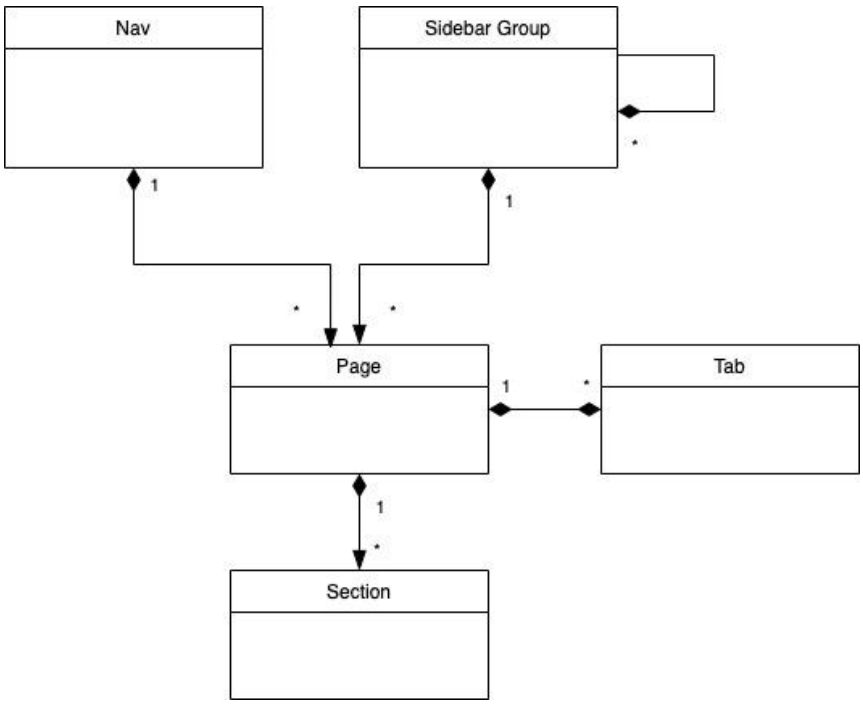


Figure 4. Class diagram of element categories

4.1.1 Organization Systems

Rosenfeld & Morville (2002) states that organization systems are composed of organization schemes and organization structures. Organization schemes define the shared characteristics of items that influence how they are grouped and are either exact (alphabetical, chronological, etc.) or ambiguous (topical, task-oriented, etc.). Organization structures define the relationships between items and their groups (p. 103).

Components

The organization schemes for sidebar groups are topical for all cases, except for Spectrum, which groups them by task (Actions, Data Visualization, Feedback, Navigation, etc.). Component Pages in Spectrum are one to two levels deeper due to these grouping. Component Pages under a Sidebar Group are listed alphabetically, across all design systems.

Pages on Accessibility

As opposed to Components, there is more variation in the way each design system approaches the organization of pages on Accessibility. A specific example, Lightning Design System (see Figure 5, p. 22, below), has a group of sidebar links grouped by topic (Overview, Guidelines, Patterns), with each topic further grouped into tasks for Guidelines (Web Design, Mobile Design, Keyboard Interaction, etc.) and topical for Patterns (component-specific guidelines).

