

Master's Programme in ICT-Innovation

Web Accessibility Evaluation for the Fair- data Website

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Abstract

The significance of web accessibility has been recognized by many authorities and imposed by national legislation. In accordance with the legal requirements, the aim of this study is to determine all potential accessibility issues and make the target website accessible. The target website is a public site called Fairdata, which introduces multiple services designed for research data.

In order to assess the accessibility level of the website, automated testing and manual testing are combined to analyze whether each page complies with WCAG 2.1. An initial assessment is conducted to obtain an overview of accessibility problems, and then a comprehensive evaluation is performed to identify defects.

The results reveal that the website has many accessibility aspects violating WCAG 2.1 conformance level A and AA: lack of text alternatives, insufficient contrast ratio, and incomplete keyboard navigation. There are also specific problems when accessing tables and videos by screen readers. Besides, the target website tends to be more compatible with the combination of Voiceover with Chrome than other combinations. In the end, all findings are sorted out one by one according to WCAG 2.1 guidelines, respectively. Suggestions and solutions for meeting the accessibility standards are also provided correspondingly.

Keywords Web Accessibility, Web Design, WCAG 2.1

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Preface

I have received support and assistance throughout the writing of this dissertation. This study would not accomplish without all of these outstanding individuals being part of this journey during this unprecedented situation.

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Espoo, 23 August 2020
Ling Sun

Introduction

The World Wide Web, also known as the Web, was essentially designed for spreading and sharing information for all people. As Tim Berners-Lee [14] said, “The power of the Web is in its universality. Access by everyone regardless of disability is an essential aspect.” Indeed, the Web has significantly benefited people with disabilities. It grants them an unprecedented opportunity to access the world [10]. However, there are still a certain number of websites remaining inaccessible to people with disabilities regardless of the growing emphasis on Web accessibility [2]. In the context of the Web, being accessible means that the design and development of a website should enable people with disabilities to perceive, understand, navigate, interact and contribute to the Web.

To address the inaccessible online world pose to users with disabilities, the European Union’s Accessibility Act and the Finnish Digital Services Act oblige public sectors to comply with accessibility requirements [11, 12]. The Fairdata service is offered by the Ministry of Education and produced by CSC - IT Center for Science (CSC). There is no doubt that the official website of Fairdata must comply with accessibility guidelines. The official website provides information such as services description, user guides, training information, and latest news.

The objective of this study is to evaluate the overall web accessibility in accordance with the legal requirements. In order to assess the accessibility level of the Fairdata website, a combination of evaluation tools and manual testing is deployed to identify the potential accessibility issues. The evaluation strictly follows the web content accessibility guidelines (WCAG) 2.1, which is an international guide to web content accessibility.

This study is structured in the following manner. First, Chapter 2 introduces different disabilities, legal responsibilities for achieving web accessibility, evaluation methods and the relationship of usability and accessibility. Then, Chapter 3 describes the evaluation procedure of the study. Chapter 4 presents the evaluation findings. In the end, the study is concluded with conclusions and perspectives.

Background

This chapter explores Internet access for people with disabilities, legal responsibility, evaluation methods, and usability and accessibility.

Section 2.1 describes the typical disabilities and barriers to be considered regarding web accessibility. The World Wide Web Consortium (W3C) explored the diversity of disabilities and investigated into the tools and barriers that people with different disabilities commonly encounter. In Section 2.2, it introduces the legal responsibility and requirements, which is significant when conducting the accessibility audit. Section 2.3 examines methods for evaluating web accessibility. In Section 2.4, the relationship between usability and accessibility of websites is investigated. Accessibility and usability are two concepts that closely related to each other in web design. Both of these have a similar goal to provide a better user experience when creating a web. They also have considerable overlap between design for accessibility and design for usability.

2.1 How people with disabilities use the web

According to Web Accessibility Initiative (WAI), web accessibility entails all disabilities that affect users to use the web, including visual, auditory, physical, cognitive, and speech [32]. Disabilities may come from birth and disease, even from accidents, illness and aging. Different disabilities lead to distinct experiences and obstacles, but inaccessible websites can result in experiencing some common barriers. This study discusses disabilities concerning visual, auditory, and cognitive, taking into account the types of web content.

2.1.1 Visual

The website is a visual medium. Visual communications and graphical interfaces take the dominant roles in the current online world. Thus, the accessibility for people with visual-related disabilities is more emphasised than people with other disabilities during product design and development. However, visual disabilities are diverse, ranging from blurred vision to low vision, to vision loss in both eyes [10]. Some people have colour vision deficiency. They are less sensitive to specific colours or even have difficulty in distinguishing between colours. Typically, visual disabilities can be divided into colour blindness, low vision, blindness, and deaf-blindness [32].

The conventional assistive technologies for visual-impaired users are screen readers and refreshable braille displays. Refreshable braille displays also commonly support screen readers so that users can switch in between or utilise both functions depending on the situation [6]. Additionally, people with color vision deficiencies use contrast-enhanced assistive technology.

The primary barrier for visual-impaired users is to maintain the information processing speed. Thus, many screen reader users adjust the speech rate to accelerate reading. On average, these users can understand synthesised speech at a breathtaking speed of 500 words per minute [6].

The browsing pattern varies from person to person. The dominant use pattern of screen readers is to navigate through headings or focusable elements to find information, which takes up to 68.8% of respondents [29]. Some users also use the 'find' feature. While other users tend to be more process-oriented, they read through the whole page to understand the page structure. They incline to remember the structure so that they can go back to the beginning and navigate through the page again if they cannot find the desired information [6].

According to the survey in 2019 [29], the three most popular screen reader software were NVDA, JAWS, and Voiceover. NVDA has surpassed JAWS becoming the most widely used screen reader, and Voiceover users were also steadily increasing. On the other side, the most popular browser for screen reader users was Chrome, taking up to 44% among respondents. Firefox usage was ranked at second place with 27%, while Internet Explorer(IE) accounted for 14.5% of respondents. Safari was about 10.0%. There was a surprising number of respondents still using old versions of Internet Explorer such as IE 6, 7, or 8.

2.1.2 Auditory

Similarly, there is a wide range of auditory disabilities from mild hearing loss to completely deafness. Some people with hearing impairments use sign language, while some deaf people do not understand sign language or do not speak the same sign language [30].

The main challenge for auditory disabilities comes from multimedia. They are dependent on text alternatives such as transcripts and captions to understand the audio contents. It can be beneficial to interpret contents to sign language, but many people with hearing impairments do not understand sign language. They tend to understand web content visually since visualizations and illustrations convey essential information in a more understandable way, which is opposite from visual disabilities [32].

2.1.3 Cognitive

Cognitive disability is a rather broad concept, which covers neurodiversity, neurological disorders, behavioural and mental health disorders. Considering of web accessibility, the following categories of cognitive disabilities are more related to the concerns [31].

