MASTER THESIS

Web Accessibility

Incorporating User Requirements into a Guide for Usable Web Accessibility

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Executive Summary

The economy and society are becoming more and more digital. This requires the possibility for everyone to contribute to and benefit from the services and products offered online. However, studies reveal that most websites are not fully accessible. To achieve digital inclusion, the EU has increased legal pressure on public sector bodies to make their web and mobile applications accessible. This fact challenges public authorities and their software providers to implement accessibility in a timely manner in existing applications and new developments.

Although research on web accessibility has been conducted for over 20 years and produced various approaches and checklists, the concept has not yet been established in processes and projects of organizations and its added value for all users has not been understood either.

This research proposes a guide for organizations to address and implement accessibility in web applications and to improve the user experience. It consists of six components, whereof three provide fundamental knowledge on the definition and differentiation of web accessibility and usability, on user groups and their needs as well as legal obligations. Furthermore, general recommendations concerning the key issues of the concept and a test strategy for the evaluation of accessibility are added. The main part entails user-centered accessibility requirements based on the technical standard extended by relevant user requirements.

The guide as a designed artifact is the result of design science research, conducting a first iteration of the Design Science Research Methodology by Peffers et al. [1]. Along the process, different research methodologies were employed. Definitions, regulations and user requirements have been identified through a systematic literature review and validated through semi-structured interviews with experts in the field. The synthesized results have extended the technical standard for web accessibility and are incorporated into the proposed guide.

The guide has been validated in three steps: First, it was applied to a case study in order to demonstrate the artifact in use. Afterwards, the result, an accessible website, was tested through user testing with participants with different disabilities. Finally, the guide as a holistic approach was evaluated in terms of comprehensibility, usability, completeness and potential improvements through interviews with practitioners. Further evaluations are recommended.

The contributions of this research to theory and practice are manifold. Among others, the guide serves as introduction and reference work for practitioners and raises awareness for the needs of users with and without disabilities. In terms of research, it provides state of the art theoretical knowledge on the concept, regulations, user requirements and key issues that should be addressed in future in order to promote accessibility and ensure its establishment in the web.

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List of Abbreviations

A1-A3	ID for the definitions of web accessibility
A, AA, AAA	Conformance levels of the WCAG
BITV	Barrierefreie-Informationstechnik-Verordnung (German regulation)
CONET	CONET Technologies Holding GmbH, CONET Solutions GmbH
CSS	Cascading Style Sheets
DSRM	Design Science Research Methodology
E1-E8	ID for the participants of expert interviews
EU	European Union
HTML	Hypertext Markup Language
IP1-IP4	ID for the participants of validation interviews
ISO	International Organization for Standardization
R1-R3	ID for the relations between web accessibility and usability
RE	Requirements Engineering
RQ	Research question
SLR	Systematic literature review
U1-U4	ID for the definitions of usability
UCD	User-centered design
UR	User requirements
UT1-UT3	ID for the participants of user testing
UX	User experience
WAI	Web Accessibility Initiative
WCAG	Web Content Accessibility Guidelines
W3C	World Wide Web Consortium

1 Introduction

The web has become an ubiquitous source of information, services and interaction over the past years. More and more activities of daily life are carried out over the Internet, such as e-commerce, public, financial, health and social services, education, communication and content creation [2, 3]. Figures from 2017 confirm this trend, as half of the world's population (more than 3.7 billion people) use the Internet frequently. This is an increase of 938.8 % compared to the numbers in 2000, which was only possible because of the web's own development [4].

The initially static web pages have been replaced by new technologies, such as web applications (apps), based on client-server architectures using HTML, HTTP and user agents [5]. These, in turn, have been extended by client-side interface components (widgets) and asynchronous communication with the server side, creating Rich Internet Applications [6]. The use of JavaScript, AJAX and FLASH in combination with the latest versions of HTML and CSS enable dynamic behavior of elements and lead to an improved interactivity and user experience (UX) [7, 8].

This development is accompanied by an increasingly complex design and implementation for web applications in terms of navigation, layout and interaction behavior. Hence, sensory (visual, auditory, tactile), physical and cognitive abilities of users are essential to engage with digital content [2]. In this respect, the key issue is web accessibility. It is suggested that web content is universally accessible to everyone, independent of any situational or long-term circumstances or impairments [9]. In order to promote digital inclusion, it is required to address the needs of those who face additional barriers due to disabilities or other restricting conditions. In this context, ‘barrier’ is understood as “a condition, which prevents a specific user, who has specific traits and is using specific assistive technologies, from achieving his specific goals. A barrier is not just a defect on a web app but an attribute of the interaction between the user and the system.” [10]. Thus, barriers must be avoided and existing ones removed in order to make web content accessible to all users. As the Web Accessibility Initiative (WAI) states [11]: “It [accessibility] is essential for some, but useful for all.”.

Web accessibility is not a new topic. It has been discussed by researchers and practitioners for more than 20 years. Despite the increasing role of the web and the enforcement of accessibility laws by several governments across the world (such as [12-15]) concerning the web content of public sector bodies, accessibility has not yet been established as a standard non-functional requirement in web or software development. Several studies reveal that most public web sites lack to conform with accessibility standards, even though legal obligations exist to implement

accessibility in information and communication technologies [2, 16, 17]. This may be a result from a lack of awareness and understanding among practitioners like project managers, designers, developers and UX professionals for web accessibility and its target users [4, 5, 18].

The need to increase awareness and understanding for web accessibility has been recognized by the legislator. Recent changes in the legal framework of the European Union (EU) and its member states force public sector bodies on federal, state and communal level to ensure accessibility in their applications; though do their web and software providers. Consequently, the concept needs to be understood in its complexity in order to be implemented in user interfaces: legal and technical requirements as well as the real needs of end-users. Although past research efforts produced several methodologies approaching the concept, they are mainly focused on one aspect only, such as guideline conformance, requirements engineering or accessibility evaluation [10, 19, 20].

There is, therefore, a need for research on the one hand to examine the legal and technical framework conditions that accessibility entails. On the other hand, users, their abilities and needs must be researched in order to foster a better understanding. Furthermore, this work aims to develop a holistic approach that promotes awareness and knowledge and thus supports the implementation of accessibility.

1.1 Background

This section provides background information about the case study company CONET, its interest in web accessibility, the concept itself and concerned user groups as well as existing legal obligations.

Case Study Company

CONET Technologies Holding GmbH is a medium-sized IT consulting and software company based in Germany and has provided a case study for demonstration purposes in chapter 6. Founded in 1987, it has about 1.000 employees and has been growing steadily over the last few years. The company's portfolio comprises customer solutions for the digital transformation using various innovative technologies. Infrastructure, communications and software, among others, belong to the strategic service areas. Actors from industry, retail and especially the public sector in Germany are among CONET's customer base.

CONET provides its services in specialized subsidiaries in which the technical know-how and the expertise of consultants, developers and system integrators are bundled. The oldest subsidiary is CONET Solutions GmbH with focus on infrastructure and software solutions. The

software engineering department has recently been supplemented by a UX team, which supports the design and implementation of usable user interfaces in web applications in order to improve the user experience of the product users.

Especially since the EU and subsequently Germany have legally obligated public authorities to guarantee accessibility in their web, mobile and software applications, the topic has gained importance for CONET. In addition, the company sees potential in web accessibility not only in terms of new customer projects, but also in the overall improvement of the user experience of its products. Therefore, CONET aims to integrate the concept into its processes in order to ensure legally compliant user interfaces of the applications which enhance the user experience through usable accessibility.

Web Accessibility

Existing research on web accessibility has produced different methodologies in order to address the concept. According to Reichling and Cherfi [20], different models and methods are proposed to address web accessibility. The two categories of methods are 1) the design of accessible web content and 2) the evaluation of web sites on accessibility flaws and on the conformance level as an afterthought.

The latter, accessibility evaluation, can be done by three different types of testing: first, automated testing by evaluation tools such as software programs, and secondly, manual testing by human evaluators like accessibility experts. Both are guideline-based and focus on the conformance with prescribed criteria. The third type is user testing with real end-users to test usability and accessibility from their point of view [21, 22].

Some studies suggest to address accessibility from the beginning of the project. The AWA approach (Accessibility for Web Applications) is a methodology framework that includes conceptual elements capable of abstracting guideline-based accessibility requirements into a web engineering method by a participatory design process [19]. Moreover, Henka and Zimmermann [10] provide a persona-based approach for representing accessibility guidelines in order to help web designers and developers create a better understanding of the target audience and their specific needs for accessible and usable user interfaces. They criticize the existing guidelines for being too technical and lacking sufficient support for the implementation. The approach of Reichling and Cherfi [20] is also based on user-centered design (UCD). The authors aim to integrate users' needs for accessibility with known standards in an iterative process of three main phases: analysis, design and evaluation [23]. The success of the method mainly relies on collecting requirements, since it is the basis for the following phases [20].

These approaches highlight that user requirements are essential for designing accessible web applications as well as testing them. Since UCD places users at the center and focuses on their interaction with systems, their tasks, goals and personal abilities [24], it is used in several studies to explore user requirements of people with and without disabilities [21, 25-28].

User Groups

As the Web Accessibility Initiative states [11] that web accessibility "[…] is essential for some, but useful for all", different user groups have to be considered when addressing web accessibility. A special focus lies on people with disabilities and elderly.

According to the World Health Organization (WHO) [29], 15 % of the world's population have some form of disability. In the EU in 2012, 73 million people aged over 15 years lived with a disability which equals to 17.6 % of the population, resulting in approximately one out of six people with some kind of impairment [30].

In general, disabilities can be grouped into the following categories [17]:

- Visual impairments (e.g. blindness, low vision, color blindness)
- Hearing impairments (e.g. deafness, hard of hearing)
- Motor impairments (limited movement or control of arms, hands, fingers, e.g. tremor, broken arm)
- Cognitive, learning and neurological impairments (e.g. learning, language and intellectual disabilities, inability to process, remember or focus on information, such as dyslexia, dementia or down syndrome)

In addition, people of age 60+, commonly referred to 'elderly', are considered to form a separate user group because of possible accompanying characteristics attributable to the ageing process. Due to rising life expectancy, people over 60 years of age forming 12 % of the global population in 2015, represent the fastest growing segment [31]. However, their sensory, physical and cognitive abilities are gradually declining and at different stages of their life, they face difficulties interacting with the web. An increasing number of health-related issues lets them deal with several barriers across the groups of disabilities which makes accessibility a crucial requirement for being able to use the web on a daily basis [32, 33].

An overview of user groups affected by web accessibility is provided in Appendix A (Table 30): such as people with certain disabilities, older people and also users without disabilities (general). It illustrates typical barriers which people of all user groups face as well as tools they use to overcome them. The table serves as an introduction into the users and their needs.

Legal Obligations

In December 2006, the UN adopted the Convention on the Rights of Persons with Disabilities in order to change attitudes and approaches to people with disabilities. It has now 163 signatories and was ratified by 181 parties, including the EU. The Convention is intended to ensure that all people with all types of disabilities must enjoy all human rights and fundamental freedom within the ratified countries [34].