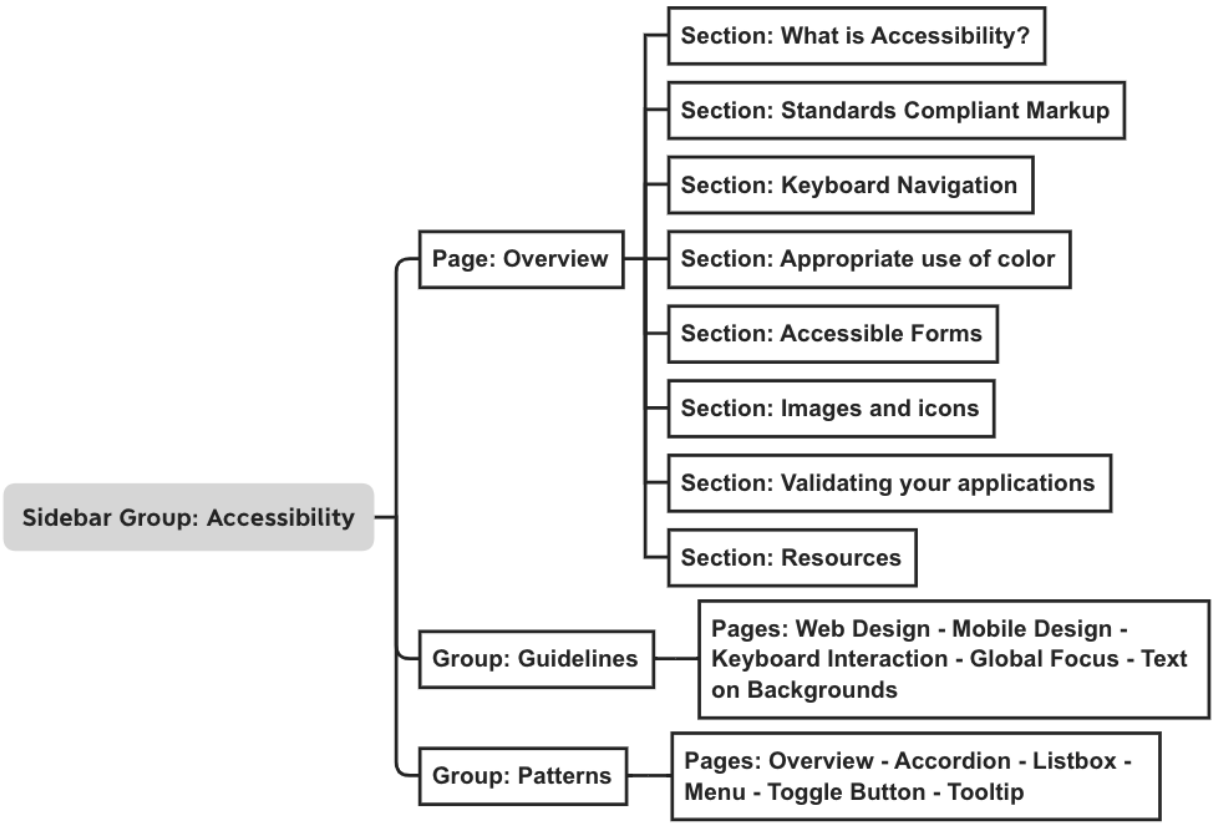


Figure 5. IA model of the accessibility guidelines of the Lightning Design System (see Appendix B3, p. 42, for the complete sitemap).

Most of the design systems follow the same approach of organizing guidelines by task or topic, although Carbon Design System applies a hybrid scheme. Its Page on Accessibility is divided into the following Tabs: Overview, Color, Developers, and Keyboard, a mix of topic-based, audience-

specific, and task-based, respectively. Each Tab is further divided into Sections that are a mix of topics (Color tab: Color contrast, Tools) and tasks (Developers tab: HTML best practices, CSS best practices, Mouse-specific events).

Organization Structure

In both Components and Pages on Accessibility, all elements across the sample follow a hierarchical (top-down) approach. As shown in Figure 2 (p. 1), elements follow a hierarchy.

4.1.2 Labeling Systems

Components

While design systems can have variations on naming components (Werle, 2021, pp. 53-54), this study focuses on the nomenclature of the actual category of the component pages fall under. All design systems seem to agree on using "Components". The only difference is Lightning Design System, which uses "Component Blueprints".

Pages on Accessibility

Every design system uses the same term "Accessibility", except for Spectrum, which favors the term "Inclusive". However, it accepts "accessibility" as an alias for search keywords (see 4.1.4, p. 26).

With regards to the navigation system under which the Pages on Accessibility appear, there is more variation on the labels:

Label of Parent Category	Classification	Design System
Getting Started	Sidebar Group	Bootstrap
Guidelines	Sidebar Group	Carbon Design System
Accessibility	Page	Lightning Design System
CDK	Nav	Material Design
Foundation	Sidebar Group	Spectrum

Table 3. Labels of parent categories of Pages on Accessibility

4.1.3 Navigation Systems

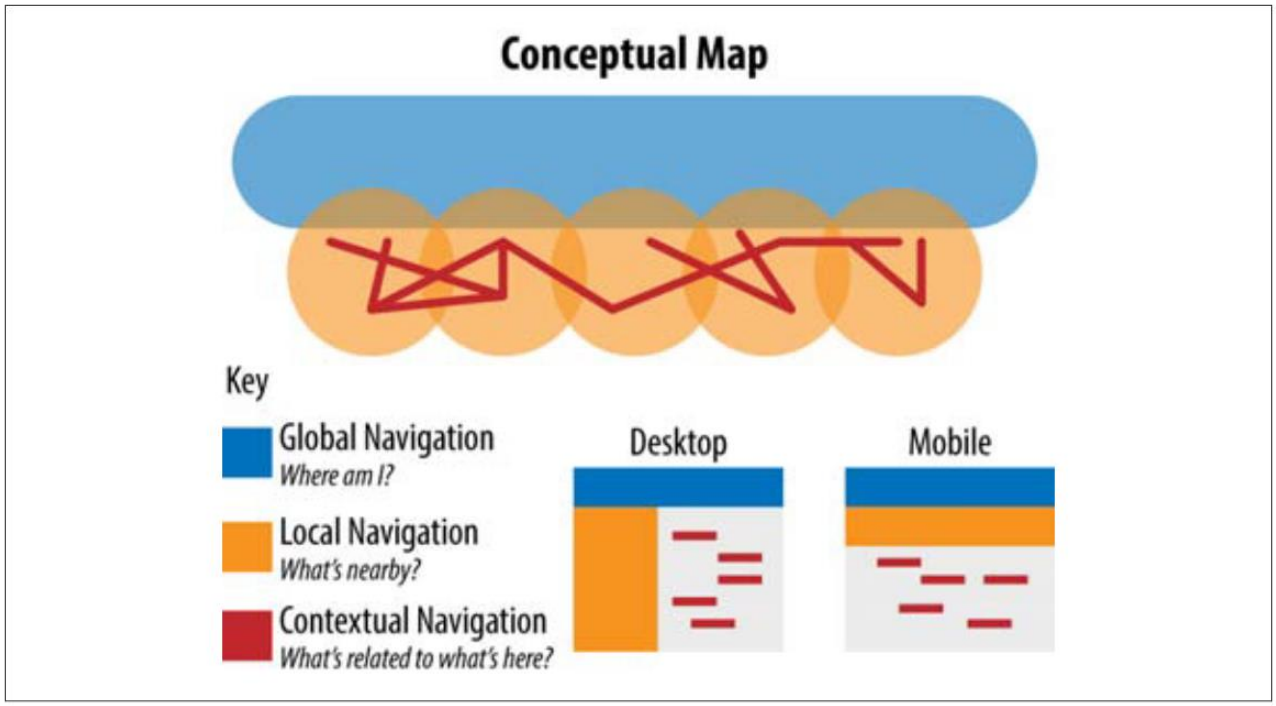


Figure 6. Diagram of navigation systems from Rosenfeld & Morville (2002, p. 177).