- Memory: the ability to recall what a user has learnt over time
- Problem-solving: the ability to persistently solve a problem
- Attention: the ability to pay attention to the task
- Reading, linguistic, and verbal comprehension: the ability to understand the text
- Visual comprehension: the ability to process the visual information

People with cognitive disabilities may have difficulties memorizing the contents or a precise procedure [31]. A typical example is that when multiple error notifications appear, they have difficulties to remember multiple errors or maybe forget the error information before taking actions. Meanwhile, these users have low resilience to solve problems, and they drop off the website easily. Besides, many individuals are readily distracted from contents such as blinking elements or popping-up windows [31].

Some individuals may have a hard time to comprehend texts. This kind of disability also ranges from mild challenges to a complete inability to read any text. Even for users without disabilities, unclear text and compound sentences are not well-welcomed. Generally speaking, to make text easy for the college-level readers, it is suggested to target at a 12th-grade reading level. If the readers are broader, it is sufficient to target at an 8th-grade reading level [19].

On the contrary, people who suffer visual comprehension difficulties may not be able to recognize the object for its meaning [31]. For example, they do not understand an image of a flower is a representation of a flower. They just see the image as an image. Thereby, multimedia contents such as a video with narrative would be a better way to communicate with these people. A vividly blooming flower is more natural for them to recognize than a mere static image.

People with cognitive disabilities usually rely on screen readers or screen magnifier to process the written text so that they can understand the content better [32]. Correspondingly,

this leads to different types of web browsing strategy. Screen reader user with cognitive disabilities read the web visually while hearing the synthesized speech, whilst screen magnifier users resize text and spacing to help reading.

The common barriers for people with cognitive disability are complex navigation mechanisms and page layouts [32]. Besides, complex sentences, long passages, and unusual words can also increase cognitive load.

2.2 Legal Responsibility

In Finland, the national legislation – Act on the Provision of Digital Services(306/2019) came into force on 1st April 2019 [12]. This law brings the Directive 2016/2102 of the European Parliament and the Council on the accessibility of the websites and mobile applications of public sector bodies into effect.

The Digital Services Act obliges the public authorities and some private organisations to comply with accessibility requirements. It covers all digital services and requires broadly to the content and functionality of these digital services [12]. Accessibility requirements are defined in the European harmonised standard EN 301 549 for ICT. The minimal compliance is equivalent to WCAG 2.1 AA level [9]. The only exception is 1.2.4 Captions for live audio content in synchronised media within AA level, which is not required to meet the criteria [11, 22]. Consequently, there are a total of 49 criteria required by law.

The concept of authorities includes ministries, government agencies, universities, municipalities, and state-owned enterprises[12]. CSC is owned by the Finnish state and Finnish higher education institutions, administered by the Ministry of Education and Culture. In other words, the digital services provided by CSC are required to be accessible in many senses.

On the other hand, the EU Accessibility Directive demands the websites published after 23rd September 2018 must be accessible no later than 23rd September 2019, while the websites published before 23rd September 2018 must meet the accessibility demands no later than 23rd September 2020 [11].

2.3 Evaluation Methods

Currently, the standard methods for evaluating web accessibility consists of WCAG 2.1 guidelines, automated tools, user testing, and manual testing.

Literally, automated assessment tools are more productive than the manual testing. Automated tools are cost-efficient and fast to complete the evaluation without the assistance of experts. Even for a large website, a web accessibility evaluation can be conducted within a shorter period and lower cost [20]. Subsequently, automated assessment can also be incorporated into the development process. Automated assessment is good at detecting common accessibility problems such as missing or invalid properties and finding

out violations, but statistically, it can only discover less than 40% accessibility issues [26]. Some of the tools detect many violations but lead to an increase in false results. Thus, it is suggested that effective web accessibility audit should not merely depend on automated testing, but also combine expert-based inspections and user studies [17].

Nevertheless, automated testing tools, as well as computers, cannot understand the context the same way as humans, and end users are ultimately human beings. Their experience of the website is different from a computer. For example, automated testing tools can instantly ascertain whether the ALT attributes present in HTML, but human evaluators can judge whether the text in these attributes is adequate and descriptive [1]. Consequently, manual testing demands the evaluator with expertise in this subject, who should be familiar with WCAG 2.1, assistive technologies and usage behaviors of people with disabilities. The quality of results is largely dependent on the expertise [8]. Manual testing also examines the compatibility with screen readers and keyboard.

The W3C introduces Website Accessibility Conformance Evaluation Methodology (WCAG-EM) as an approach for evaluating how well websites comply with WCAG guidelines. This approach requires expertise in accessible design and assistive technologies. In particular, the users of this methodology should be familiar with how people with different disabilities use the web and their accessibility barriers. Whereas, the methodology does not require to have combined expertise, real users with disabilities, or any web accessibility evaluation tool [27].

The evaluation procedure is displayed in Figure 2.1. In practice, it does not necessarily follow the sequential steps. These steps can be performed at the same time or iterate any step in between.

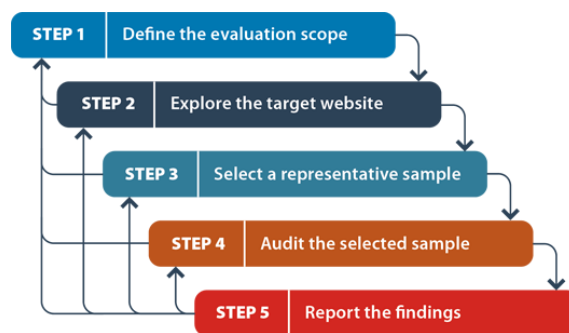


Figure 2.1: Evaluation Procedure [27]

The first step is to define the evaluation scope, including the target pages, the conformance target, and the accessibility support baseline. It should be crystal clear whether each page of the website is within the scope of evaluation, and whether the website has third-party content and services. In terms of the conformance target, WCAG 2.1 “A”, “AA”, or “AAA” level will be selected for the evaluation. In addition, the accessibility

support baseline is to define the minimum set of combinations of operating systems, web browsers, and assistive technologies that should be accessibility supported.

Exploring the target website includes identifying the common pages, identifying website functionalities as well as figuring out the web technologies. The common pages are typically linked from the header, navigation, and footer sections, while website functionality may not easily be identified. The functionality can be to purchase products from the webshop, provide necessary service information, and register an account. Web technologies include base web technologies such as HTML and CSS; and auxiliary web technologies such as JavaScript and WAI-ARIA.

The following step is to select a sample of web pages that represent the target website. In this step, the evaluator selects the page samples representing the target website to be evaluated. The purpose is to increase the evaluation efficiency and reflect the reasonable validity of the accessibility performance. This step is particularly essential to large websites. If it is feasible to evaluate the whole website, this sampling procedure can be skipped especially for small websites. A small website can result in selecting all the web pages.

Step 4 is to audit the selected sample or all web pages based on the conformance level defined in the first step. This step is usually completed with the assistance of automated testing tools and manual testing.

In the end, the outcomes of each step and evaluation specifics should be documented throughout the evaluation so that all findings can be justified and replicated at any time [27].

2.4 Usability and Accessibility

Accessibility and usability are two closely related concepts in web design. Steinfeld and Danford [23] propose that usability is based on personal interpretations. Similarly, when considering specific needs and requirements, accessibility is also subjective to individuals. However, with the enactment of the legislation, the concept of accessibility has become a relatively objective word, mainly addressing the compliance with accessibility requirements [15].