Building on this, the EU has established the 'European Disability Strategy 2010-2020', which aims to remove barriers, that prevent people with disabilities from participating in society, in order to foster social inclusion. It involves actions in various fields, including accessibility of information, communication technologies and systems, with the objective to ensure accessibility to goods, services, including public services, and assistive devices for people with disabilities [35].

The growing importance of web accessibility has led the EU to adopt the directive (EU) 2016/2102 in 2016 that requires the uniform implementation of accessible web and mobile applications by public authorities [36]. The EU member states had to incorporate this directive into their national legislation by 2018. This means that public bodies at federal, state and communal level are obliged to comply with certain deadlines to make their existing and new web and mobile applications accessible in accordance with technical standards. Publicly accessible websites and mobile apps of federal authorities have had to be designed barrier-free for several years. However, the new introduction of national monitoring bodies is increasing the pressure to implement them. In addition, new obligations have been added regarding intranets and extranets, for apps used exclusively internally and for electronic administrative processes.

This means the following at a glance:

- Websites published after September 2018 must be accessible from September 2019,
- already existing websites from September 2020.
- As of September 2019, new intranet offerings must be developed barrier-free. For previously published intranet applications, this only applies after a fundamental revision.
- For mobile applications the directive shall apply from June 2021.

In addition to that, accessibility requirements for products and services of organizations, such as smartphones, computers and operating systems, ATMs, ticketing and check-in machines as well as e-books and e-commerce, will be applicable from June 28, 2025 as per European Accessibility Act [37, 38].

1.2 Problem Statement

The current legal obligations force public sector bodies to act. They must consider web accessibility for new developments and check their existing applications for conformity with legal standards in order to implement any necessary changes or to initiate a re-launch with the deadlines in mind. This requires extensive efforts and knowledge.

Companies, that offer web and software applications, such as CONET, have acknowledged the clients' need for accessible solutions but have also recognized significant business potential that results from this. Nevertheless, web accessibility is a complex topic. It includes legal requirements that must be met, technical aspects that have to be considered in the design and development of applications, and the needs of diverse user groups with a focus on people with disabilities. The company has only occasional experience with the implementation of accessibility. The concept is neither integrated into processes nor anchored in the mindset of the employees. Furthermore, the available knowledge is limited and not bundled to enable an exchange.

In order to address web accessibility holistically, consultants, designers and developers must gain the awareness and understanding of the concept. This includes the implementation of legal requirements as well as test methods for the evaluation of accessibility. Furthermore, it is essential to understand the end-users and their specific needs, interaction behavior with applications and assistive technologies in use in order to integrate the concept into the design of usable interfaces. For the improvement of the user experience, accessibility requirements must not only contain legal but especially user needs. Therefore, user requirements must be identified and analyzed.

Previous work shows that there are user-centered approaches, but these are limited to methodologies for requirements engineering [10, 19, 20]. What is missing is a practical guide that fully covers the complexity of web accessibility while considering legal and user requirements as well as testing procedures. The relevant knowledge must be conveyed in a compact form in order to be usable for consulting and software companies.

1.3 Research Goal

The objective of this research is to design a comprehensive guide for practitioners, such as consultants, designers and developers, that supports organizations in implementing web accessibility in web applications in accordance to international standards. This artifact should increase the awareness for the need of accessible web content and deliver a checklist to follow in web development projects.

In addition, the goal of the research is to shape a common understanding on the special needs of people with disabilities in order to improve their user experience with more accessible and usable solutions. But next to that, it should be highlighted that web accessibility supports everyone and is not limited to people with disabilities. Moreover, this work aims at revealing the limits of legal requirements and overcoming them by means of a user-centered approach in order to ultimately enable the successful implementation of accessibility in web applications.

To achieve these goals, the following steps were taken in order to create the accessibility guide:

- Conducting a systematic literature review (SLR) in order to classify the non-functional requirements ‘accessibility’ and ‘usability’, identify standards and guidelines for web accessibility and explore user requirements
- Conducting semi-structured interviews with experts of web accessibility in order to obtain practical knowledge and insights of professional experience
- Comparing and synthesizing the results of the SLR and interviews
- Developing the guide based on the synthesized results and the legal standard
- Applying the proposed guide to a case study
- Validating the proposed design through user testing and practitioner interviews
- Discussing the results, recommendations, limitations and directions for future work

1.4 Research Questions

Within the scope of the thesis, research questions were defined which are answered in the course of this work by means of the aforementioned steps. The research questions are aligned with the objectives of the research in order to address the identified problem. Consequently, the main question is as follows:

How can accessibility be implemented to meet regulatory requirements while improving the user experience of web applications?

This central question gives reasons to take a closer look at web accessibility, for which the following sub-questions must be answered.

RQ1. What are the definitions of accessibility and usability and their relation?

It is required to define the term ‘accessibility’ in context of the web in order to shape a common understanding. This definition is then compared to the ones of ‘usability’ and possible relations of both terms are explored. The results of RQ1 form the basis for answering the succeeding questions. Especially regarding user experience and for the elaboration of user requirements for accessibility (RQ3), it is necessary to be able to distinguish between both concepts and to put them into context.

RQ2. What are the guidelines and regulations for web accessibility?

The next step is to identify existing guidelines and regulations for web accessibility. This information can then be used to extract legal and technical requirements which need to be considered for the implementation of the concept.

RQ3. What are the user requirements for accessibility in web applications?

This question aims to explore the needs of people with and without disabilities among different user groups and determine requirements for more accessible and usable user interfaces. This collection of user requirements represents the addition to legal and technical requirements and serves as input for the design steps regarding RQ5.

RQ4. What are the reasons that prevent practitioners from ensuring accessibility?

It is essential to identify and understand the reasons that prevent practitioners from considering this concept in the development of web products. These insights can then be used as starting points for the proposed guide in order to address web accessibility.

RQ5. How can the WCAG be extended in order to make web content not only accessible but also more usable?

The criticism of the technical standard calls for an inspection in detail. A comparison with user requirements may provide insights in whether legal requirements satisfy the need of users for more accessible and usable interfaces. This may also reveal potential for improving the accessibility requirements. Moreover, an extensive collection of requirements can be used in order to implement accessibility in the design and development of user interfaces while simultaneously meeting legal, technical and user-related demands.

RQ6. How can web accessibility be addressed in web development projects?

This question focuses on the composition of the gained information, user requirements and testing procedures obtained from answering the previous questions 1 to 5 in order to design a guide for addressing accessibility in its many facets. This result can then be used for learning about the concept and implementing it in web development projects.

RQ7. Does the composed accessibility guide hold up in practice?

This question follows up on the design of the artifact by validating whether the guide supports practitioners in implementing accessibility in web development projects and whether it positively affects the user experience of web applications. The obtained findings can be used for potential improvements of the guide and as starting points for further research on the concept of web accessibility.

1.5 Research Design and Methodologies

This study addresses problems at the intersection of information technology and organizations. In order to produce an applicable solution by answering the defined research questions, a commonly accepted framework in the discipline of information systems has been adopted: the Design Science Research Methodology (DSRM) by Peffers et al. [1]. The process model consists of six activities in a nominal sequence: the problem identification and motivation, the definition of objectives of a solution, the design and development, the demonstration, the evaluation and communication. Figure 1 presents the DSRM process model [1].

According to Peffers et al. [1] "design science […] creates and evaluates IT artifacts intended to solve identified organizational problems' by following a rigorous research process. The main research question represents a design problem that calls for a change in the real world. The proposed solution is a design, the artifact, that interacts with a problem context in order to improve something in the context. According to Wierenga [39] there might be many solutions but not a single best one. It is essential to evaluate the solution by its utility with respect to stakeholder goals.

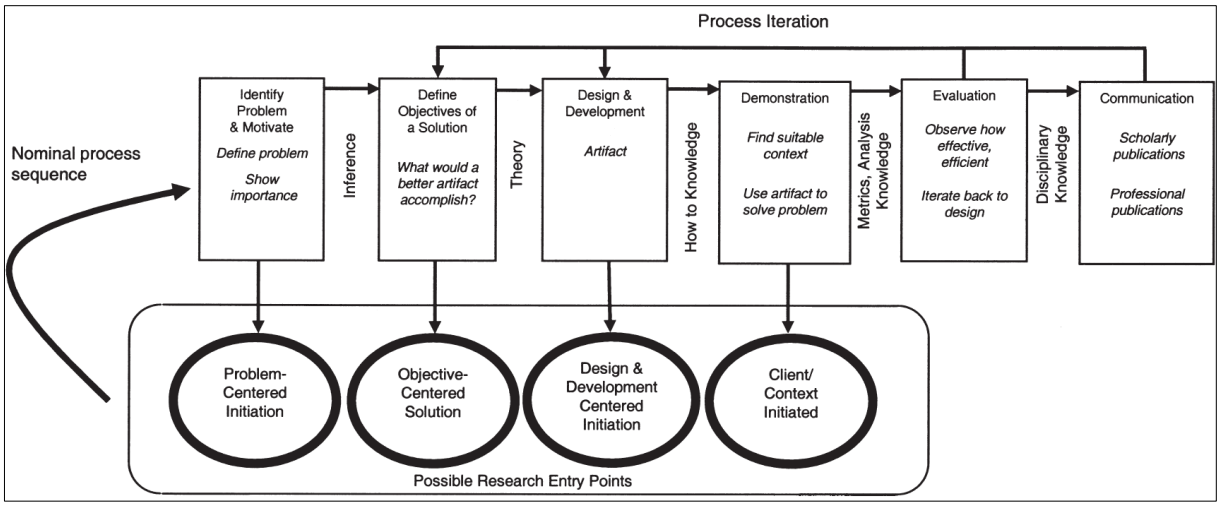

Figure 1: The DSRM Process Model

For designing a solution that contributes to the achievement of stakeholder goals, several research methodologies have been applied. First, the problem context needs to be understood by answering knowledge questions. Hence, research questions 1 to 4 are answered by the conduction of a systematic literature review and empirical research in form of expert interviews. Through the SLR, existing scientific literature is explored by applying a rigorous search process in order to identify answers to the research questions (chapter 2). Furthermore, empirical research in form of qualitative semi-structured interviews has been chosen as a method to gain

additional insights from expert experience, which support the validity of literature results by confirming or respectively denying them (chapter 3). For the demonstration of the artifact in use, a case study of CONET has been carried out which included the application of the guide with focus on identified user requirements (chapter 6). The result of this step has then been evaluated by user testing involving three users with different disabilities. In addition, semi-structured interviews have been conducted with practitioners in order to validate the artifact itself (chapter 7). The demonstration as well as the evaluation activities are essential for the assessment of the artifact in terms of its efficiency, effectiveness and usability. The comparison of defined objectives and results of the artifact in use reveals how well the artifact solves the identified organizational problems (chapter 1.2).

All applied methods are described in detail in the respective chapters. They are also incorporated into the DSRM guidelines. Moreover, this research follows a problem-centric approach which arises from the identification of the problem context. A roadmap is created in order to map the applied research process and the research questions onto the DSRM process model activities. Table 1 shows how this procedure is implemented in the report of the thesis.