Rosenfeld & Morville (2002) classifies navigation systems used in websites on levels of scope: Global, Local, and Contextual (p. 177). While other types of navigation systems exist, this study will focus only on these three.

Global Navigation

Complex design systems, which include not only design or developer guidelines, such as a blog or News section, or an About or Contact section, would usually have a Global navigation. Earlier in 1.1.1, the starting point for IA modeling was from a specific URL because certain design systems have landing pages that do not immediately display design and developer guidelines. Such design and developer guidelines still fall under the main website, so the Global navigation is constantly shown. This is the case for Bootstrap and Material Design. Considering Lightning Design System's sidebar as its Global Navigation, it is the only design system where Accessibility is listed on the top level without requiring to open a Sidebar Group.

Local Navigation

For other design systems where the typical top navbar is absent, the Global navigation is transposed to the sidebar and merged with Local navigation, like most cases. Carbon Design System is the only

one that uses Tabs as Local navigation and has a Tab dedicated to Accessibility in its Component Pages.

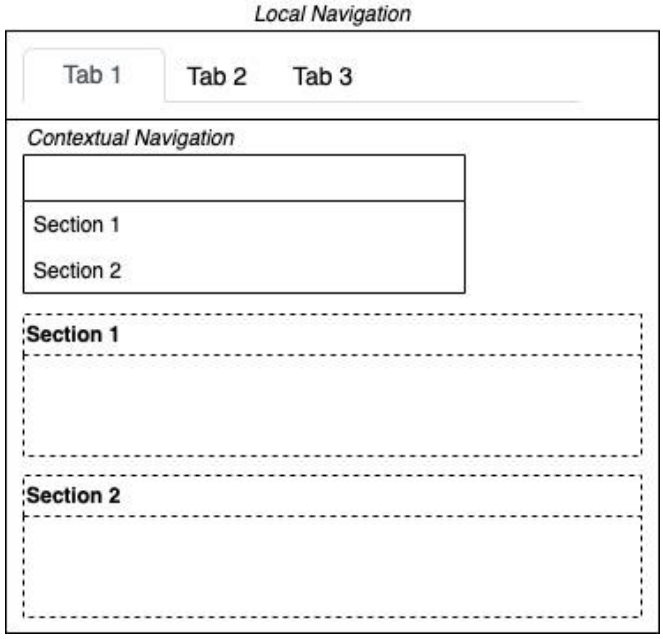


Figure 7. Wireframe of a page using Tabs as Local Navigation.

Contextual Navigation

While there seems to be some consistency in the way each design system organizes its Contextual Navigation, their differences can be analyzed according to the following aspects:

- Placement – where the Contextual navigation is positioned on the page.
- Consistency of Accessibility guidelines across all components
    - Naming
    - Presence – Existence in the page
    - Hierarchy – Structure and order in the page

Placement of the Contextual Navigation is either:

- Fixed at the right of the page and remain in place even when the user scrolls through the page.
- At the top of the page, but scrolls with the page, which requires the user to scroll in order to jump to a section, which is less ergonomic.

Among the design systems, Carbon Design System, Material Design, and Spectrum have the most consistency in both aspects of placement and naming. At least 97% of the components of each design system contain a section on Accessibility (see Table 2, p. 17) which is also structured systematically. This helps users easily find information about Accessibility as predictability is an important factor in findability (Rosenfeld & Morville, 2002, p. 155).

Carbon Design System displays a dedicated tab on Accessibility for each component. Each Tab is divided further into the following sections: “What Carbon provides”, “Design recommendations”, and “Developer recommendations”, all linked in the contextual navigation.

Each Component Page in Material Design has a section on Accessibility, whether it is highly specific to the component and highly detailed, or just a reminder on which ARIA attributes to include.

Spectrum displays a checklist of design specifications, notably of WCAG compliance, on each Component Page (show screenshot).

4.1.4 Search Systems

Search functionality in websites is commonly presented as a search box, indicated with either a magnifier icon or instructions prompting the user to enter a search term. It is usually placed at the upper region of the page.

Search can be as basic as word or character matching of raw text content of all pages of a website and can be as advanced as giving the user more control over the results, by allowing them to specify search parameters, such as modified date, author, or tags.

Leveraging sophisticated algorithms that are optimized for a website’s structured content can be useful in bringing the most relevant results to the user. Indexing, tagging, fuzzy matching, and scoring are some principles of search that can be fine-tuned and unique to a website. For example, prioritizing page titles over paragraph text when matching a search term is one of the common strategies.

In the case of design systems, listing matching Component pages at the top of the search results is a possible specialization.

While the topic of search is complex and vast, this study will focus only on the following aspects:

- Search box
    - Presence – the existence of a search functionality in the design system
    - Placement and Access – location of the search functionality and activating the search.
- Search results
    - Number of results
    - Sort order of results
    - Structure of information
    - Highlighted keywords – how the relation of the search result to the search term is presented.
    - Persistence – whether the search history is saved.

Search box

All search boxes are textual and there is no advanced search with the option to tweak parameters. They are placed in either the global navigation or local navigation. All search boxes have a placeholder text “Search”, with some of them displaying a magnifier icon as a supporting indicator. Among the sample, only Material Design did not offer search functionality.

Carbon Design System’s search box is collapsed by default, with a button containing a magnifier icon when clicked reveals and autofocuses on a text box.

Some of the design systems make use of Algolia (Algolia, 2023) an open-source library that offers tools for websites to integrate search functionality adapted to their content. Some of the design systems allow users to use shortcut keys to jump to the search box for faster access when browsing.