On the other side, Thatcher and Waddell [24] suggest that accessibility is a subset of usability, which is a particular type of usability problems. There is significant overlap between design for people with disabilities and design for people operating with situational limitations [13]. For example, captions are useful for people in a noisy or quiet environment as well as people with auditory disabilities.

However, if we set aside those people with situational limitations and focus accessibility on people with disabilities, the overlap is much smaller than expected. A study [21] examined the relationship between usability and accessibility with both sighted and blind people. It turned out that the common issues encountered by both groups were only about 15%. In essence, the interaction of the Web is unique for each group. Blind users rely on

screen readers to obtain web contents, while sighted users receive visual presentations of the information directly. Hence, some of the problems encountered by the blind may not necessarily happen to sighted people. It was evident that some of the problems that blind participants encounter are caused by using screen readers. Screen readers scan the HTML code. If the HTML code is not properly written, it will seriously affect the blind users. On the other side, sighted users encounter problems mostly related to the unclear interface design and ambiguous graphic components. For example, redundant animations can be misleading to sighted people while they will not affect the blind. Moreover, blind people tend to perceive higher cognitive load when encountering issues. They reported issues with higher severity than sighted participants.

Generally, a usable website is not necessarily accessible, but being accessible can improve usability for all users [21]. In the same manner, usability issues also have an equal impact on all users. However, people with disabilities are still at a disadvantage position. Poor accessibility can hinder access to the Web for people with disabilities [24]. In order to achieve web accessibility, usability techniques can also be applied to achieve web accessibility, such as incorporating people with disabilities into the design process. Addressing both accessibility and usability can bring a more accessible and usable experience to all users.

Method

This chapter describes the evaluation methods and tools that apply in the accessibility audit. The study utilises a combination of accessibility evaluation methods and tools.

To uncover all potential accessibility issues, both automated and manual testing are conducted in the study. In Section 3.1, it introduces automated testing tools. Automated accessibility evaluation tools are used to detect common accessibility issues such as colour contrast, headings, and alternative text. Since algorithms cannot recognise all issues, Section 3.2 presents manual testing that is applied to prevent gaps, such as keyboard focus, digital forms, and multimedia controls. Section 3.3 explains the scope of the evaluation.

In this study, WCAG-EM is altered and implemented to guide the procedure of the accessibility evaluation [Figure 3.1]. The evaluation procedure consists of 8 steps and conducts two evaluations: a preliminary evaluation is conducted first to develop a basic understanding of the accessibility of the target website by automated evaluation tools; and a further evaluation is then conducted with a combination of automated tools and manual testing [Figure 3.1]. Eventually, the aggregated results, along with suggestions, are presented in one table [Appendix B] and reported to the team for further improvements.

3.1 Automated Testing

There are a variety of accessibility testing tools and software that support WCAG 2.1 and other major international accessibility standards. They provide different functionalities and cover a varied breadth of the requirement. Some emphasize certain provisions, such as title, img alternative text and contrast, while others are more general. With these tools, automated testing can be iterated quickly without additional costs. It can also improve efficiency and avoid repetitive manual testing.

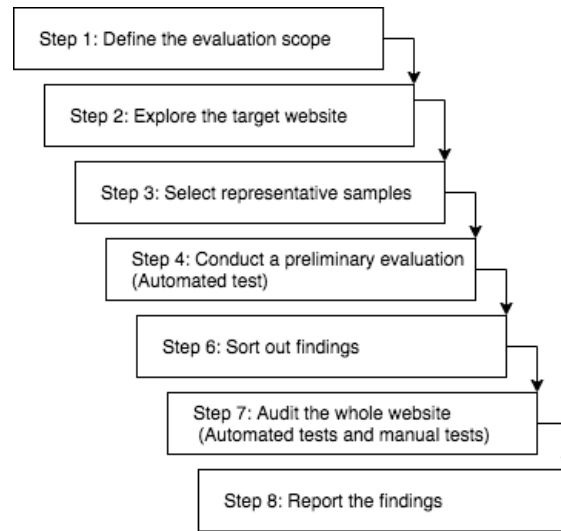


Figure 3.1: Evaluation Procedure

Multiple tools are selected and employed in this study to provide a robust accessibility evaluation. The selection criteria are free, easy-to-learn, and complementary. In order to capture all possible failures, this study employs three tools: WAVE, total1y, and ARC toolkit.

WAVE and ARC toolkit are designed to measure website compliance with accessibility standards. In particular, WAVE is primarily used for detecting the majority of accessibility problems [28], while ARC toolkit is applied to detect the code-level issues [25]. total1y is specifically deployed for the feature called 'Screen Reader Wand' [16]. 'Screen Reader Wand' simulates the browsing experience with screen readers.

3.1.1 Alternative text

All non-text content should have a text alternative that conveys the equivalent meaning and purposes [3]. Text alternatives are one of the main approaches to make information accessible since text can be presented in any sensory modality. For example, an image with alternative text can be recognised by assistive technologies, and assistive technology can read text or convert it to braille. Alternative text should be concise to transfer useful information for people who do not see the image. However, images with decorative purposes are not required to have alternative text.

In brief, text alternatives help people with visual disabilities, cognitive disabilities and auditory disabilities [3]. Visual-impaired users highly rely on image alternative text, audio description and text transcript to understand the visual information. For people with cognitive disabilities, text alternative can help those who are unable to comprehend visual presentations. On the other side, people with auditory disabilities read captions and

transcripts to get all the content of the video. The captions should synchronise with the spoken audio and contain sounds other than dialogue, while transcripts should include all audio information.

3.1.2 Contrast ratio

In professional terminology, the contrast ratio is called “luminance contrast ratio”. In web accessibility, it is to check whether the contrast between the text and background is sufficient.

There are diverse colour vision deficiencies making it impossible to specify a universal colour pair based on the quantitative data [5]. For different types of disabilities, the requirement of contrast ratio is opposite, especially for people with dyslexia, high luminance is not readable. In order to overcome this problem, it is recommended to provide a mechanism to adjust the foreground and background colors of the content. Of course, individuals with colour vision deficiencies also rely on some assistive technologies to achieve appropriate contrast ratio.

The minimal contrast ratio legally required by WCAG 2.1 is 4.5:1. The goal is to provide sufficient contrast between the text and the background so that people with low vision can read the text, but does not include people who use contrast-enhancing assistive technology. The AA level 4.5:1 contrast ratio was chosen because it can compensate for the decreased contrast sensitivity commonly encountered by users whose vision loss is approximately equal to 20/40 vision [5].

3.1.3 Headings

In HTML, headings are ranked h1 through h6. Hierarchical headings can divide information into sections visually, since headings are more prominent and bolder than regular text.

Headings have to be marked up and followed a numerical hierarchy from h1 to h6. Each page should typically have one <h1>heading level as the title. It is not recommended to skip heading levels, e.g. from h2 to h6. For people with disabilities, screen readers identify headings by heading tags. Clear and descriptive headings can assist users to find the information smoothly and understand the relationships between different sections of contents. It is especially helpful for people with memory difficulties.