DSRM Activity	**Description**	**Research Questions**	**Chapters**
Problem identification and motivation	The research problem, its context and stakeholders are identified. In addition, the research relevance is demonstrated.		1
Define the objectives for a solution	The research objectives are specified by inferring from the problem context and knowledge gained from the SLR and expert interviews.	1-4	1-3
Design and development	Desired elements for the artifact are synthesized from merging results of SLR and interviews which are then used to construct the proposed artifact based on the extension of existing guidelines.	5-6	2-4
Demonstration	A case study is used to apply the artifact in context.	7	5
Evaluation	The performance and utility of the artifact applied in context is evaluated by observing how well the artifact supports a solution to the problem.	7	6, 7
Communication	The research process and its results are reported in form of this thesis and additionally by defending this work after the submission of this report.	1-7	

Table 1: Roadmap of the DSRM process

1.6 Structure of the Thesis

This report is structured in accordance to the DRSM roadmap (Table 1): In chapter 1, the problem, objectives, derived research questions and the applied research design are introduced. In a next step (chapter 2), the theoretical background on the topic is systematically explored in order to identify definitions, guidelines and user requirements for web accessibility. Afterwards, expert interviews are conducted in order to gain insights from professional and personal experiences (chapter 3). In chapter 4, the findings from literature and interviews are merged. The results are then composed into a comprehensive accessibility guide (chapter 5). In chapter 6, a case study demonstrates the application of the guide and the identified user requirements which is evaluated through user testing in chapter 7. The validation of the guide is then carried out through interviews with practitioners (chapter 7). Finally, the discussion and conclusion of the results as well as contributions, limitations and an outlook are presented in chapter 8.

2 Literature Review

2.1 Research Method

For the purpose of this study, a systematic literature review has been chosen as the applied research method in order to explore the field of web accessibility and answer the defined research questions 1, 2 and 3 (chapter 1.4). Following the guidelines of Kitchenham and Charter [40], a SLR “is a means for evaluating and interpreting all available research relevant to a particular research question, topic area, or phenomenon of interest”. The method has three distinct phases: planning the review, conducting the review and reporting the review. These phases represent the main tasks in a SLR.

2.1.1 Review Plan

This part describes the activities of the first phase, which lays the foundation for the review.

Search Process

The search for the SLR is focused on scientific articles, conference papers and book chapters. Therefore, different scientific databases with relevance to software engineering are used:

- Scopus (https://www.scopus.com/home.uri)
- IEEE Xplore (https://ieeexplore.ieee.org/Xplore/home.jsp)
- Science Direct – Elsevier (https://www.sciencedirect.com/)
- ACM Digital Library (https://dl.acm.org/)

An exploratory search is conducted in all the listed databases in order to get an overview of existing literature about the topic of web accessibility and to define the keywords for finding relevant results.

Based on the gained knowledge, the following combinations of keywords are determined and used for the search:

- RQ1: ("usability" AND "accessibility" AND (“web application" OR "web development"))
- RQ2: ("accessib*" OR "inclusi*" OR "disab*" OR "impair*") AND ("checklist*" OR "guideline*" OR "standard*" OR "regulation*" OR "law*") AND ("web development" OR "web application")
- RQ3: ("accessib*" OR "inclusi*" OR "disab*" OR "barrier*" OR "impair*") AND ("requirement*" OR "need*" OR "*condition*" OR "specification*" OR "demand*" OR "prerequisite") AND ("usability" OR "user experience") AND ("web development" OR "web application")

Review Protocol

A review protocol was specified to document the research questions as well as search rules and attributes, such as databases and keywords. It is continuously updated along the review process. It is also necessary to limit the possibility of researcher bias during the study selection. In addition, selection criteria are defined and recorded in the protocol, as described in the following section.

2.1.2 Review Conduction

This part elaborates on the second phase of the SLR: conducting the review.

Inclusion and Exclusion Criteria

A set of criteria are defined for narrowing the search and selecting appropriate and relevant results. Papers are included if their date of publication ranged between the years of 2010 to 2020, the language of the full text is English or German and the document type is either conference paper, article or book chapter. Results are also considered if the subject areas are related to computer science, engineering, social sciences, health, psychology, decision sciences or business, accounting and management. However, if the papers do not address web accessibility, usability related to accessibility, guidelines or regulations and user requirements for user interfaces of web apps or any related topic in scope of this work, then they are excluded from the selection. Furthermore, duplicate papers are filtered out.

Study Selection

During the individual searches per research question and database, keywords and inclusion criteria are used. Exclusion criteria are applied throughout the assessment of the obtained results. The papers, that are extracted from the search, are firstly reviewed for their relevance by title and abstract and sorted into three folders: folder named ‘YES’ (meaning ‘Yes, this paper fits the purpose’), ‘MAYBE’ (‘Maybe, this paper needs to be further analyzed’) and ‘NO’ (‘No, this paper does not provide answers to the RQs’). The latter is not considered any further and the respective papers are removed. The results in the ‘YES’ and ‘MAYBE’ folders, are assessed for their relevance based on a full-text reading and analysis, resulting in a selection of papers for ‘YES’ or ‘NO’, and no more ‘MAYBE’.

Quality Assessment

During the full-text analysis and the review of selected papers, a set of questions is asked in order to assess the quality of the results.

The questions and their evaluation scales, which were applied, are defined as follows:

1) How well are the terms ‘accessibility’ and ‘usability’ defined?
   - ‘Yes’: Proper definitions for both are provided.
   - ‘Partially’: A definition is provided for at least one of the terms.
   - ‘No’: No definitions are provided for the terms.
2) How well are the guidelines and regulations for web accessibility explained?
   - ‘Yes’: Guidelines and regulations are explained in detail.
   - ‘Partially’: Guidelines and regulations are mentioned but not further explained.
   - ‘No’: Guidelines are not mentioned.
3) How well are user requirements for web accessibility explained?
   - ‘Yes’: User requirements are explained in detail.
   - ‘Partially’: User requirements are provided but not further elaborated.
   - ‘No’: User requirements are not mentioned.
4) How well is the applied research method described?
   - ‘Yes’: The applied method is described properly.
   - ‘Partially’: The applied method is mentioned but not further explained.
   - ‘No’: The applied method is not mentioned.

These questions are then scored by applying the following scheme to the answers: ‘yes’ rated with 1, ‘partially’ rated with 0.5 and ‘no’ rated with 0.

This assessment helped us to ensure the quality of results based on carefully selected papers.

Data extraction form

Relevant information from selected studies are extracted and collected into specific forms per research question. Table 2 provides an overview of the extracted data.

Synthesis

With the initial search in four databases, a total of 807 papers are found by using the defined keywords and applying the inclusion criteria: 326 papers in Scopus, 303 papers in the ACM Digital Library, 154 papers in ScienceDirect and 24 papers in IEEE. Moreover, 176 papers are retrieved for RQ1, 138 papers for RQ2 and 493 papers for RQ3. After considering also the exclusion criteria, reviewing the results by title, abstract and eventually full-text, a final count of 82 papers are selected for answering the defined research questions: 19 papers for RQ1, 44 papers for RQ2 and 32 papers for RQ3. An overview of the found and selected papers per

database and research question is provided in Table 3. The final selection of papers is labeled and numbered by using labels of P1-P82, shown in Table 31 in Appendix B.

Most of the studies are contributions from conference proceedings (57 %) and journals (37 %), followed by book chapters with only 6 %. This is shown in Table 4.

Extracted Data	Description	Type
Bibliographic references	Authors, title, year of publication, source	General
Type of study	Primary study, literature review, etc.	General
Definitions of accessibility	Explanations used to describe the term	RQ1
Definitions of usability	Explanations used to describe the term	RQ1
Relations of accessibility and usability	Descriptions of the relationship between both terms	RQ1
User groups and disabilities addressed	General, vision, hearing, motor, cognition, elderly	RQ2, RQ3
Guidelines and regulations	Guidelines and legal standards that exist to support the implementation of web accessibility	RQ2
User requirements	Description of user needs and design patterns that are essential for accessible user interfaces	RQ3

Table 2: Data extraction form

Source	RQ1	RQ2	RQ3	Total
Scopus	86	113	127	326
ACM Digital Library	8	11	284	303
IEEE	11	0	13	24
ScienceDirect	71	14	69	154
Total Papers Found	176	138	493	807
Total Papers Selected	19	44	32	82

Table 3: Papers found in databases per RQs

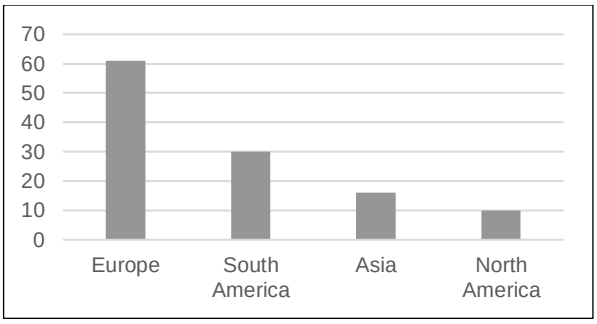

Figure 2: Distribution of publications (%) per continent

Paper	Count	Percentage
Book Chapter	5	6 %
Conference Proceedings	47	57 %
Journal Article	30	37 %

Table 4: Overview of papers per document type

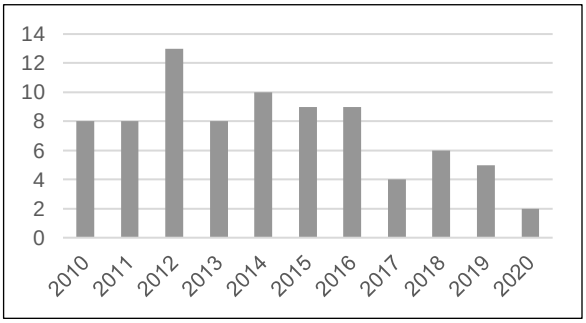

Figure 3: Numbers of paper per year of publication

Most authors (98 %) of these papers are academic and scientific researchers from universities and research institutes. Only 2 % of the writers are employees of two companies, a technology and a consulting company. These numbers expose the urgent need for more company-university collaborations in context of web accessibility in order to combine the knowledge from both disciplines.

The countries of the affiliations of the authors are mainly located in Europe (61 % of the papers) and South America (30 %), followed by Asia with 16 % (Figure 2).

It is surprising that only ten papers origin from North America (9 papers from the U.S.; 10 %), although the national regulations from the U.S. are addressed several times. Eleven papers are published by a cross-county collaboration of different universities. What stands out is that the highest count of publications belongs to Brazilian affiliations (19 papers). It can be assumed that accessibility in Brazil is receiving such a high level of attention in research, because the percentage of people with at least one disability, 23.9 %, is 9 % higher than the global average [4, 41].

Figure 3 provides an overview of the years when the selected papers were published. The peak of publications is marked in the year of 2012 by 16 % of the studies. From 2010 to 2016 the level of published papers is all in all on a high level with at least eight papers per year. In the last three years (2017 to 2019), an average of five studies per year are published with the lowest number of four papers in 2017. The count for 2020 is not representative, because at the time of the search (Jan to March 2020) the year just started and more publications can be expected.