Search results

Some design systems cap the results to a fixed number, either to optimize displaying of results or as a way to limit the cognitive load of the user.

All design systems that offer search functionality group results by hierarchy, usually by the local navigation the page belongs to. Each design system, however, displays them differently. Matching words are sometimes highlighted. Most of the time, the results are not sorted alphabetically, but follow an order specific to the design system.

Bootstrap groups its results by a hierarchy of two to three levels: (1) Page title, (2) Section title, and (3) Sub-section title, if several sections on a page match the search term. The first result is Accessibility, grouped together with three of its topics and Additional resources. Further down the results are an alphabetical list of all the components with a section on Accessibility. It is the only one that saves search history, based on the last accessed result. There is no maximum number of search results.

Lightning Design System hierarchizes its results on four levels: (1) Sidebar Group, (2) Page title, (3) Section title, and (4) Paragraph excerpt, if the matching phrase is found in a paragraph. For the keyword “Accessibility”, the results are grouped by Component Blueprint, in no particular order. There is no reference to the Pages on Accessibility in any of the results. However, for the search keywords “Accessibility <component name>”, level 1 groups are Accessibility, followed by Component Blueprints. Results are capped at 5 items.

Carbon Design System displays “Content” accessibility guidelines as its top result, followed by “Get Started”, “Accessibility”, and “Step 4 of Creating Components”. Results are capped at 8 items. For the search keywords “Accessibility <component name>”, the top result is always the Usage tab of the matching component. In contrast, the Accessibility tab is shown inconsistently in the middle or at the end.

Spectrum, which uses the term “Inclusive” in its texts, interestingly accepts the alias “accessibility”. Searching for both terms displays similar results. The first result is “Inclusive design” under the “Foundation” group, followed by Content” guidelines, then Usage guidelines. There seems to be no maximum number of results.

When searching for accessibility guidelines specific to components, knowledge of the existence of a component and its name is necessary. For first-time users of the design system, familiarity of the available components would be built from looking at the local navigation first, followed by memory recall from frequent and regular exposure to the design system. Regarding references to the design system’s Pages on Accessibility, most of the design systems list them at the top, with the exception of Lightning Design System.

4.2 Alignment with the WCAG

While the findability of the term “accessibility” is a factor in helping a user implement accessibility guidelines, there is an added value in knowing the actual WCAG linked to a component. This second part of the analysis looks at the level of information provided.

Design systems in the sample have a section listing all its components, each with its own page. This section could be in any form if it is systematically recognizable when viewed across different component pages.

When viewing a component’s page, sometimes accessibility guidelines are not instantly visible. Sometimes a quick in-page search for the keyword “accessibility” reveals a section that is found at the bottom of the page and the user would need to scroll. Other times, using a related keyword, such as “assistive” or “ARIA” would bring up a result. This would require the user to be familiar with the specific terminology related to the accessibility guideline they wish to view, with the risk of several trial-and-errors before reaching the desired information.

Reiterating the evaluation methodology (see 3.4.2, p. 19): Alignment is *good* if it links to the official WCAG Success Criteria or Sufficient Techniques. It is *fair* if it only mentions implementation details, without any links to the official WCAG documentation. Alignment is *very good* if it warns users of an inaccessible component and offers workarounds to solve accessibility issues. Lastly, a design system has *no alignment* if none of the previous criteria are present.

4.2.1 Very Good and Good Alignment

Carbon Design System is strongly linked to WCAG, the design system with the most links to WCAG. With all its components having a dedicated Tab on Accessibility, it lists all related links in a systematic way. Additionally, Carbon Design System displays a warning in the Accessibility tab of a component that violates accessibility guidelines, along with the link to the corresponding Success Criteria.

Lightning Design System links to specific ARIA guidelines on some of its Pages on Accessibility. There seem to be more details on the general guidelines than on component-specific guidelines, and users would have to look at both Pages on Accessibility and the specific Component Blueprint to ensure that most criteria are fulfilled.

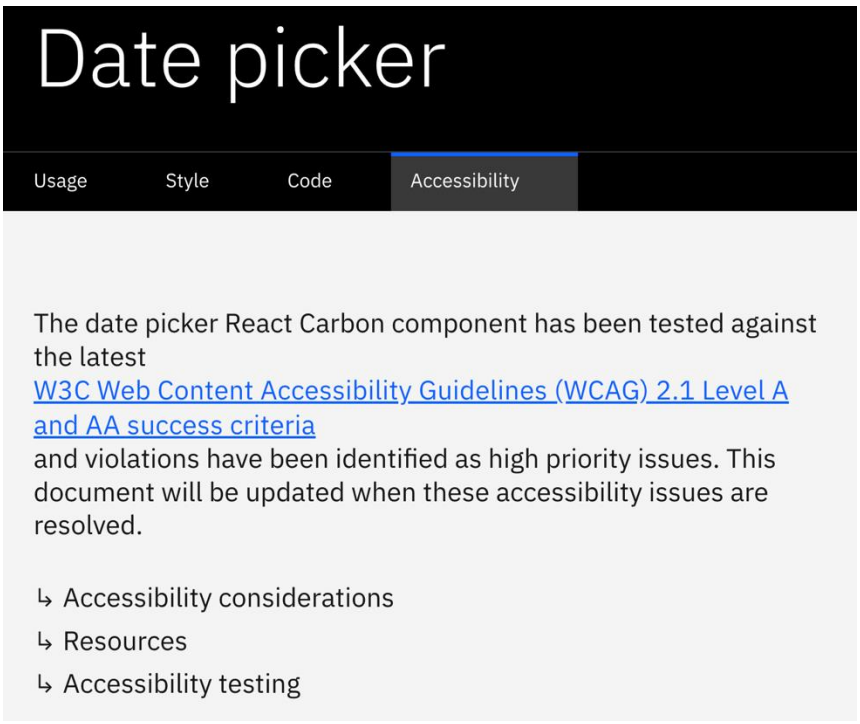


Figure 8. Screenshot of a Carbon Design System component with accessibility violations.