3.2 Manual Testing

Manual testing is performed in order to identify potential accessibility issues that cannot directly be detected by automated testing tools. It allows the evaluator to recognize potential issues on a practical level such as resize text, keyboard-only navigation and basic structure. More importantly, manual testing evaluates the compatibility with different

combinations of screen readers and browsers. This cannot be done by mere automated tools.

3.2.1 Resize content

People with low vision and cognitive disabilities would need to enlarge the web content. Enlargement enables reading, while not all websites are responsive. According to WCAG 2.1, when the page content is resized to 400%, it is crucial that functionality or content displays normally, and only one direction scrolling is required [4]. Since scrolling in both vertical and horizontal direction is not necessary, it will significantly increase the cognitive load.

3.2.2 Keyboard-only navigation

People with visual-related disabilities rely on keyboard interaction with the Web. Therefore, all elements, including links, buttons, and media player controls, should be accessible using the Tab key. Meanwhile, the keyboard should be able to activate actions, options, visible changes, and other functionalities. All these functionalities should reveal a visible focus state and respond to the common key presses. Specifically, the media player is easily being neglected by developers. The multimedia content should be ensured to be accessible by keyboard. For example, users can start or stop the video and turn down the volume through the keyboard. In addition, the keyboard tab order also requires to follow a logical reading order.

3.2.3 Basic structure check

This aspect is more general and broad. Since the screen reader translates on-screen information to speech or braille based on HTML, it is beneficial to turn off style sheets, images and linearize the page to check the basic structure. Making sure the information is logical while reading and all images have adequate alternative text. On the other side, the information architecture should be structured clearly, including navigation system and labelling system.

3.2.4 Screen reader testing

Screen readers empower the user to hear contents on websites by treating the graphic interface as a hierarchy of elements. It reads page contents in a linear order based on the source code and provides keyboard shortcuts to assist users navigating the web. Screen reader testing helps to check the structure making sure that the page is practically accessible. It supports web accessibility auditors to understand how people with disabilities browse web pages and find out the compatibility problems.

According to the selection criteria, two most popular screen readers - Voiceover and NVDA are employed to test the website. Voiceover is a built-in screen reader on all apple products, while NVDA is an open-source software running on Microsoft Windows. Both provide shortcuts to quickly navigate through headings, links, buttons, forms, and tables, but they are slightly different. Voiceover provides shortcut key combinations, while NVDA offers single-key controls. For example, Voiceover users need to press command + control + option + H to navigate the headings, and NVDA users only need to press H on the keyboard. Besides, NVDA has two modes: browse mode and focus mode. Browse mode is designed to read documents or web pages, and focus mode is used when entering form controls and enabling users to interact with form controls. There is no mode for Voiceover.

While testing with screen readers, it is crucial to verify that all the content on the page is read out and to ensure the content is organized in a meaningful manner. Screen readers should not skip any content or read hidden content to users. Specifically, headings, links, tables, images, and videos must be tested with screen readers. All content should be accessible to Voiceover and NVDA, no matter which browser we test.

3.3 Scope

The evaluation is carried out on all web contents of the public website, which is located at <http://www.fairdata.fi>. This website was published on 14 June 2018 so that it should be accessible before 23rd September 2020.

The minimal conformance target is AA level criteria of the WCAG 2.1 guidelines according to the European standard EN 301 549 for ICT [9]. The only exception is 1.2.4 Subtitling (for live broadcasts), which do not have to meet the criteria. Thus, there are a total of 49 criteria required by Finnish law [11, 22].

The natural languages of the website are English and Finnish. The content of the Finnish and English versions of the website are slightly different, but the basic structure is the same. In this study, the evaluation is only conducted on the English version. The Finnish version can be improved based on the findings in the English version.

The types of website contents are quite fundamental and visual-based. Therefore, the study aims at improving accessibility for users with visual-related disabilities, auditory disabilities, and cognitive disabilities.

The accessibility support baseline is not limited to operating systems. The website should support Voiceover and NVDA on Chrome and Firefox, which are the most popular combinations in each operating system. Since the website is primarily designed for desktop access, mobile accessibility is not considered in this evaluation, although the website supports mobile access. Also, other assistive technologies are not evaluated in this study.

Findings

In this chapter, the findings of the evaluation are presented. Section 4.1 and Section 4.2 are inspected by automated tools, which explain the issues regarding alternative text and the contrast ratio failures, respectively. The following three sections are conducted manually. Section 4.3 justifies issues about keyboard-only navigation, and Section 4.4 describes the results of headings and resize content. In Section 4.5, the basic structure of the website is investigated. Section 4.7 clarifies the limitations of this study in the end.

Fairdata.fi is designed to support the research process and management of digital data. It provides necessary information and support for using Fairdata services. The main target users are researchers and research support staff. The website relies upon HTML, CSS and Javascript while the web contents are managed through Wordpress platform by different content producers.

The website structure is relatively simple. The common web pages are home page, sitemap, contracts and privacy, and terms and policies. There are 38 pages in total.

The website serves the purpose of providing information regarding Fairdata services. Thus, most of the contents are text-based, including the other essential types of content, such as forms, tables, lists, headings, multimedia and toggles.

This is the first time for this website to be audited.

4.1 Alternative Text

WAVE and ARC toolkit are applied to identify whether each media content has an alternative text. 'Screen reader wand' of total1ly is also employed to simulate the screen reader. Media contents that provided appropriate alternative text are considered to be accessible.

First, all images do not have proper text alternatives. The alternative text of Fairdata logo does not present its function. The other images are descriptive screenshots of the

services that give instructions and explain features. These are significant visual materials for novel users, but there is neither 'alt' text nor additional explanation passages that supports web accessibility.

Second, videos do not have a title attribute. Video is also a necessary content type on the website, and the video content is embedded by inline frames(<iframe>). There are five embedded videos on the website. However, the inline iframes of the two videos, Fair Principles and Fairdata Benefits, lack the title attribute. Another inline iframe of the video, research data lifecycle, is named inappropriately. Since screen readers read the title attribute aloud, an empty title attribute or an ambiguous title attribute can confuse screen reader users about the subject of the video.

Third, videos do not have Finnish captions. On the website, pre-recorded videos are provided with spoken audio in Finnish and captions in English. Although transcripts in both languages are offered, people with cognitive disabilities have difficulties in comprehending texts and static images. They rely on the video to understand the contents. Thus, it is also crucial to provide captions in Finnish. Besides, CSC offers training and webinars once in a while and then upload video links later. These sessions typically present in a single language, either Finnish or English. If it is an online webinar, CSC will not provide captions or text transcripts. This undoubtedly increases the difficulties for disabled people.

Last, tables on the website do not have table headers(<th>). An empty <th> can result in incorrect header information or missing cells, which may cause misunderstanding by screen reader users.