2.2 Quality Assessment

In order to guarantee and emphasize the quality of the selected papers and results, a quality check is carried out. The assessment questions formulated in section 2.1.2 are used for this purpose. Questions 1, 2 and 3 are each only applied to the papers that deliver results for the respective research questions RQ1, RQ2 and RQ3. Question 4 is applied to all papers. The gained results are summed up per paper and divided by the number of assessment questions answered. This means a minimum of two and a maximum of four questions. The calculations are documented in Appendix C.

Table 5 provides an overview of the assessment result. The first row presents the final scores in percent of the maximum score of 100 %. Row 2 shows the number of papers that reached the respective score. The percentage distribution is illustrated in the third row.

Half of the papers reached the maximum score of 100 %, meaning that all applied questions are answered with ‘yes’ (1 point). Another 27 % of the studies were assessed with 75 % or more of the maximum score. 22 % of the papers reached only a score of 50 - 67 %. Regarding these twelve of 14 papers, each of the questions 1, 2 and 3 were answered with ‘yes’. This means that they make a valuable contribution to this review. The low overall rating is because the applied method is often only mentioned or not discussed at all. However, answers, especially for RQ1 and RQ2 can also come from the presented introduction and related work in the papers. Therefore, the papers were assessed with a sufficient quality. Papers with an overall quality below 50 % would not have been used for this review.

All in all, the quality of the articles can be rated positively, since 78 % of the papers achieve a quality score of 75 % or more. The average quality of the papers is 79 % (median).

Score [%]	**50**	**67**	**75**	**83**	**88**	**100**
No. of Papers	14	4	18	3	1	42
Distribution [%]	17	5	22	4	1	51

Table 5: Quality assessment of selected papers

2.3 Literature Results

After analyzing and selecting the relevant papers, the content for answering the defined research questions was gathered in the specific extraction forms in order to ensure further analysis. The following part presents the results, obtained from the selected papers per RQs.

2.3.1 Web Accessibility and Usability

RQ1: What are the definitions of accessibility and usability and their relation?

Answering this question is based on the extracted data of a total number of 19 selected studies. The data focuses on the provision of definitions for accessibility and usability as well the characterization of the relation of both terms. In addition, attention is paid to the source of the data, either obtained from related work or as a result from own primary studies. All of the 19 papers refer to definitions of other studies and sources. Only two papers contribute additionally with results from own studies (P76, P77). 17 papers provide definitions for accessibility, whereas eleven papers define usability. This results in two papers not defining accessibility and eight papers not defining usability but using both terms as keywords or in the papers’ abstracts or titles. Ten papers mention the relation of accessibility and usability, nine papers do not refer to this.

#	Definition	Papers	No. Papers
A1	“Web accessibility means that people with disabilities can use the web. More specifically, web accessibility means that people with disabilities can perceive, understand, navigate and interact with the web and that they can contribute to the web”	P27, P28, P31, P37, P40, P41, P66, P76, P77, P78	10
A2	“Web accessibility is the possibility that any person accessing the Web in different situations. These situations involve not only technology requirements necessary for the interaction, but also user characteristics such as your skills, preferences, needs and different motor and cognitive limitations”	P5, P10, P20, P23, P24, P28, P76, P77	8
A3	“The concept of accessibility is approximated to usability using the terms "usability for people with disabilities".”	P28, P44, P76, P82	4

Table 6: Number of papers addressing the identified definitions for accessibility

The definitions of accessibility show similarities and differences among each other and are therefore classified into three categories (Table 6):

- A1 with focus on the unlimited use of the web for people with disabilities, incl. elderly (10 papers)
- A2 with focus on the unlimited use of the web for all people, independent of any disabilities (8 papers)
- A3 with focus on usability for people with disabilities (4 papers)

Most of the papers provide one definition for accessibility in the context of the web. Only three papers address more than one definition. P77 refers to A1 as well as to A2. All three categories (A1-A3) are discussed by P28 and P76.

Regarding the explanation of A3, which defines accessibility by using the term ‘usability’, a definition for usability is required. Eleven of the selected 19 papers define this term (Table 7). Six papers describe usability (U1) as “a quality attribute related to the ease of use of using something. More specifically, refers to the speed with which users can learn to use something, their efficiency in using it, how much resemble what his level of error-prone and how much they enjoy using it. If people cannot or do not use a feature, it may as well not exist.” (P10, P23, P28, P44, P54, P77). Another definition (U2) used by four papers describes usability as “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use” (P41, P54, P66, P78). P82 does not precisely define usability itself but rather problems related to usability (U3) “as the issues found by non-disabled people [which prevent them from using the website]”. P31 also defines usability (U4) by its problems: “Usability problems are considered any observed characteristic that might prejudice the performance of a task, might annoy or distract a user.”. In addition, P31 refers to the dependency of users’ abilities to usability by saying “Even though

usability issues determine the easy use of an interface, one cannot forget that interactions are also influenced by the users' ability in properly detect, interpret and respond to the systems' information.”.

Eleven papers refer only to one definition each, except for P54 which provides two definitions (U1, U2).

The third part of RQ1 focuses on what can be found in literature about the relation between accessibility and usability. In order to answer this, data was extracted from the selected 19 papers, whereof ten papers mention the relation.

Seven out of the ten papers support the view that accessibility and usability are highly related and perceived as interrelated qualities (R1) which improve the user experience of all users, not only users with disabilities (P23, P31, P40, P47, P76, P77, P78). Accessibility parallels usability and should be incorporated from the beginning rather than as an afterthought. Both factors should go hand in hand. In contrast to this view, three papers (P24, P76, P82) describe the relation of accessibility and usability (problems) “as two distinct, non-intersecting sets of problems, meaning people with disabilities and people without disabilities experience different sets of problems” which puts both terms on the same level but highlights the group of users (with disabilities or without) as the distinguishing factor between both terms (R2). Another relation is presented by two papers (P5, P76) which view accessibility as a subset of usability (R3). Accordingly, an accessible design and development is needed to support usability.

#	**Definition**	**Papers**	**No. Papers**
U1	“Usability is a quality attribute related to the ease of use of using something. More specifically, refers to the speed with which users can learn to use something, their efficiency in using it, how much resemble what his level of error-prone and how much they enjoy using it. If people cannot or do not use a feature, it may as well not exist.”	P10, P23, P28, P44, P54, P77	6
U2	“Usability is the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use”	P41, P54, P66, P78)	4
U3	“[Usability problems] as the issues found by non-disabled people [which prevent them from using the website]”	P82	1
U4	“Even though usability issues determine the easy use of an interface, one cannot forget that interactions are also influenced by the users' ability in properly detect, interpret and respond to the systems' information. […] Usability problems are considered any observed characteristic that might prejudice the performance of a task, might annoy or distract a user.”	P31	1

Table 7: Number of papers addressing the identified definitions for usability

Standard	Papers	No. Papers
Web Content Accessibility Guidelines (WCAG)	P1, P3, P8, P9, P11, P12, P13, P16, P17, P19, P21, P24, P25, P26, P27, P29, P30, P32, P33, P34, P35, P37, P38, P40, P41, P42, P44, P46, P48, P50, P55, P62, P63, P64, P67, P68, P69, P71, P72, P73, P78, P79	42
National Laws (AU, BR, CA, CI, DE, ES, FR, HO, IT, JP, KR, NL, PT, UK, US, EU)	P3, P8, P17, P27, P32, P34, P35, P38, P46, P64, P67, P69, P71, P72, P78	15
Accessible Rich Internet Applications (WAI-ARIA)	P1, P3, P4, P8, P15, P27, P32, P71	8
User Agent Accessibility Guidelines (UAAG)	P8, P40, P44, P50, P62, P79	6
Authoring Tool Accessibility Guidelines (ATAG)	P11, P40, P44, P50, P62	5
ISO 9241-171:2008 Ergonomics of human-system interaction – Part 171: Guidance on software accessibility	P13, P21, P40, P72	4
Mobile Web Application Best Practices (MWABP)	P1, P41, P79	3
ISO 9241-210:2010 Ergonomics of human-system interaction – Part 210: Human-centered design for interactive systems	P40, P44, P68	3
ISO/IEC Guide 71:2014 Guide for addressing accessibility in standards	P27, P72	2
BBC Accessibility Guideline	P3, P27	2
Barrier Walkthrough	P27, P32	2
WebAIM – Introduction to Web Accessibility	P37, P67	2
IBM Accessibility	P27	1
ISO/IEC TR 29138-1:2018 Information technology – User interface accessibility – Part 1: User accessibility needs	P27	1
ISO/IEC 24751-1:2008 Information technology – Individualized adaptability and accessibility in e-learning, education and training – Part 1: Framework and reference model	P27	1
IMS Access for All	P27	1
GuAMA – Guide to the Development of Accessible Mobile Applications	P3	1
ISO 14289-1:2014 Document management applications – Electronic document file format enhancement for accessibility – Part 1: Use of ISO 32000-1 (PDF/UA-1)	P25	1

Table 8: Number of papers addressing the identified guidelines

2.3.2 Guidelines and Regulations

RQ2: What are guidelines and regulations for web accessibility?

The results for answering RQ2 are extracted from 44 selected papers. All papers refer to related work regarding existing guidelines. Ten papers address these standards in a literature review only, 34 papers provide information about the standards from related work and combine this by using or adapting them during the conduction of their primary studies.

A total of 17 guidelines, 15 national legal regulations and one directive of the EU are extracted from the selected papers. Table 8 provides an overview of the guidelines and the number of papers referring to these.

The most addressed standard is the *Web Content Accessibility Guidelines (WCAG)* in one of the existing versions (1.0, 2.0 or 2.1), published by the World Wide Web Consortium (W3C) within the Web Accessibility Initiative in 1999, 2008 and 2018 (42 papers). 15 papers address national laws from a total of 15 different countries, whereof 14 papers refer to the US law (*Section 508 Standards*). Regulations from Germany and United Kingdom are mentioned by five papers each; Brazil, France and Japan by four papers; Canada and Italy by three papers; Spain by two papers; Australia, Chile, Honduras, the Netherlands, Portugal and South Korea by one paper each.

In addition to the *WCAG*, other standards from the W3C WAI are referred to: *WAI-ARIA – Accessible Rich Internet Applications* (8 papers), *UAAG – User Agent Accessibility Guidelines* (6 papers) and *ATAG – Authoring Tool Accessibility Guidelines* (5 papers).

Furthermore, accessibility is addressed by several guidelines from the International Organization for Standardization (ISO) which cover human-system interaction with focus on human-centered design and accessibility for software, user interfaces and PDF documents (*ISO 9241, ISO Guide 71, ISO/IEC TR 29138, ISO/IEC 24751, ISO 14289*).

Other guidelines provided by the selected studies are the following: *MWABP (Mobile Web Applications Best Practices* (3 papers), *WebAIM – Introduction to Web Accessibility* (2 papers), *BBC Accessibility Guideline* (2 papers), *Barrier Walkthrough Guide* (2 papers), *IBM Accessibility* (1 paper), *IMS Access for All* (1 paper), *GuAMA – Guide to the Development of Accessible Mobile Applications* (1 paper).