Bootstrap displays accessibility information in banners with heading titles containing the keyword "Accessibility". The corresponding Page on Accessibility is linked. The Page on Accessibility contains a section Additional Resources which links to the WCAG and ARIA landing pages. There is no systematic presentation of WCAG Success Criteria or Sufficient Techniques in the component pages, and it is encouraged to use the search box to search for ARIA guidelines for a specific component. While it does mention a component that violates accessibility guidelines (notably, the Carousel), it is only mentioned in a paragraph, and its design does not stand out enough to call attention to the user.

Spectrum links to WCAG Sufficient Techniques in its Pages on Accessibility, but none in its component pages. However, all its component pages contain a checklist of the component's accessibility compliance.

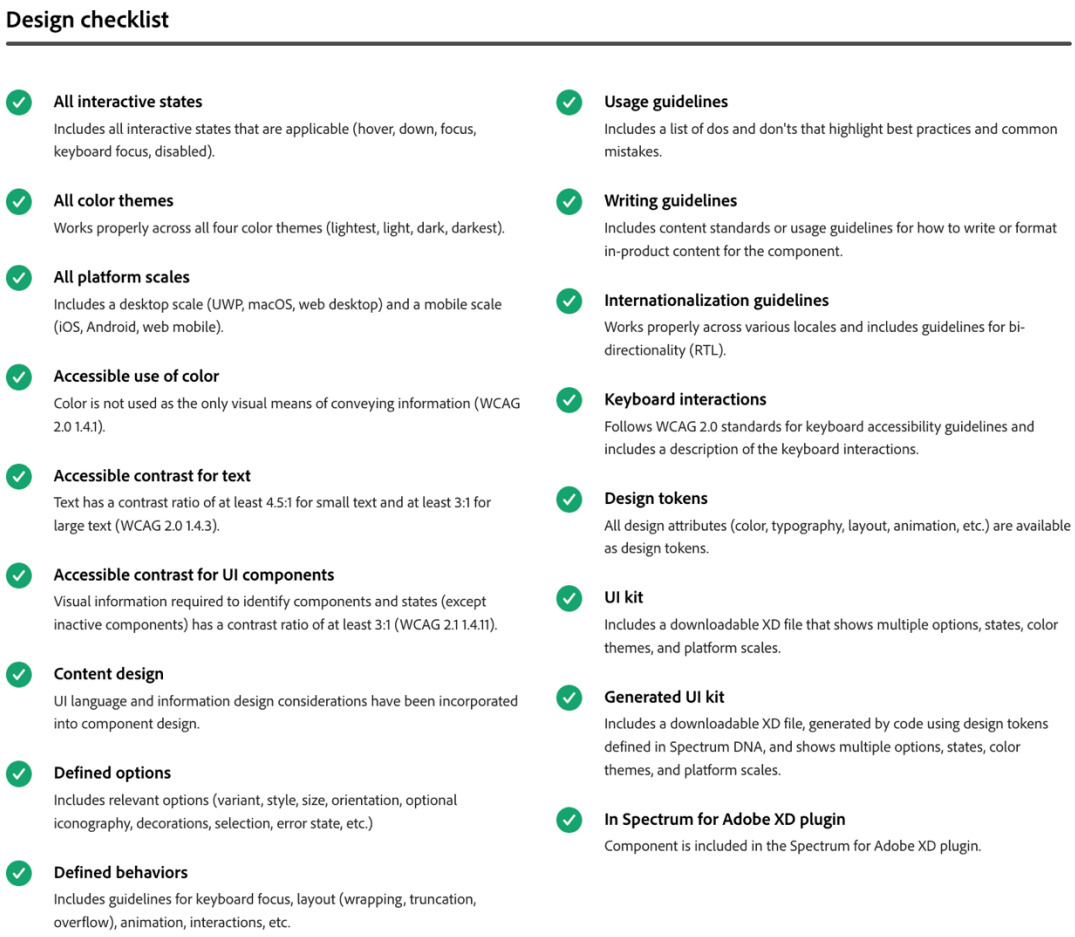


Figure 9. Checklist of accessibility compliance of Spectrum components

4.2.2 Fair Alignment

While Lightning Design System enumerates all necessary ARIA attributes needed in each Component Blueprint, there are no links to the actual WCAG Success Criteria or Sufficient Techniques. Most of the information on Accessibility, including the related links to WCAG, is gathered in the Pages on Accessibility.

4.2.3 No Alignment

Although 97% of Material Design components contain an Accessibility section, none link to any official WCAG Success Criteria nor Sufficient Techniques. Its Page on Accessibility mentions none either.

5. Discussion

Information Architecture plays a huge role in the findability and retrievability of information in complex systems. With some of the challenges in web accessibility mentioned (see 2.2.2, p. 9), such as the lack of awareness (Rosson et al., 2005, p. 531), a first step would be the introduction of such accessibility in areas of design systems that users would frequently use (Sparkbox, 2022).

Having evaluated and compared each design system on how their IA components relay accessibility guidelines, several similarities confirm patterns that may influence other design systems to architect their documentation. Notably, having dedicated pages that mention global accessibility guidelines or promote the company's vision and statement on valuing Accessibility is an effective starting point (Lehner, 2023).