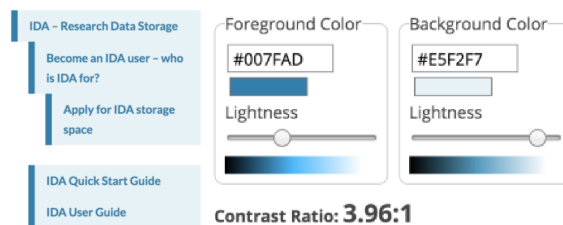


Figure 4.1: Color Ratio of the Side Navigation

4.2 Contrast Ratio

WAVE is used to assess the contrast ratio of the website. Contrast ratio of text and background is required at least 4.5:1 [5]. Large text (18.66px bold or 24px) and images of large-scale text have a contrast ratio of at least 3:1. WAVE detects the insufficient colour contrasts and provides the visual feedback of the specific contrast failure on the web page.

The main contrast error happens on the side navigation [Figure 4.1]. The colour 007FAD and E5F2F7 are two primary colours on the website. When these two colours apply to text and background, the contrast ratio does not meet the minimum contrast ratio.

Similarly, the contrast ratio of 'MORE NEWS' button is not sufficient to reach the standard with only 3.24:1.

4.3 Keyboard-Only Navigation

Keyboard-only navigation is manually examined so as to identify whether the web page supports mere keyboard interaction.

In this evaluation, Keyboard-only navigation is the most severe accessibility issue on Fairdata site. First, the tab order is poorly structured on the home page and FAQ page. For keyboard users, the square graph on the main page traps them for 14 meaningless tabs, as Figure 4.2 shows. The square graph is meant to describe the relationships between Fairdata services and provides shortcuts to access these services. Nevertheless, these service shortcuts have already offered next to the graph, which makes the graph look like a decorative picture. In other words, it is redundant to place any link in the square graph causing keyboard traps.

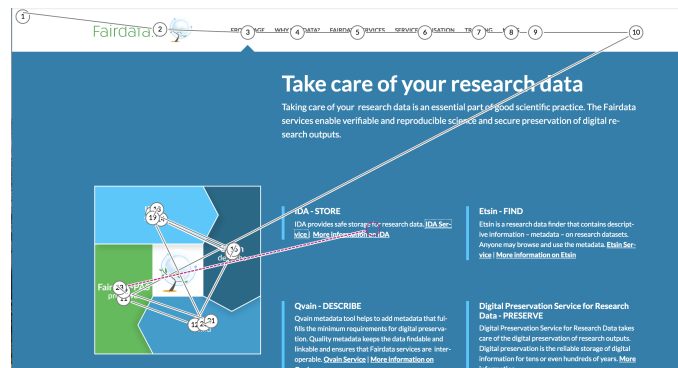


Figure 4.2: Tab Order on the Main Page

Besides, the accordion design on the FAQ page does not serve its purpose for the quick navigation [Figure 4.3]. The accordion is vertically stacked items. Each item can be toggled to display the content associated with the item. In essence, the accordion should provide the same experience for people with disabilities. However, as Figure 4.3 shows, the tab order of the page is messy and confusing when using the keyboard to navigate. It simply goes through all contents linearly as Figure 4.4 indicates. An accessible accordion supposes to allow keyboard users to tab through items one after another, then select the topic, and finally toggle to display the content. Note, terrible tab order overwhelms people with disabilities and would eventually contribute to a high drop off rate.

Second, the visual focus is not well-supported on the website. Having the keyboard focus indicator is essential for people to know which element has the keyboard focus. The visual indicator is especially crucial for people with cognitive disabilities who has memory

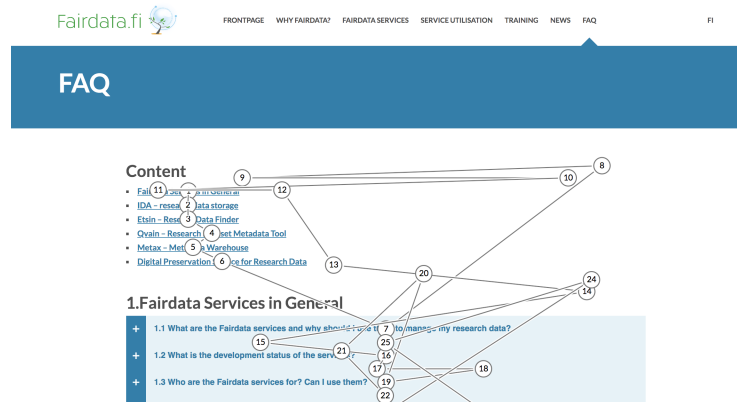


Figure 4.3: Tab Order on FAQ Page: Accordion Closed

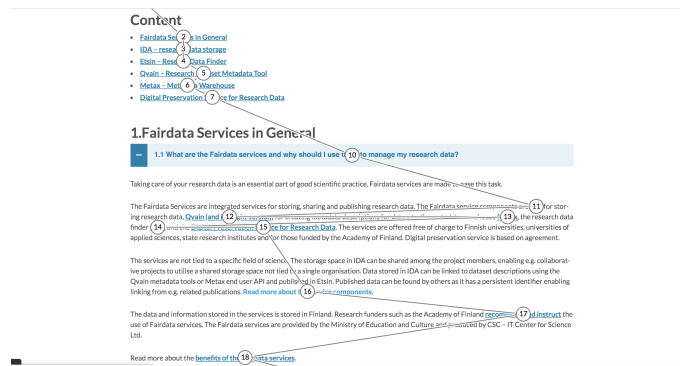


Figure 4.4: Tab Order on FAQ Page: Accordion Open

and attention problems. On the fairdata.fi, the visual focus state disappears when tabbing from the navigation bar to the main content. Also, the visual focus state is not available when tabbing through the accordion on the FAQ page. On the other pages, the keyboard indicator is not visually distinctive. It should be prominent with consistent focus styling.

4.4 Headings, Resize Content

Heading levels are checked by WAVE. Hierarchical heading levels help users to understand the information structure. All headings are marked up but do not follow the numerical hierarchy. The heading level skips from h1 to h4, but it does not affect users to understand the content structure and relationships between different sections.

Resize content is manually tested with the browser's zoom feature. The website is responsive when zooming in 400%. There is no horizontal scrolling or loss of content. All functionalities are displayed well.

4.5 Basic Structure

Fairdata.fi is a simple website with a broad and shallow structure [Figure 4.5]. It is explicit for users to access each page quickly with two clicks maximum.

The website provides global navigation, local navigation and sitemaps for supplemental navigation. However, hierarchical categories are not explicitly exclusive due to the labelling confusions such as Fairdata services and Service utilisation. Some pages are not placed in the reasonable categories, e.g. Fairdata components. These page titles either fail to simply describe the content on the page or overlap with another page title. This labelling problem can affect everyone. Moreover, the website does not provide a search bar to assist users in finding information quickly.