2.3.3 User Requirements for Web Accessibility

RQ3: What are user requirements for accessibility in web applications found in literature?

A total of 32 papers were selected that serve as a source for answering the third research question. An extensive number of user requirements are extracted from work focusing on the provision of results based on user studies. Redundant and similar needs are summarized into a total number of 40 user requirements. In addition to that, data about the disabilities in context of the studies are extracted in order to relate the requirements to the possible limitations that people have to deal with and create an understanding and awareness for the wide range of user needs. Based on the selected studies, the following disabilities are addressed: people with disabilities in general (not related to a specific limitation), with vision impairments, hearing impairments, motor impairments, cognitive impairments and elderly people who face barriers due to an increasing number of issues.

The identified user requirements address not only one but usually several disabilities at the same time. Out of 40 user requirements 37 of them are related to visual impairments, 31 to elderly, 25 to cognitive impairments, 22 to people with disabilities in general, ten to motor impairments and seven to hearing impairments.

The most addressed user requirements are mentioned each by 13 papers:

- large and adjustable font size
- carefully selected and adjustable choice of colors for font, background and foreground
- use of simplified language

Twelve papers mention that the *navigation must be easy* (use of sitemap, breadcrumb, etc.) and the *layout must be designed in a consistent and simple manner*. In addition, web pages must be *operable by keyboard* commands only – without the need for a mouse – and *contrast levels must be high and adjustable* (11 papers). The *size and distance of clickable and input elements need to be sufficient and adjustable* for reduced target accuracy (10 papers). *Closed captions, subtitles and transcripts as alternative text for non-text content* like audio and videos is required (10 papers) as well. *Sufficient controls* for speed, volume, pitch, play, replay, stop, etc. needs to ensure the freedom of users during the use of content (9 papers). *Information overload needs to be avoided* by simple structure of content and layout (9 papers). *Identification of elements* like images and input forms must be ensured by *proper use of semantically meaningful HTML*, e.g. textual equivalents provided for images (9 papers). Nine papers also suggest to *provide help documentation, tips and guidance* for the structure and tasks of web pages, also as audio output.

The following requirements are mentioned each by eight papers:

- provide feedback for interactions or any changes on the web page, e.g. show location
- enable shortcuts for content and keyboard use
- provide speech/audio output, e.g. make content readable by screen reader
- add relevant visualizations of text in form of symbols, icons and images and avoid animations for reducing cognitive load

Seven papers remind to *make visual content perceivable by other senses* as by providing audio descriptions or haptic feedback. In addition, it is recommended by six papers to *keep only one open window, avoid pop-up windows and manage focus properly*. When *text is read out, it should be highlighted* (6 papers) and an *effective use of headers and titles (short and simple)* is recommended (6 papers). *Proper identification of links and their actions* needs to be ensured (clearly named and in a bulleted list) as well as *sufficient and adjustable word, paragraph and column spacing, length, width and alignment* (6 papers). Following requirements are mentioned by five papers each:

- ensure functions are working and understandable
- provide efficient search system (also for navigation)
- use plain sans serif font type that can be changed
- avoid text decorations, enable users to remove them

Four papers address the need to *avoid time outs* or to offer extended time limits for slower processing of e.g. input forms and suggest providing *error prevention mechanisms* in combination with *helpful error messages*. The use of *high resolution for images* which can be enlarged is recommended by three papers as well as the *content customization* by users. Two different sources mention to *use CSS for styling*, to *make tables understandable and accessible* for navigation by keyboard, to *use a button matrix* rather than navigation menu, drop down or pull-down menu and to provide *content in sign language*. Requirements, that are each only recommended by one selected paper, are to *allow users to cancel ongoing operations*, to *avoid flashing effects*, to *make PDF documents accessible* and to *restore hidden text properly* (independent of position of element).

Table 9 shows an overview of the identified user requirements and related disabilities

#	Principle	Summarized Requirements	Papers	No. Papers	General	Vision	Hearing	Motor	Cognition	Elderly
1	Perceivable	Large and adjustable font size (at least 12-14 point; some dyslexic readers need larger font; for headings, use larger font size in bold, lower case)	P2, P3, P6, P7, P18, P20, P23, P51, P59, P60, P65, P70, P82	13	x	x			x	x
2	Perceivable	Carefully selected and adjustable choice of color, regarding color blind, do not use only color for conveying meaning, make color of text, background, foreground adjustable	P2, P3, P6, P7, P18, P20, P23, P39, P43, P51, P60, P65, P70	13	x	x			x	x
3	Understandable	Use simplified language	P2, P14, P18, P23, P31, P43, P51, P52, P59, P61, P70, P75, P81	13	x	x	x		x	x
4	Understandable	Easier navigation: Sitemap, search engine, breadcrumb	P6, P7, P18, P20, P39, P49, P57, P59, P61, P70, P75, P81	12	x	x	x		x	x
5	Understandable	Screen layout and navigation should be clear and consistent; avoid irrelevant information on the screen and highlight important ones	P6, P14, P20, P22, P31, P39, P43, P45, P56, P61, P75, P82	12	x	x	x	x	x	x
6	Operable	Enable use by keyboard commands, without the need for a mouse	P2, P3, P23, P31, P51, P58, P60, P61, P63, P65, P70	11	x	x		x		x
7	Perceivable	Use high contrast levels, make contrast adjustable	P6, P20, P22, P23, P43, P53, P60, P70, P74, P75, P82	11	x	x		x	x	x
8	Operable	Bigger size and further distance of clickable/input elements; should be adjustable	P2, P22, P23, P31, P39, P51, P60, P61, P70, P81	10	x	x		x	x	x
9	Perceivable	Provide alternate text of non-text content: subtitle, closed captions, transcripts	P2, P22, P23, P36, P56, P59, P60, P70, P74, P75	10	x	x	x		x	x
10	Perceivable, Operable	Provide controls for speed, volume, pitch, play, replay, stop, etc.	P7, P14, P20, P53, P60, P61, P70, P75, P81	9	x	x	x	x	x	x
11	Perceivable	Avoid information overload, structure of layout and content should be simple	P6, P7, P18, P20, P57, P58, P60, P61, P63	9		x			x	x

#	Principle	Summarized Requirements	Papers	No. Papers	General	Vision	Hearing	Motor	Cognition	Elderly
12	Perceivable, Operable, Robust	Enable identification of elements, a site is coded with semantically meaningful HTML; like input forms by labels, with textual equivalents provided for images	P2, P3, P18, P31, P57, P58, P59, P61, P63	9	x	x				x
13	Understandable	Provide help documentation, tips and guidance for structure and tasks (e.g. forms, search bar, etc.), also as audio output	P7, P14, P18, P20, P31, P39, P61, P70, P80	9		x			x	x
14	Operable, Understandable, Robust	Provide feedback for interactions or any changes on page, e.g. indicate current location	P14, P31, P53, P56, P57, P59, P61, P75	8		x	x	x	x	x
15	Operable	Enable shortcuts for content and keyboard use, like skip links	P3, P31, P56, P57, P59, P61, P70, P82	8	x	x				x
16	Understandable	Provide speech/audio output, e.g. make content readable by screen reader	P3, P6, P7, P18, P20, P31, P51, P81	8	x	x			x	x
17	Perceivable	Add relevant visualization of text in form of symbols, icons, images, no animations, in order to reduce cognitive load	P7, P14, P22, P39, P51, P61, P63, P81	8	x	x			x	x
18	Perceivable	Make visual content perceivable by other senses, provide audio descriptions or haptic feedback	P20, P23, P31, P36, P57, P58, P63	7		x				x
19	Perceivable, Operable, Understandable	Manage focus and avoid pop-up windows, keep only one open window	P3, P31, P56, P57, P59, P61	6		x		x		x
20	Perceivable	Highlight text, when read out	P6, P7, P23, P31, P70, P81	6	x	x			x	x
21	Operable	Provide proper identification of links and their actions; links should be clearly named and should be in a bulleted list	P2, P31, P57, P59, P61, P63	6		x				
22	Operable	Effective use of headers and titles, should be short and simple	P3, P20, P22, P59, P61, P63	6	x	x			x	x
23	Perceivable	Sufficient and adjustable word, paragraph and column spacing, length, width and alignment	P6, P7, P51, P52, P61, P81	5	x				x	x

#	Principle	Summarized Requirements	Papers	No. Papers	General	Vision	Hearing	Motor	Cognition	Elderly
24	Robust	Ensure functions are working and understandable	P6, P14, P18, P56, P57	5		x			x	x
25	Operable	Provide efficient search system (also for navigation)	P6, P49, P61, P70, P82	5	x	x		x	x	x
26	Perceivable	Use plain sans serif font type that can be changed	P6, P7, P23, P51, P70	5		x			x	x
27	Perceivable	Avoid text decorations or enable user to remove them	P6, P7, P23, P31, P61	5		x			x	x
28	Operable	Offer extended version of "time out" / avoid time limitations	P14, P45, P53, P61	4				x	x	x
29	Understandable	Provide error prevention mechanisms and helpful error messages	P22, P31, P59, P61	4		x			x	x
30	Perceivable	Use high resolution for images, make them enlargeable	P2, P80, P82	3		x				x
31	Perceivable	Enable content customization per user	P14, P31, P74	3	x	x			x	
32	Operable	Use button matrix rather than navigation menu, drop down or pulldown menu	P31, P81	2	x	x		x		
33	Perceivable	Use CSS for styling	P14, P59	2		x			x	
34	Perceivable	Make tables understandable and accessible for navigation	P57, P63	2		x				
35	Perceivable	Provide sign language	P75, P81	2	x		x			
36	Understandable	Allow cancellation of operation	P57	1		x				
37	Operable	Avoid flashing effects or make them optional	P2	1	x	x				
38	Perceivable	Make PDF documents accessible	P57	1		x				
39	Operable	Input fields to be grouped together	P59	1		x				
40	Perceivable	Hidden text must be properly restored; the information should not be given by the position of an element	P59	1		x				

Table 9: Numbers of papers addressing user requirements and user groups

2.4 Discussion on the Results

This section discusses the results of the SLR per RQ and connects the dots where needed.

2.4.1 Web Accessibility and Usability

In order to implement accessibility in web apps, it is necessary to shape a clear understanding of the term and its relation to other quality attributes. The results of RQ1 show that several definitions exist which differ in fundamental aspects: A1 limits the focus of accessibility to a restricted user group of people with disabilities, incl. elderly, who face additional difficulties in their environment and should be able to interact equally as other users [17]. The unlimited access to the use of the web for this target audience represents the meaning of accessibility, addressed by additional studies (P28, P31, P37, P40, P41, P66, P76, P77, P78).

It has to be noted that Inal et al. [5], among others, explain the term by providing the definition of the W3C WAI [11], that focuses on the use of websites and tools by people with disabilities, but they neglect the fact that this definition is broader than the focus on disabilities mentioned in their paper.