The consistent inclusion of accessibility guidelines in each of the component pages keeps the user experience predictable. At the minimal level, a link to the corresponding WCAG Success Criteria or Sufficient Techniques would help address some of the challenges technology professionals face. Patel et al. (2020) recommend clearly written resources to support tight development cycles, where an accessibility-driven design system can fill the gaps (p. 6).

While this study aims to compare the IA of the various design systems in the sample, the goal is to explore the emerging patterns in labeling, searching, and navigation and the innovative ways each design system brings. The outcome is not to find the best way to architect an accessibility-driven design system or rank the sample by effectiveness. This could be explored in another study.

A mix of the unique solutions offered by the various design systems in the sample could also be included when architecting a design system. Spectrum's checklist on WCAG compliance and Carbon Design System's tab on Accessibility are good examples of information and consistently presented accessibility information. However, some other challenges remain to be explored, which were not covered by this study, notably on testing, interpretation of WCAG, and advocating for the inclusion of accessibility in business needs (see 2.2.2, p. 8).

As mentioned in the Review of Related Literature, there is currently limited research on the intersection of IA, Design Systems, and Web Accessibility, with Janetschke's (2021) research as the most relevant to this study. Janetschke's (2021) methodology for evaluating WCAG compliance of the Siemens Design System is more thorough and exhaustive, evaluating all 78 Success Criteria, specifying which ones were included (p. 90) and excluded (p. 68). The methodology also includes end-user testing. Future research can build upon Janetschke's research and this study for a more

comprehensive evaluation of possible solutions to bridging knowledge gaps of developers on WCAG.

Due to time constraints, the methodology and scope of this study can be further improved in the following aspects:

- Keywords – expanding search terms beyond "accessibility" to aliases and other related terms, such as ARIA, WCAG, and a11y, would cover a wider breadth.
- More design systems – The sample has been derived from the Open UI Design System Catalog to 5, but other design systems that fit into this study's criteria can be explored.
- Automation – Making use of web scrapers to search for the list of keywords in each of the pages of the design system would provide a more detailed map of the variety and coverage of accessibility information available. Web scraping can also save time in building a sitemap, especially if the sample size is increased.

Lastly, an additional step in the methodology would involve user testing. A sample of users, from designers, developers, and testers, grouped by experience in design systems in general and familiarity with the chosen sample of design systems, will be given tasks to perform. Testing the effectiveness of a design system's IA in relaying WCAG to the users would be one of the objectives.

6. Conclusion

The resurgence of web accessibility has become a priority for governments, institutions, and companies, with the American Disabilities Act in full force and the arrival of the European Accessibility Act in 2025. The challenges of web accessibility have spanned decades since the inception of the Web and have been a relevant research subject. Web accessibility remains a complex topic that can be approached from several angles. The view of Information Architecture and the WCAG has been chosen for this study.

The recent trend of companies and governments adopting design systems was also explored in this study. As design systems heavily use IA principles in dealing with the complexity of design and user experience guidelines, they are a good candidate for studying the different ways design systems could integrate WCAG into their IA. The chosen sample of design systems was derived from the catalog published by Open UI, a chapter under W3C, the same organization responsible for Web Accessibility and the drafting standards for the Web in general. With thousands of design systems publicly available, this list was a viable and robust starting point for the study. While the Open UI Design System Catalog is still a work in progress, current and future standards may encourage companies to build on these patterns and innovate novel ways to support their collaborators in developing accessible user interfaces.

While not every company may not have sufficient resources to invest in design systems and accessibility, the results of this study could provide teams with the necessary information to reinforce the information architecture of their products, leverage design systems to improve alignment within their organizations and gain awareness of the importance of web accessibility.

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Appendix A

Sampling criteria applied to the Open UI Design System Catalog

Name	Maintainer	C1	C2	C3	C4.1	C4.2
AntDesign	AFX	Yes	Yes	Yes	No	0
Bootstrap	Twitter	Yes	Yes	Yes	Yes	71.9%
Auth0 Styleguide	Auth0	Yes	No			
Material Components	Google	Yes	Yes	Yes	Yes	97.1%
Carbon Design System	IBM	Yes	Yes	Yes	Yes	97.5%
Chromium	Google	No				
Evergreen	Twilio Segment	Yes	Yes	Yes	No	
Atlaskit	Atlassian	Yes	Yes	Yes	Yes	27%
Fluent UI	Microsoft	Yes	Yes	Yes	Yes	0
Kolibri	IZB	Yes	Yes	No		
Primer Design System	GitHub	Yes	Yes	Yes	Yes	51.7%
Lion	ING	Yes	Yes	Yes	Yes	0
Fast	Microsoft	Yes	Yes	Yes	No	
Lightning Design System	Salesforce	Yes	Yes	Yes	Yes	72.6%
Semantic UI	Semantic Org	Yes	Yes	Yes	No	
Spectrum	Adobe	Yes	Yes	Yes	Yes	100%
Stardust UI	Stardust UI	Yes	Yes	Yes	No	
WAI-ARIA	W3	No				
Web Platform	WHATWG & W3C	No				