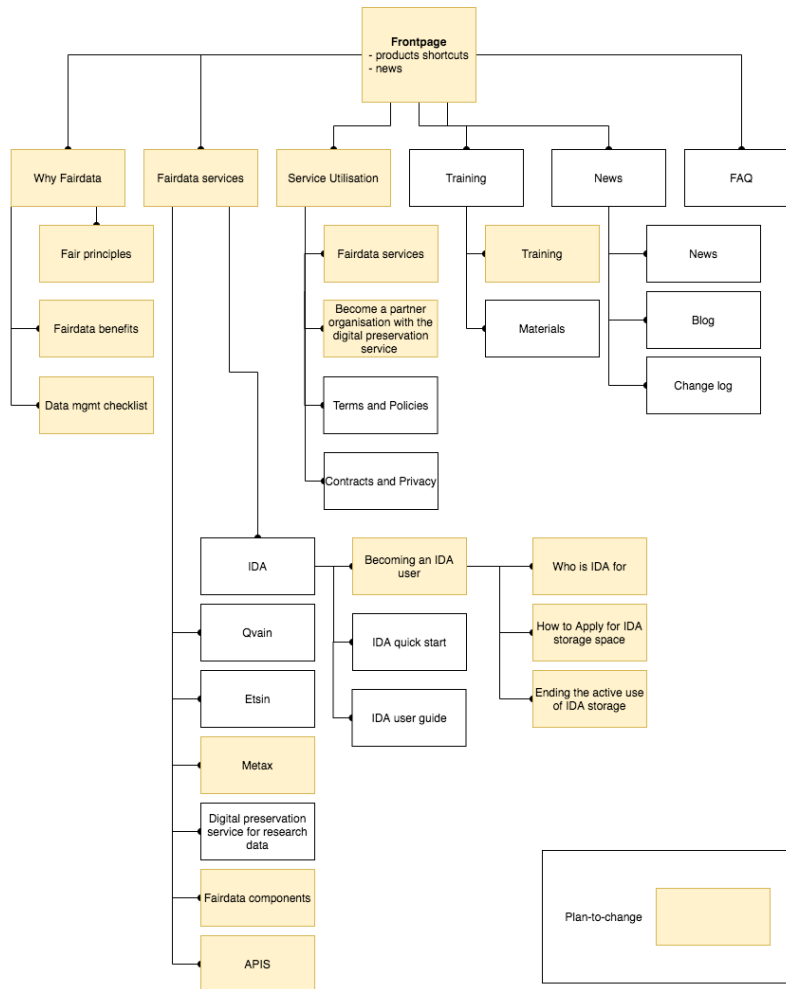


Figure 4.5: Information Architecture of Fairdata.fi

4.6 Screen Reader Testing

Screen reader testing is applied to inspect the compatibility with different browsers and to detect unexpected practical issues. In this study, Voiceover and NVDA are deployed to test the target website on Chrome and Firefox. Each screen reader browses headings, links, tables, images, and videos in two browsers. Then read through the entire web page to check that the content is well-organized and logical.

Task with NVDA	Chrome	Firefox
Go to headings	No focus indicator	
Go to links	/	/
Go to tables	Do not speak the 'blank' cell	
	/	Does not read each cell of one table with its associated header
Go to images	/	/
Video	Do not speak the title attributes; do not speak the video play controls	

Table 4.1: Screen reader testing with NVDA

To begin with NVDA, NVDA offers the single-key controls that can efficiently jump to headings, links, images and tables. First, there is no focus indicator when navigating the heading. Without focus indicators, disabled users are not able to locate the focused element by NVDA. Second, NVDA does not speak empty cells in tables. Take Figure 4.6 as an example. This table is visually explicit to display the differences between two services - Qvain and Qvain light, while the experience for screen reader users is quite different. Screen readers speak one cell at a time and refer to the associated header cells. When encountering an empty cell, NVDA merely speaks the associated header. NVDA speaks the highlighted row as “Qvain, row 2, X”, and “Qvain light”. In comparison, Voiceover reads “Qvain, X, column 2 of 3” and “Qvain light, blank, column 3 of 3”. Voiceover automatically recognizes the blank cell and speaks out “blank”, but NVDA fails to read the empty cell. It is best to avoid using blank cells and replace them with “No value” or “- (dash)”. Third, NVDA seems to be unable to recognize the inline frames. It does not speak the title attribute of the video, let alone video player controls. Correspondingly, this makes it frustrating for NVDA users to watch videos. Table 4.1 lists the issues detected by NVDA.

Compared with NVDA, Voiceover has fewer accessibility issues identified through this test. Voiceover also supports keyboard shortcuts to headings, links, tables and images. The major issue with Voiceover is to browse tables. The shortcut to next table (control + command + option + T) does not work on Chrome. Only if Voiceover users go through the

whole page, they will find the table. In addition, Voiceover unnecessarily speaks images with null alternative text, whereas NVDA ignores images with a null alternative text. It is useless to speak images with null alternative text because these are merely decorative images. Table 4.2 lists the issues detected by Voiceover.

Task with Voiceover	Chrome	Firefox
Go to headings	/	/
Go to links	/	/
Go to tables	Shortcut to next table doesn't work	Does not read each table cell of one table with its associated header
Go to images	/	Speak 'image' with the null alternative text
Video	/	/

Table 4.2: Screen reader testing with Voiceover

Feature	Qvain	Qvain Light
Implements the whole data model	X	
Save as draft	X	
Keywords as a reference data	X	
Mandatory fields that are not mandatory in other version of Qvain		Mandatory: Keywords, Publisher
Fields that can have multiple values in other version of Qvain but only one value in the other	Multiple values: Curator, License	

(x) = To be implemented later

Figure 4.6: Differences Between Qvain and Qvain Light

Both screen readers have the same problem when browsing one specific table [Figure 4.6] on Firefox. Neither NVDA nor Voiceover succeeds in referencing each cell with its associated header cell, even though the table header cell is correctly marked with <th>. Besides, screen readers go through the content linearly, so the annotation under the table is recognized last. If screen reader users use the shortcut to jump to this table, they will not hear the annotation at all, because the annotation is not coded as a part of this table. What's more, it can be misleading since the "x" means "to be implemented later" instead of having the feature.

Besides, screen reader testing detects a code-level accessibility issue. When a screen reader reads the language selector button, it uses the language abbreviations and is currently recognized as “visited, linked, FI list 1 item”. The aria-label attribute in HTML is missing. This might make it difficult for screen reader users to select the website language.

In general, Chrome is more compatible with both screen readers than Firefox. Firefox reveals more accessibility issues, especially when browsing with NVDA [Table 4.1 & 4.2]. In this screen reader testing, the best combination is Chrome with Voiceover, which shows fewer accessibility issues.

4.7 Limitations

Apparently, web accessibility cannot be easily achieved by complying the WCAG guidelines.

Automated assessment tools do an excellent job of capturing issues, and their capture speed far exceeds human capabilities. However, these tools provide false results, requiring the human evaluator to eliminate these results manually. Some automated tools also fail to reveal accessibility issues so that more accessibility failures are revealed in the manual testing. Eventually, it consumes more time for the evaluator to determine and organize the final results.

Apart from these, the evaluator is not only responsible for identifying potential accessibility issues, but also eliminating false results. The entire accessibility evaluation requires the evaluator to have extensive experience and solid skills to ensure the quality of the results, especially some guidelines are confusing and complicated to understand [7, 17]. Hence, the experience of the evaluator influences the accessibility findings to a large extent. Moreover, this study does not have a team of evaluators with collective expertise so that the results might be biased.