The original definition of W3C WAI also encompasses people without disabilities, like

- "people using mobile phones, smart watches, smart TVs, and other devices with small screens, different input modes, etc.
- older people with changing abilities due to ageing
- people with "temporary disabilities" such as a broken arm or lost glasses
- people with "situational limitations" such as in bright sunlight or in an environment where they cannot listen to audio
- people using a slow Internet connection, or who have limited or expensive bandwidth" [11].

The intention of the initiative is to address social inclusion by supporting equal access with the implementation of web accessibility. The target group is therefore much wider than only including people with disabilities but also older people, people in rural areas and people in developing countries [11]. The characteristics to be considered range from permanent abilities and skills over changing and situational impairments to issues created by technology, situation and context of use and do not stop at languages, culture or social aspects [18]. Although the widest range of users is concerned by web accessibility [42, 43], the focus is on people with disabilities to ensure equal access compared to people without disabilities [4, 44]. Dias et al. [45] point out that accessibility needs to be addressed from a technical as well as from a social view during the implementation in web applications.

Other opinions on the meaning of accessibility try to explain the term as ‘the usability of people with disabilities’ [46]. This results in the synonymous use of accessibility and usability, with the *user group* as the distinguishing factor. According to this, accessibility ensures the use of websites for people with disabilities and usability does the same for people without disabilities [47]. In order to evaluate this view, a closer look on the definition of usability is required.

The results from the second part of RQ1 reveal that the two most cited definitions by the selected papers are U1 by Nielsen [48] and U2 by ISO [23], as reported in section 2.3.1. Nielsen describes the term as “a quality attribute that assesses how easy user interfaces are to use”. Whereas ISO says it is “the extent to which a system, product or service can be used […] with effectiveness, efficiency and satisfaction”. Both assign components to the definition of usability for describing the use of something by its quality. Efficiency and satisfaction are mentioned by both. Furthermore, effectiveness [23], learnability, memorability and errors [48] are added.

According to the provided definitions for both terms, accessibility aims at the equal access to the use of the web and accessible interactions with the content, whereas usability addresses the quality of use. This conclusion indicates a difference in the meaning of both terms, which is also independent of specific user groups. However, the focus in accessibility is on people with disabilities, as they face additional barriers when using the web.

The results of the third part of RQ1 support this differentiated understanding of accessibility and usability. The majority views both as highly related quality attributes which improve the user experience for all users, not only people with disabilities [5]. It is explicitly expressed that usability also concerns people with disabilities and that both qualities “should go hand in hand, so disabled users can access information in a usable way, since it is not fair to settle with accessibility for disabled users” [18, 49]. Dias et al. [45] describe usability and accessibility even as “crucial factors” in the development of user interfaces to “allow for interaction and increase people’s satisfaction” during the use. However, Dias et al. [44] claim that accessibility has not gained the recognition as a “fundamental non-functional requirement” in a software project, such as security, performance and usability. Therefore ‘access-first design’ needs to be promoted, that prioritizes accessibility rather than treating it as an afterthought [50].

2.4.2 Guidelines and Regulations

All selected papers for RQ2 – except for two – refer to the WCAG as a main standard for web accessibility, as Figure 4 shows. National regulations, which have the second highest count in selected papers, seem to play a role for accessibility in web apps but a minor one compared to the WCAG. The first version of the guidelines, WCAG 1.0, was published in 1999; WCAG 2.0

followed in 2008. The latest version, WCAG 2.1, was published in 2018. Especially as of version 2.0, the WCAG serve as technical standard for legal regulations of different governments around the world. Among others, Brazil, Canada, Germany, Italy, Japan, UK and the U.S. adopted or refer to the specifications [12-15]. It is therefore not surprising that the number of papers addressing the WCAG increased during 2010 to 2012 after the publication in 2008. It can be assumed that less papers were published in 2017, because the new version 2.1 was awaited for the following year.

In 2016, the European Union approved the directive (EU) 2016/2102 for “the accessibility of the websites and mobile applications of public sector bodies” that forces the EU members to enact national laws that ensure conformity with EN 301 549 [36]. This norm adopted the current version of the WCAG 2.1 as an implementation standard [51]. It is therefore to be expected that accessibility will play a more important role in the development of web apps and the number of publications will consequently increase again in the future.

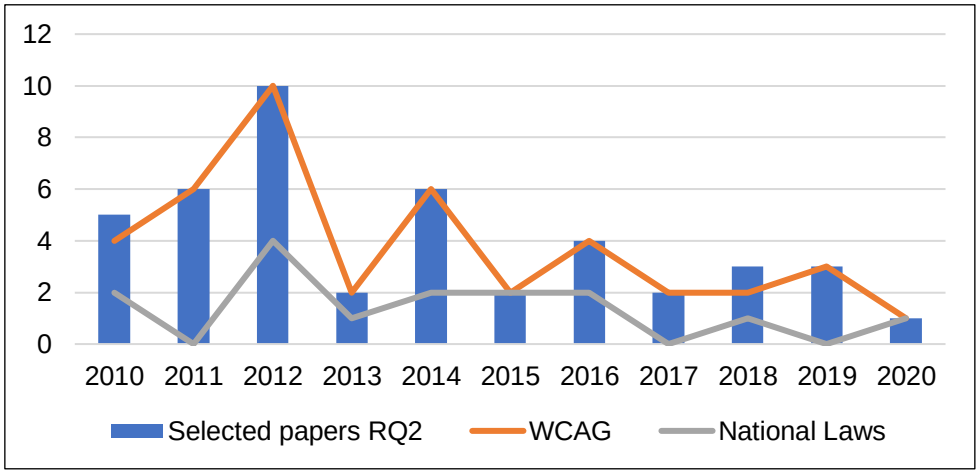

Figure 4: Selected papers addressing the WCAG and national regulations

The WCAG address several disabilities and aim to cover a range of barriers for ensuring accessible web pages or apps. The guidelines are organized in four principles and twelve to thirteen guidelines. The principles, short as P.O.U.R., represent the basic approach and include the following four: perceivable, operable, understandable and robust [52]. ‘Perceivable’ means that the presentation of user interfaces and its content must be perceptible with several senses:

- Text alternatives for non-text content
- Captions and other alternatives for multimedia
- Content can be presented in different ways
- Content is easier to see and hear

‘Operable’ means that the user can navigate and interact with different controls, like mouse, keyboard or other devices:

- Functionality is available from a keyboard
- Users have enough time to read and use the content
- Content does not cause seizures and physical reactions
- Users can easily navigate, find content, ad determine where they are
- Users can us different input modalities beyond keyboard

‘Understandable’ means that the content is clear and easy to read and the user interface acts in a predictable manner:

- Text is readable and understandable
- Content appears and operates in predictable ways
- Users are helped to avoid and correct mistakes

‘Robust’ means that the content can be accessed easily and is compatible with current and future user tools and technologies [53, 54].

Each principle contains a set of guidelines that can be tested with a total of 78 success criteria (according to version 2.1). These criteria are assigned to one of three levels of conformance: A (minimum), AA (intermediate; success criteria of A and AA need to be satisfied) and AAA (highest; web pages satisfy success criteria from all levels A, AA and AAA) [9]. Success criteria can either be satisfied or failed. The EU defined in EN 301 549 level AA as the minimum requirements for public sector bodies to be met, which is also the recommended conformance level by W3C.

Wanniarachchi and Jayathilake [55] highlight some reasons for adopting WCAG:

- “WCAG is widely accepted as the definitive guidelines on how to create accessible web sites.
- Guidelines keep up to date.
- Most user agents and assistive technologies conform to WCAG recommendations.
- Provide guidelines in a more generic and technology neutral manner.
- Guidelines are structured and classified properly.”

Although the WCAG are considered as recognized standard, criticism of the guidelines states that web developers need to know the guidelines inside out for implementing and satisfying the criteria [56]. Farrelly [57] also criticize the interlaced organization, lack of clarity and detail as well as the enormous length of the specifications. In addition, the use of complicate formulations and obtuse language makes the interpretation of the WCAG more difficult and many elements

of accessibility techniques are highly subjective [58]. The latter is caused by the normative nature of the specifications that describe design solutions with a higher abstraction avoiding technical details of web applications [59].

2.4.3 User Requirements for Web Accessibility

The results for RQ3 show that there are several user requirements of people with disabilities which address the needs of multiple user groups at the same time. Although half of the selected studies focus on only one group of users, such as people with autism [60], with down syndrome [25, 61], with dyslexia [62, 63], with Parkinson disease [28], deaf people [64], visually-impaired people [65-68] or older users [27, 31-33, 43, 69], it was possible to cluster requirements, when they were overlapping. All in all, the requirements refer to an average of three user groups, like general accessibility issues, different specific impairments or needs of elderly (median = 3; arithmetic mean =3.275). For example, requirement #13 ‘provide help documentation, tips and guidance for structure and tasks’ supports users with visual and cognitive impairments as well as elderly. Table 9 presents the respective overview.

That one requirement may match three or more user groups, is good news as this implies that meeting one of the requirements in a piece of software will allow developers to satisfy several users at the same time. However, users with different disabilities or degrees of severity face diverse barriers and even though the identified requirements are assigned to them, the degree to which they benefit highly depends on the detailed implementation.

In my opinion the selected studies provide design patterns and user requirements as results of user studies, but it is left open how to ensure the correct implementation. Therefore, results of RQ3 have been compared to the success criteria of WCAG 2.1 with the aim of classifying the requirements and to extending the accessibility guidelines. 18 out of 40 requirements are assigned to criteria of the principle ‘perceivable’; ten requirements to ‘operable’; seven requirements to ‘understandable’ and one to ‘robust’. Four requirements cover several WCAG-criteria of multiple principles.

This comparison reveals some interesting insights: For instance, the requirement #3 ‘use simplified language’ has the highest count (13 papers) among others. Implying that this equals a high relevance for users, it is surprising that it corresponds with success criterion ‘3.1.5 Reading Level’ with conformance level AAA which represents the highest level but is neither a mandatory requirement nor a recommended level as general policy for entire sites [11, 70]. Concluding that *simple language* does not need to be implemented as minimum requirement of level A or AA according to the WCAG but is still highly valued by end users. The same

relation can be observed for requirement #8 ‘bigger size and further distance of clickable/input elements; should be adjustable’ (10 papers) matching criterion ‘2.5.5 Target Size’ with level AAA.

Moreover, ten user requirements from RQ3 cannot be assigned to any WCAG criteria but may represent possible additions being worth to evaluate. The most-mentioned requirements are:

- #11: Avoid information overload; structure of layout and content should be simple [31, 32, 43, 53, 62, 63, 67, 68, 71]
- #20: Highlight text, when read out [33, 45, 62, 63, 65, 72]
- #24: Ensure functions are working and understandable [21, 25, 63, 68, 71]
- #25: Provide efficient search system (also for navigation) [31, 33, 47, 63, 73]

This comparison points out that it may be worth looking into WCAG criteria to make them more accessible and usable for end users and ultimately improve their user experience. Even Baptista et al. [74] mention that mere compliance with WCAG does not produce a satisfactory user experience. However, they leave it open how to address this issue. Therefore, our work suggests incorporating requirements from user studies with the widest range of people in the WCAG in order to meet the needs of real users by applying the minimum criteria in an accessible and usable way.