Appendix B

Models of Design System IA

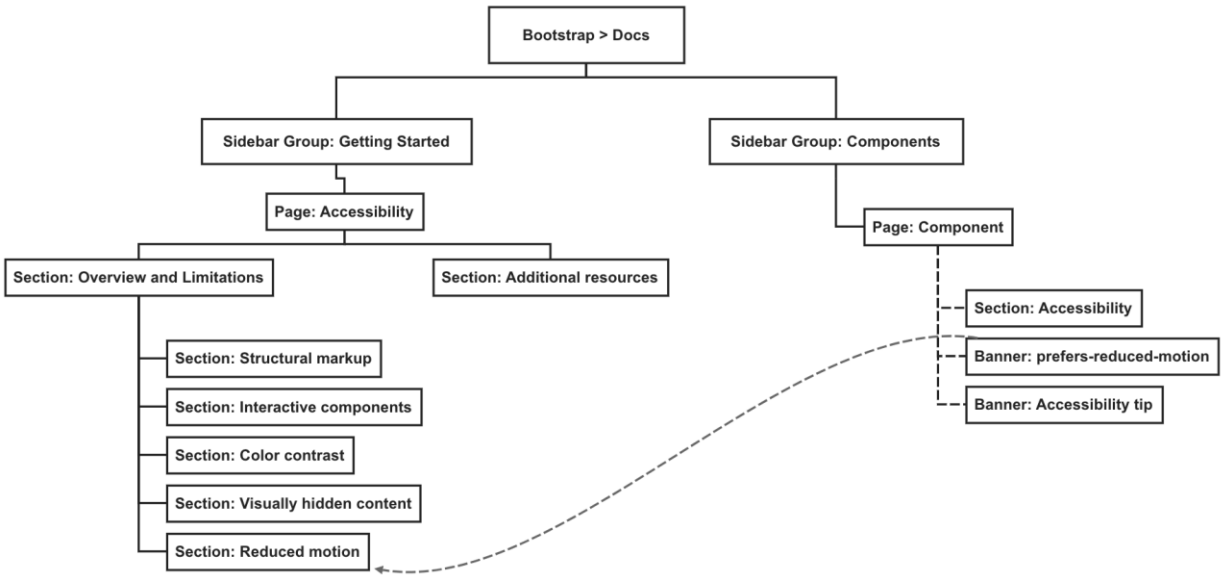


Figure B1. IA of Bootstrap Accessibility and Component Pages

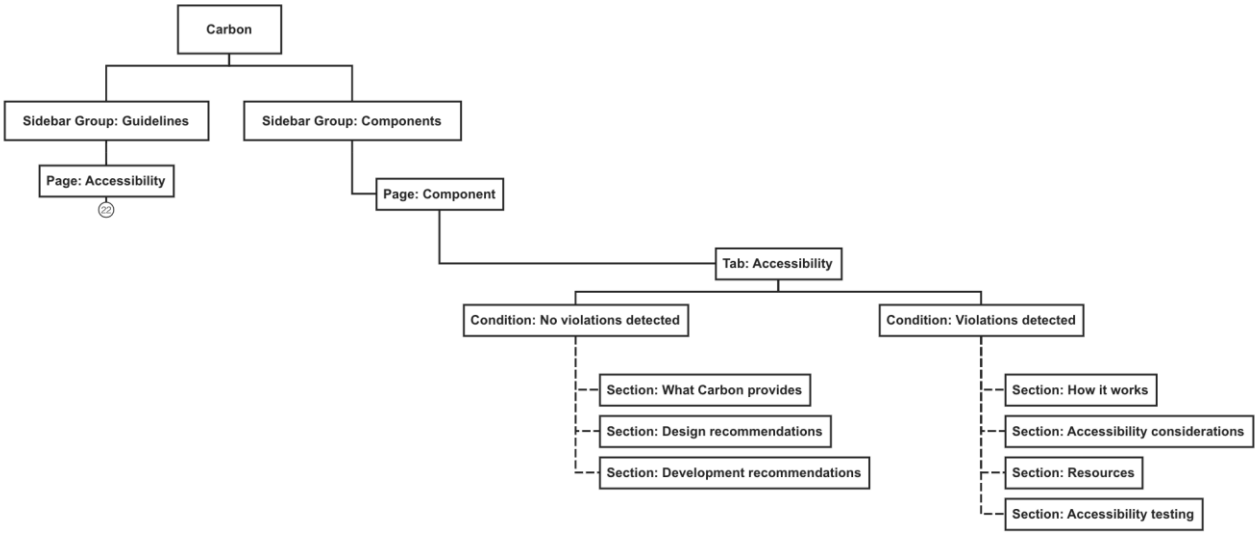


Figure B2. IA of Carbon Design System Accessibility and Component Pages

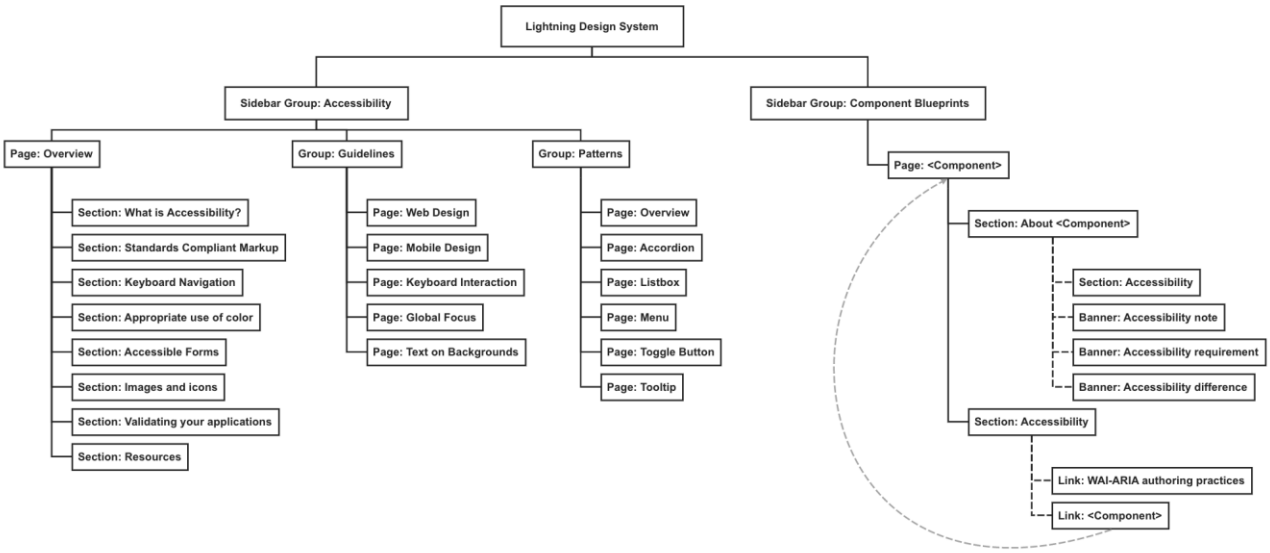