The study pays more attention to comply with WCAG 2.1 instead of real users with disabilities. Even though screen reader testing is conducted, it does not mean that all real-world accessibility issues have been identified. The experience of the evaluator cannot replace the experience of the real user. Specifically, Fairdata website targets researchers and research support staff as the primary user group. However, recruiting real people with disabilities is not easy, let alone researchers with disabilities, especially during the unprecedented period of the COVID-19 pandemics. In consideration of time and other projects, WCAG-EM is eventually selected to evaluate the accessibility without user testing.

Conclusion & Perspectives

Improving accessibility is not only beneficial to people with disabilities but also useful for people without disabilities in certain circumstances. For example, the elderly encounter difficulties in accessing the Web; people with “temporary disabilities”, i.e. fracture of hand; people with “situational limitations”; and people using a poor internet connection. By all means, it is essential to recognize the necessity of accessibility and be familiar with technologies and tools for the Web to be accessible. After all, achieving Web accessibility depends on the awareness and joint efforts of the project team, especially the recognition of the developers.

People with disabilities need different support for web content accessibility. Auditory disabilities users rely more on visualization, while people with cognitive disabilities have difficulties in visual communication. On the other hand, visual content is basically meaningless to blind users.

This study set out to verify the web accessibility compliance and identify accessibility issues. The study applies the WCAG-EM methodology [Figure 2.1] to guide the accessibility assessment. First, a preliminary accessibility evaluation using automated tools is performed to check for common accessibility barriers. After categorizing the results, through the application of automated tools and manual testing, a comprehensive evaluation is further carried out to assess accessibility compliance. Automated testing tools play a good role in identifying missing alternative text, poor contrast ratio, and skipped heading levels. However, automated testing tools are essentially algorithms. It returns true or false within a few seconds while requiring human evaluators to judge the adequacy. For example, the web page works perfectly in the screen reader simulation, but it reveals many unexpected issues in the screen reader testing. Screen reader simulation fails to display the same results as the screen reader. It cannot replace the actual screen reader testing. Manual testing is irreplaceable. It can reveal practical issues that affect people with dis-

abilities, such as the compatibility issues with screen readers and context-related problems. Precisely, human manual testing can judge the context and determine the adequacy.

The major accessibility issues are alternative text, contrast ratio and keyboard-only navigation. These issues can be easily resolved by adding descriptive alternative text, changing colour combinations and using ARIA labels. Screen reader testing indicates that the website is compatible with both screen readers to some extent. Nevertheless, the performance of the two browsers is different. Compared with Firefox, Chrome is a better choice for both Voiceover and NVDA users, especially for Voiceover users. Firefox is still working on the compatibility with Voiceover [18]. The detailed findings and improvement suggestions are sorted and reported for further development [Appendix B & C]. Ultimately, the target website should meet the WCAG 2.1 AA level and be accessible to everyone.

The future work should involve target users into the web accessibility evaluation so that more real-world accessibility issues can be discovered. With feedback from real users, the project team can concurrently deepen the understanding of people with disabilities. On the other side, accessibility evaluation, especially manual testing, should be an iterated process incorporated in the regular maintenance to ensure web accessibility.

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Results of the Preliminary Evaluation

Preliminary Criteria	Outcome	Suggestion
Page title	Pass	
Image text alternatives	Pass	
Headings	Fail	Heading level is skipped from h1 to h4. But it doesn't affect the browsing experience.
Contrast ratio	Fail	Contrast ratio of text and at least 4.5:1. Change the color combinations 1. frontpage - "more news" button 2. accordion - the color of selected content color and its background
Resize text	Pass	
Keyboard access and visual focus	Fail	The keyboard focus doesn't follow a logical order on the front page. The visual focus is lost when jumping to the square on the left. 1. Visual focus state is better to have a bold border and more obvious color 2. Visual focus is not obvious due to the background color of the Frontpage. 3. Visual focus state should be added to the accordion.
Forms, labels and errors	Pass	

Moving, flashing, or blinking content /

Multimedia(video, audio) alternatives	Fail	<ol style="list-style-type: none"> 1. Transcript and open/close captions are provided, but captions are in English. 2. Video iframe is missing an alternative name.
Basic structure check	Fail	<p>Improve the focus order</p> <ol style="list-style-type: none"> 1. The big square on the front page should be improved. Users stuck in the square for 14 meaningless tabs. This makes users confused and lose track of website browsing. 2. When tab on "skip to content", it should take users to main contents instead of table of contents. 3. Tab order on FAQ page requires huge improvements.

Results of the Comprehensive Evaluation

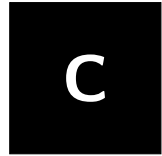
Guidelines	Outcome	Suggestion
1.1.1 Non-text Content (A)	Fail	1. Add title attributes to <iframe>elements a. Video on 'Fair Principles' - title="Fair Principles" b. Video on 'Fairdata benefits' - title="Benefits of Fairdata services" c. Video on 'Data Management Checklist' - title="Research Data Management" 2. Change alternative text: Fairdata logo - alt="Fairdata Home"
1.2.1 Audio-only and Video-only (Prerecorded) (A)	Pass	

1.2.2 Captions (Prerecorded) (A)	Fail	<p>Captions are missing. The current videos only have synchronized English subtitles with Finnish audio.</p> <p>1. Add multilingual captions including tutorial and training videos. (only "metadata in science" has captions)</p> <p>- https://www.fairdata.fi/en/why-fairdata/fair-principles/</p> <p>- https://www.fairdata.fi/en/why-fairdata/benefits/</p>
1.2.3 Audio Description or Media Alternative (Prerecorded) (A)	Pass	
1.2.5 Audio Description (Prerecorded) (AA)	Not critical	Audio description is missing, but the spoken audio has described and presented the visual content.
1.3.1 Info and Relationships (A)	Fail	<p>1. Provide the appropriate header (<th>) cells</p> <p>2. Multiple header landmarks are presented. (need to be discussed with developers)</p> <p>3. Avoid blank cells, replace with 'No value' or '-'</p>
1.3.2 Meaningful Sequence (A)	Pass	
1.3.3 Sensory Characteristics (A)	Pass	
1.3.4 Orientation (AA)	Pass	
1.3.5 Identify Input Purpose (AA)	Pass	
1.4.1 Use of Color (A)	Fail	<p>Other than using color to indicate an action, apply other visual representations such as underlines, arrows.</p> <p>1. main navigation: add underlines with hovering effect</p> <p>2. accordion: add underlines on selected items</p>
1.4.2 Audio Control (A)	Pass	/