2.5 Conclusion

This chapter presented the state-of-the-art knowledge of web accessibility by exploring the concepts of accessibility and usability as well as their specific relation, by identifying existing guidelines and regulations for web accessibility and by gathering user requirements for an improved accessible user experience of user interfaces in web applications.

In summary, the literature results let us conclude that accessibility and usability should go hand in hand during the design and development of web apps. The focus of accessibility should be on people with disabilities, but it needs to be stressed that all people benefit from more accessible user interfaces. In addition, it is worth reevaluating and extending the WCAG by user requirements and a user-centered-design approach for improving the overall user experience of web applications.

3 Empirical Research

This chapter presents the details of the qualitative research study conducted in the form of semi-structured interviews and discusses the results obtained. In section 3.1, the selection of the research approach is explained, as well as the organizational settings with regard to the preparation, the design of the interview guide and the selection of participants. In addition, the applied analysis process is described. In the subsequent section 3.2, the results obtained are presented and discussed according to the categories to which they have been assigned. These interviews serve the purpose of supporting or even refuting the literature results through findings from professional and personal experience of the experts.

3.1 Interview Setup

3.1.1 Selection of the Research Approach

The insights gained from the literature analysis helped to classify accessibility versus usability and offer an overview of guidelines and user requirements. A comparison of the latter shows similarities and differences in terms of the priority of user requirements. These must be examined, confirmed or even invalidated with an empirical study. For this purpose, qualitative research techniques were chosen and applied in order to collect, analyze and interpret material for describing the context in detail and developing hypotheses and theories. The focus of qualitative research is on meanings and it has a theory-discovering character in contrast to quantitative research which is based on standardized measuring instruments (e.g. numbers) that are statistically collected and evaluated in order to test theoretically based hypotheses [75].

Semi-structured interviews were used as qualitative research approach since this method asks open questions to which the respondents answer in their own words and which can be adapted individually depending on the course of the interview. New insights and background information can be gained and facts can be discussed in depth. Own opinions, thoughts and reactions can be documented and included in the analysis. In general, oral interviews provide much more information in a shorter time compared to written questionnaires such as surveys.

On the other hand, there are the disadvantages of such a method. These are, among others, that it takes a lot of time to contact the participants, to conduct the individual surveys personally and to transcribe them afterwards. There can also be distortions because the respondents know that it is an interview and their reactivity in live-situations can be impaired [76].

However, in the context of this thesis the advantages of gaining new and more in-depth knowledge outweigh the disadvantages, so that this method was chosen in order to be able to classify the results of the literature analysis.

The research work is checked for validity using six general quality criteria of qualitative research by Mayring [77] in order to ensure a high-quality study. The process documentation (1) on how the research method has been applied in terms of preparations, data generation and analysis are explained in detail in the following sections. Interpretations are grounded on theoretical argumentations of the literature analysis in order to ensure argumentative safeguarding (2). In addition, the interviews are only evaluated by the author herself and the category system is checked several times based on the obtained data. During the interpretation, the conclusiveness and possible alternative interpretations are considered. Rule-governed proceeding (3) is guaranteed by applying the qualitative content analysis by Mayring [78]. The procedure is illustrated in Figure 5 in section 3.1.6. The conduction of interviews creates the proximity to the research object (4) by selecting participants who are experts in the field of accessibility and web development and by exploring the online accessibility community. Another criterion for proving the validity of research results is the informant feedback (5). Questions are asked to confirm answers and interview questions will be adapted to examine received answers with other participants. The sixth quality criterion is the triangulation that aims on connecting multiple steps of the analysis. Therefore, the semi-structured interviews are analyzed by applying deductive as well as inductive category formation and in addition, several participants are interviewed on their personal and professional opinions.

3.1.2 Conduction of the Interviews

A total of eight semi-structured interviews were conducted during the empirical study. The interview participants selected for inclusion in this study, are described in more detail in section 3.1.5 ‘Participants’. Table 11 indicates their jobs in the organization where they are employed. As one could see, the study strives to include a diverse set of perspectives, which is reflected in the choice of practitioners involved. The participants are experts in their professions in the fields of web and software development, web accessibility consulting or testing, easy language and legal obligations for web accessibility. In addition, all of them share the enthusiasm for web accessibility and they were pleased that this work is dedicated to this topic. More in detail, the participants selection process is described in section 3.1.4 ‘Selection of the Sample’. In what follows, we present the organizational aspects of carrying out the interviews considering the social distance standards currently adopted in many businesses.

Due to the current circumstances and contact restrictions caused by the Covid-19 pandemic, it was not possible to carry out the interviews in form of personal meetings. Instead, all eight interviews were individually conducted by telephone, two via landline, five as online-interviews and one interview as video conference.

All interviewees were contacted via e-mail requesting their active participation in this study. The selected persons received a letter of information and a declaration of consent informing them what the topic and goal of the research work is, that the thesis will be done in cooperation with the University of Twente and CONET Solutions GmbH, and what the general procedure of the interviews is like. Furthermore, the persons contacted were informed that their participation was voluntary, that they could withdraw their consent at any time, that their data would be protected and used exclusively within the scope of this study – in an anonymized form that would not allow any conclusions to be drawn about individual persons.

In general, the questions were not known to the participants before the interviews. However, two of the participants asked for the interview guide to be sent to them in advance. With the consent of the participants, all interviews were recorded as audio files to allow a detailed transcription afterwards. Since all participants are native German speakers, the conversations and transcriptions were conducted in German, but the interviews are summarized in English.

3.1.3 The Interview Guide

The questions for the interviews were defined based on the results of the literature review in order to collect in-depth opinions on the known aspects or to reveal new insights. Before the first interview took place, the list of questions was discussed with the company supervisor and adjusted based on her feedback. As one of the main characteristics of semi-structured interviews is to keep them flexible [75], these questions only served as an outline for guiding the course of the interview to the targeted topics. The natural flow of the conversations mostly addressed the majority of topics even without following the interview guide.

The participants were asked to provide their definition of web accessibility and to report on their personal experiences with accessible or inaccessible web content. If a participant had a disability, their interaction strategies on the web were discussed. The legal obligations on accessibility in Germany were also evaluated. Moreover, the WCAG and their advantages and disadvantages were under discussion. Further topics were user requirements and implementation aids as well as accessibility testing.

The interview guide evolved along the study. Depending on the participants, their individual characteristics and experiences, questions were adjusted and the order rearranged. Table 10 shows an overview of the main topics addressed. The questions are provided in Appendix D.

#	Main Topics	Description (deductive categories)
1	Classification of the subject	Definition of web accessibility
2	Personal experiences with web content	Experiences on websites by private authors and public sector bodies, interaction strategies and workarounds if applicable, reasons for inaccessible content
3	Legal obligations	German laws and their development, exception of disproportionate burden, WCAG conformance levels and issues
4	User requirements	Requirements for more usable accessibility, best practices
5	Testing	Methods and tools for accessibility evaluation
6	Outlook	Tipps and open topics (inductive)

Table 10: Main topics of the interviews

3.1.4 Selection of the Sample

"Theoretical sampling" was used as a method to consciously select the participants of the interviews, so that a maximum knowledge value results. The selection was made step by step during the data collection and evaluation. Based on the results obtained, it was decided which samples were to be considered as additional participants. The number of the sample was not set in stone from the beginning, but resulted from the answers obtained [76]. Due to limited resources and the time-consuming process of data collection and evaluation, no more than eight interviews were conducted. Even though, the interview responses made the impression that the theoretical saturation was reached, additional interviews with people with different disabilities are recommended in order to gain insights into new perspectives and user needs.

Various experts (E1-E8) were selected for the interviews in order to examine different perspectives and experiences on the subject. The first two interviews were conducted with software developers (E1, E2) for whom accessibility is only one aspect of their work. Points of contact, existing knowledge and experiences with accessibility were the focus of the interviews. The responses obtained showed the need to focus the sample selection on experts whose focus is on accessibility. Specifically selected experts who are active as web developers (E4, E6) or consultants (E3, E5) for digital accessibility provided valuable in-depth experience and up-to-date practical knowledge regarding the design, development and testing of accessible web content. Due to their blindness, the consultants were also able to report on their personal experiences with accessible and inaccessible websites.

Furthermore, two specialists were interviewed, one of whom is a certified translator for easy language (E7). The importance of easy language as a requirement for accessibility became clear both in the literature analysis and in the previous interviews. The last interview was conducted with a specialist for the legal framework of accessibility in Germany (E8).

The selection of the sample provides a broad insight into the practical implementation of accessibility and allows personal experience to be included in the study.

3.1.5 Participants

The selection of interview participants is a decisive factor for the success of the empirical study, which is based on the knowledge gained from them and the added value achieved. All participants of the interview group have been actively involved in web development and/or web accessibility in their professional lives, which ensures their expertise for this study. Seven out of eight experts have approximately eight to 18 years of professional experience with web accessibility. Only one participant has so far only been able to gather theoretical knowledge (E1), as the topic has not played a role in his/her software development projects for now.

Four experts are developers in the field of web and software applications (E1, E2, E4, E6), two of which have their focus on accessibility (E4, E6). Four experts are web accessibility consultants (E3, E4, E5, E6) and three of them test web content for legal accessibility requirements (E3, E5, E6). One participant is a specialist in easy language and its implementation in literature and web content (E7). Furthermore, participant E8 complements the sample as an expert on accessibility from the perspective of the German legal framework. Three of the eight participants are blind themselves and share their personal experience during the interviews (E3, E5, E8).

The average duration of the interview sessions was 1 hour 3 minutes. Table 11 shows an overview of the participants, their professions and the durations of the interview sessions.

Expert	Profession	Duration of interview [min]
E1	Software developer	00:56:00
E2	Software developer	00:39:00
E3	Consultant and examiner of web accessibility	01:15:00
E4	Web developer and consultant for web accessibility	01:24:00
E5	Consultant and examiner of web accessibility	00:47:00
E6	Web developer and examiner of web accessibility	02:01:00
E7	Consultant and translator of easy language	00:20:00
E8	Accessibility specialist of a public office	01:00:00

Table 11: Overview of the interview group

3.1.6 Analysis of the Interviews

All interviews were written down individually to enable a detailed analysis. The spoken word was transcribed as literally as possible. Readability was improved by smoothing grammar and punctuation. The use of language from dialect was adapted to High German. The analysis is

based on the complete transcriptions. However, English summaries were prepared for reference purposes, which can be found in the Appendix E.

The qualitative content analysis by Mayring [78] was selected for processing the interview material. This technique aims to filter a specific structure from the material. For this purpose, a deductive category system is derived based on the research questions and the results of the literature review. The categories are divided into main and sub-categories and anchor examples as well as coding rules are defined in order to specify the structure and to avoid confusions among findings. Subsequently, the structure is checked for necessary adjustments by means of a first sample material run. Afterwards the entire material is analyzed, whereby important findings are extracted and assigned to the categories. In a circular process, categories are modified and checked again based on the material. An inductive approach is used here, in which the formation of categories is based on the structure of the content of the material. This technique allows the combination of deductive and inductive analysis steps. After assigning the content to categories, the extracted findings are paraphrased and main and sub-categories are summarized. The process model is shown in Figure 5, based on Mayring [78] in the author's own representation.