Figure B3. IA of Lightning Design System Accessibility and Component Pages

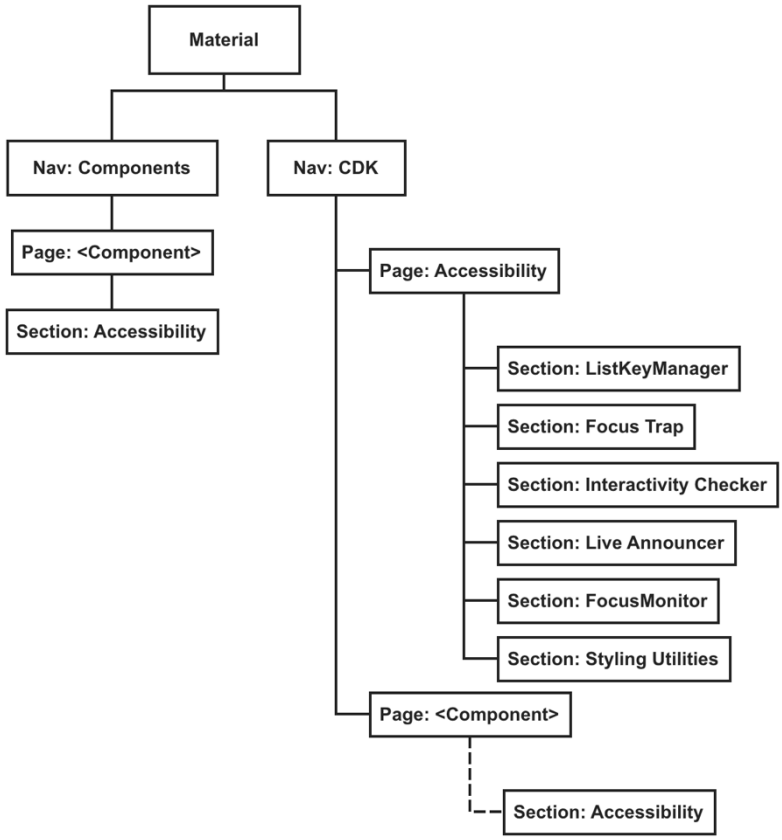


Figure B4. IA of Material Design Accessibility and Component Pages

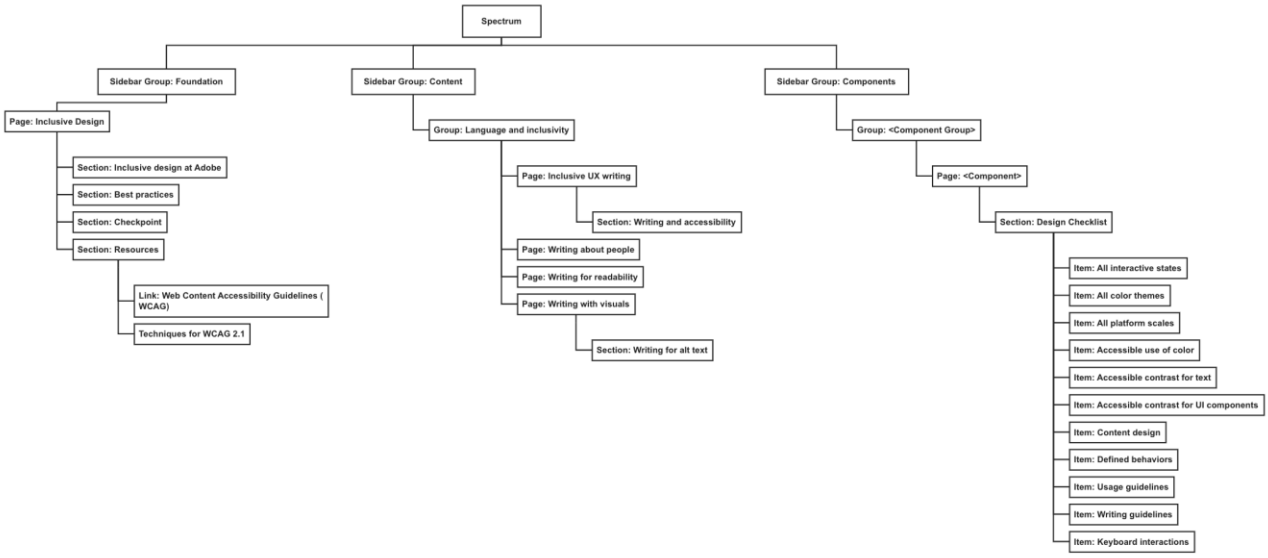


Figure B5. IA of Spectrum Accessibility and Component Pages