1.4.3 Contrast (Minimum) (AA)	Fail	Change color combination 1. "More news" button: change background green from #11A53C to #03881C 2. Accordion text color and background color: change text color from #007FAD to #0075a3
1.4.4 Resize text (AA)	Pass	
1.4.5 Images of Text (AA)	Pass	
1.4.10 Reflow (AA)	Pass	
1.4.11 Non-text Contrast (AA)	Pass	
1.4.12 Text Spacing (AA)	Pass	
1.4.13 Content on Hover or Focus (AA)	Pass	
2.1.1 Keyboard (A)	Pass	
2.1.2 No Keyboard Trap (A)	Fail	1. The square on the front page traps users: https://www.fairdata.fi/en/ 2. Accordion on FAQ page: https://www.fairdata.fi/en/faq/#content
2.1.4 Character Key Shortcuts (A)	Pass	
2.2.1 Timing Adjustable (A)	Pass	
2.2.2 Pause, Stop, Hide (A)	Pass	
2.3.1 Three Flashes or Below Threshold (A)	Pass	
2.4.1 Bypass Blocks (A)	Pass	
2.4.2 Page Titled (A)	Pass	

2.4.3 Focus Order (A)	Fail	<ol style="list-style-type: none"> 1. The focus on the front page stuck on the square. 2. "Skip to content" on the sub-pages should let the main contents go first, then accordion.
2.4.4 Link Purpose (In Context) (A)	Fail	<ol style="list-style-type: none"> 1. Provide the link text that describes the contents of the link. <ol style="list-style-type: none"> a. Link to participate: https://www.fairdata.fi/en/training/training/ change to "Click here to participate in the webinar" b. Watch the video, download and recording: https://www.fairdata.fi/en/training/materials/ change to "Download XXX materials" change to "View XXX webinar slides" change to "Watch XXX webinar"
2.4.5 Multiple Ways (AA)	Fail	Add a site search
2.4.6 Headings and Labels (AA)	Pass	
2.4.7 Focus Visible (AA)	Fail	<ol style="list-style-type: none"> 1. Visual focus should be emphasized with bold border and distinctive color. 2. Visual focus should be improved specifically on the home page, FAQ page and other pages with toggles.
2.5.1 Pointer Gestures (A)	Pass	
2.5.2 Pointer Cancellation (A)	Pass	
2.5.3 Label in Name (A)	Pass	
2.5.4 Motion Actuation (A)	Pass	
3.1.1 Language of Page (A)	Pass	

3.1.2 Language of Parts (AA)	Fail	Training page is a mix of Finnish and English. It should be improved if time is allowed. https://www.fairdata.fi/koulutus/koulutukset/ The language of page content that is in a different language is identified using the lang attribute. (e.g., <code><blockquote lang="es"></code>)
3.2.1 On Focus (A)	Pass	
3.2.2 On Input (A)	Pass	
3.2.3 Consistent Navigation (AA)	Pass	
3.2.4 Consistent Identification (AA)	Pass	
3.3.1 Error Identification (A)	Pass	
3.3.2 Labels or Instructions (A)	Pass	Language selection is missing descriptive labels so that the screen reader only recognize "EN". Add a aria-label="Select your language. Your current language is English(EN)".
3.3.3 Error Suggestion (AA)	Pass	
3.3.4 Error Prevention (Legal, Financial, Data) (AA)	Pass	
4.1.1 Parsing (A)	Fail	Duplicate id: ensures every id attribute value is unique. Need to be evaluated with developers, utilize features in their authoring tool to ensure that id attribute values are unique. Tool: https://validator.w3.org/#validate_by_uri
4.1.2 Name, Role, Value (A)	Fail	refer to 1.1.1
4.1.3 Status Messages (AA)	Pass	



Information Architecture Improvement Plan

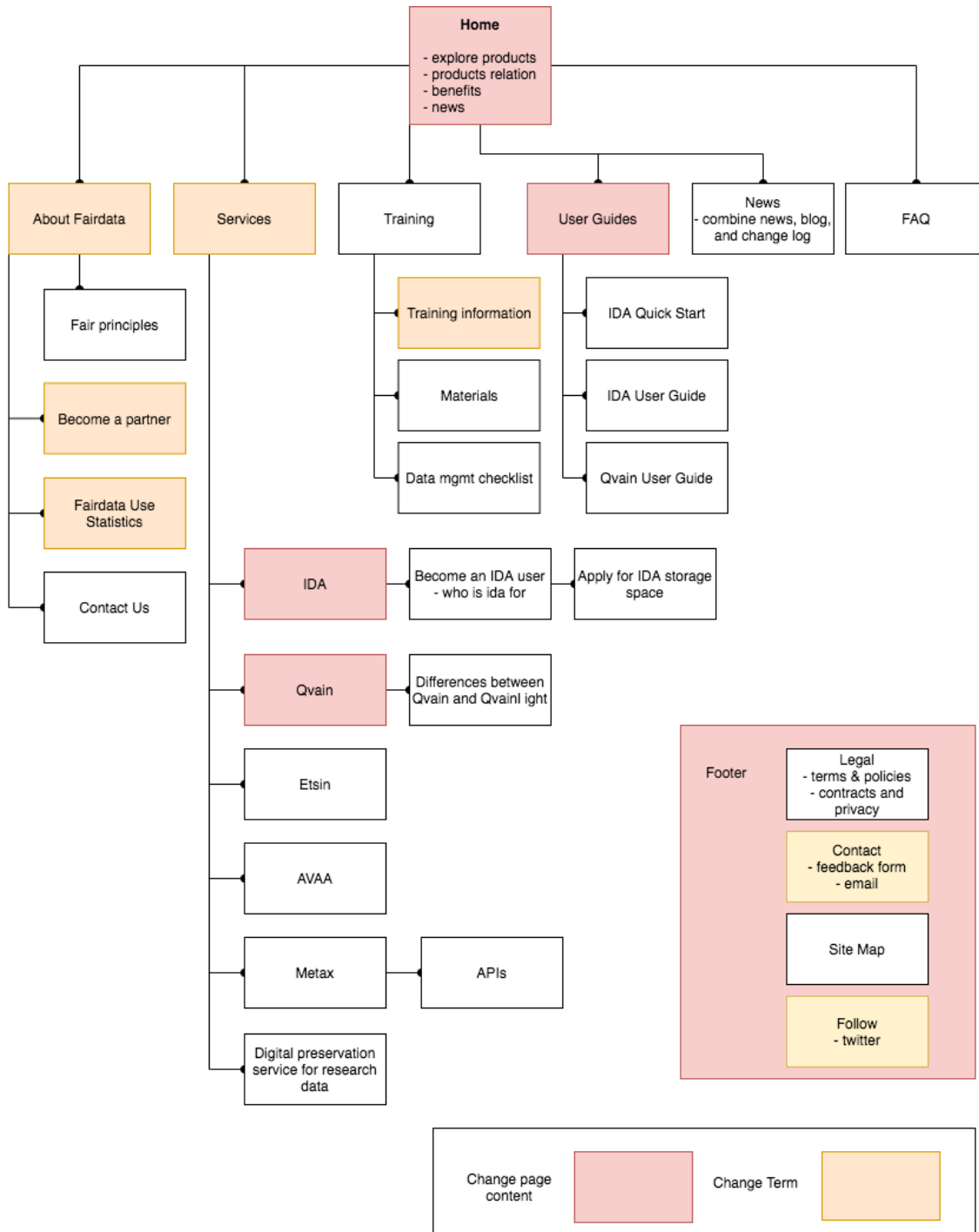


Figure C.1: Information Architecture of Fairdata.fi