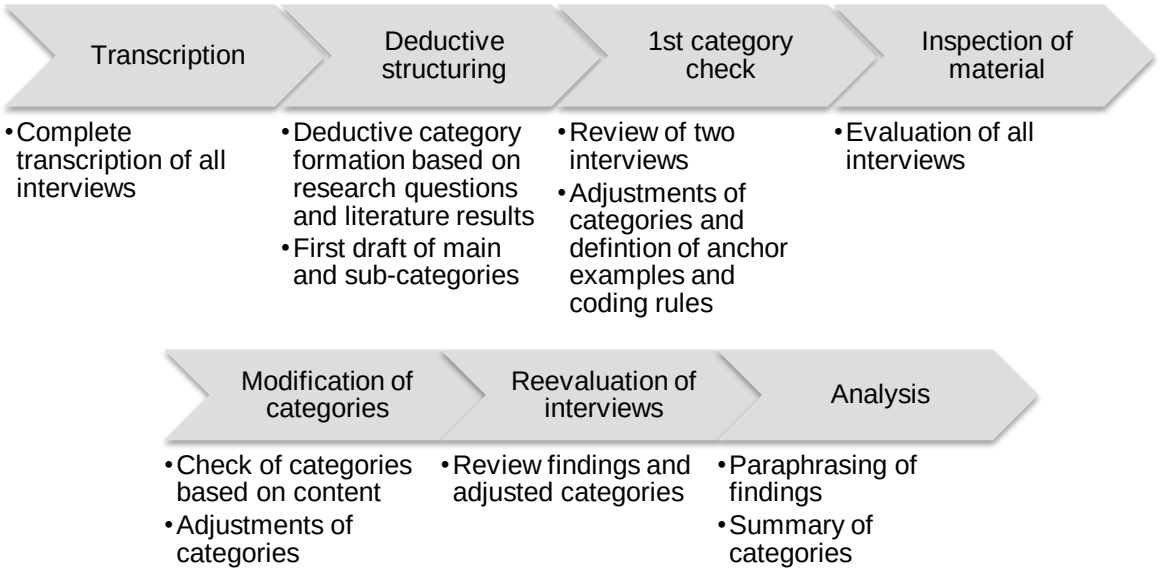

Figure 5: Process model of qualitative content analysis

The main and sub-categories have developed along the analysis process and were significantly influenced by the answers of the participants, but in consideration of the defined research questions. The following Table 12 provides an overview of the final set of categories.

Main category	Sub-categories
Definition of web accessibility	/
Experience with (in-) accessible web content	Personal experiences on websites by private authors and public sector bodies; Interaction strategies, techniques and workarounds (if applicable due to any personal disability)
Reasons for inaccessible web content	Circumstances and issues
Legal obligations	Laws and their modifications
Evaluation of WCAG	Criticism of the guidelines; Conformance level AA as sufficient minimum of legal requirements; Evaluation of conformance level AAA
Requirements for usable accessibility	General requirements; Implementation requirements
Accessibility testing	Methods and tools

Table 12: Derived categories for result analysis

3.2 Interview Results

3.2.1 Definition of Web Accessibility

The literature review revealed the need for a common understanding of web accessibility. The definitions identified in numerous studies differed mainly in the distinction between unlimited access for people with disabilities and the broader perspective on access for all.

The results of the interviews confirm these two main explanations. The majority of participants (E4, E5, E6, E7, E8) defined web accessibility as an attribute ensuring “web content is comfortable usable and accessible for all, not only people without disabilities, not only people with disabilities”, but instead it should be an equal experience for all by integrating as many as possible (E6). In addition, E4 and E5 provide their definition on a higher level of abstraction. They describe accessibility as self-determined participation in digital technologies that enables people to make their own decisions and does not exclude them by creating barriers or making false assumptions about them and their needs in advance. This gives people the opportunity to gain information, communicate in the modern world, perceive digital offers, handle personal matters online or simply have access to content.

Three participants agree with this understanding of unlimited access to the web but consider accessibility more as an attribute focused on people with disabilities (E1, E2, E8). Two experts provide another new view on the term. They define a partial aspect of accessibility as the compliance with national and international guidelines and standards (E3, E4). However, this is not so much a definition of a term as an answer to how accessibility can be ensured – namely by adhering to existing standards.

Nevertheless, these results confirm the assumption of the literature review that accessibility is the unlimited use of web content for all, with focus on the special needs of people with disabilities. In addition, it is highlighted that accessibility is more than just the functional access, it is about *equality and self-determined participation*. All participants acknowledge the essential role of web accessibility in today's modern world of digital technologies.

3.2.2 Experience with Web Content

According to the experts' personal and professional experiences, there are no fully accessible websites or web apps in Germany (E3, E4, E5, E6, E8). On the one hand, this means that more than 95 % of web content does not conform to the known standards (e.g. WCAG, BITV). On the other hand, there are always problems with navigation and interaction behavior, especially with dynamic elements or missing structures (E3, E4, E5, E8). In the U.S., the topic is already more advanced. Nevertheless, the experts are slightly positive about the future and expect more efforts to implement accessibility from public authorities due to legal pressure (E3, E8).

In the case of content that is not (fully) accessible, the participants, who are themselves blind, use their self-developed techniques and workarounds, such as the reading mode in the Google Chrome browser, which reduces content to the minimum necessary and removes advertising banners and decoration (E3, E5). Other options are to simulate the mouse control by the keyboard, which is very tiring, or to try native apps as an alternative to web apps, which are usually easier to use (E5, E8). The last option is support in form of human assistance. If usage is severely hindered, users leave the websites, which is very frustrating for them (E3, E5).

In general, blind users are dependent on the help of assistive technologies. First and foremost, they rely on the use of keyboard and screen readers, such as JAWS and NVDA for desktop computers, or VoiceOver and TalkBack for mobile devices (E3, E5, E8).

3.2.3 Reasons for Inaccessible Web Content

During the interviews the experts were asked about the reasons why web accessibility is not consistently implemented. The participants mutually agreed that there are various causes that foster and further fuel this situation (Table 13).

The *lack of awareness and understanding of accessibility* plays a special role (E1-E8). This affects all people responsible in the development process. Designers, developers, decision makers as well as customers know too little about accessibility. They do not know what it is all about, why it is important, what the needs of the users are and that it brings added value for

everyone. In addition, there are false assumptions about accessibility, that its implementation is inevitably poor, limited, useless and not fun for the user (E4, E8).

Aggravating factors are the *lack of professional knowledge* in particular. Developers are assumed to lack the skills and experience to program accessible content (E3, E5, E6, E8). The reason for this is that accessibility is not part of the curriculum in respective trainings or study programs in the area of computer science. In fact, HTML, which provides the basic structure for user interfaces in web apps, is inherently accessible if used correctly. However, developers unknowingly build barriers into the code, which can be devastating for the individual user. These errors must then be identified and corrected in a later step, which requires a great amount of time and ultimately money (E6).

Reasons	**Details**
Lack of awareness	▪ Among all (users, staff of authorities, project managers, designers, developers, etc.); ▪ About user needs, accessibility as a concept and its benefits ▪ About its role as a non-functional requirement in software projects ▪ Due to a missing lobby of the target group ▪ Due to the market and target group being perceived as too small
Lack of professional knowledge	▪ Among project managers, designers, developers, etc.; ▪ How to make web content accessible ▪ Due to accessibility not being taught in trainings and study programs ▪ Very small community of experts
(Perceived) High expenditure of time and money	▪ For projects with necessary re-launch ▪ For new development projects if accessibility is considered too late
Lack of legal pressure	▪ Due to too loose obligations among public sector bodies ▪ Due to missing obligations among economic actors ▪ Due to missing control mechanisms (e.g. sanctions, legal actions) ▪ Due to missing test capacities

Table 13: Reasons for inaccessible web content

The experts confirm the *high expenditure of time and money*, especially when a re-launch of a project is necessary. However, they point out that this only applies to new development projects in which accessibility is considered too late in the life cycle, e.g. at the end of the project when the code is already available. Instead, seven out of the eight participants argued that accessibility should be considered from the beginning (E1-E6, E8).

These practitioners indicated that, unfortunately, accessibility does not yet have the same importance as other non-functional requirements such as usability and performance (E8). In the perceptions of the participants, accessibility is still a *niche topic*, which means it receives too little attention. One reason for this is that people who depend on web accessibility more

than others, such as people with disabilities, are a minority and lack the necessary lobby to push the issue forward. The experts point here again to the lack of awareness, because the free market economy has not yet discovered this target group as potential customers and wrongly assesses the market as being too small (E3-E6).

According to the experts, the last decisive reason comprises the legal framework. The experts criticize the *absence of legal pressure* from the authorities. Laws or directives from the past that are too loose, and a lack of control mechanisms have resulted in laws not being implemented by all public sector bodies, even though they have been in place since 2002 (E4, E6). A lack of capacity to test conformity also contributes to this (E3). In addition, the private sector has no obligations whatsoever in this regard. Only by 2025 with the *European Accessibility Act*, something will change here (E1, E3-E6, E8).

These results show that the reasons are manifold and concern a wide range of areas. The lack of awareness and understanding of the concept, as well as the equally insufficient expertise and unsatisfactory efforts of the legislator, stand out.

3.2.4 Legal Obligations

All experts are aware of the current legal situation and the latest changes at European and national level. However, not all are equally well familiarized with these changes. For example, E1 and E2 are not familiar with the details, such as precise deadlines and obligations. In contrast, participants E3-E8 are very familiar with the legal situation. They consider it as important to follow the international standard, the WCAG, to create a common understanding of accessibility. Furthermore, the experts assess the BITV 2.0, the German regulation, as a good answer to the EU directive 2016/2102 and a necessary update of the previous version. E8 explained that the BITV goes beyond the EU requirements by additionally requiring sign language and simple language for essential content, as an example.

The experts think that the demand for the declaration of accessibility is an important step to assess the current status of websites, apps and software of public authorities and to track the necessary progress (E8). To pillory oneself causes pressure to implement accessibility. It also increases the awareness of digital accessibility (E6).

Nevertheless, the experts criticize that the deadlines set are not realistic and that it is not possible to implement accessibility to this extent in a timely manner (E2, E3, E6, E8). Furthermore, there are no sanctions for non-compliance with the obligations, neither for individuals nor for the federal monitoring agency. Individuals can and should, however, report

any shortcomings in accessibility via the feedback mechanism that is required by law. Legal consequences are currently only possible by means of representative actions (E8).

All in all, the experts are satisfied with the legal changes of 2016 and 2018 and look positively into the future. They hope that the European Accessibility Act, which will come into force in 2025, will lead to far-reaching progress regarding accessibility in the private sector (E1-E8).

3.2.5 Evaluation of the WCAG

Criticism of the Guidelines

The literature review showed that the WCAG are the leading standard for web accessibility adopted by many countries. However, there is also criticism of the guidelines. Therefore, the experts were also asked about the WCAG in the course of the interviews, how they evaluate the guidelines and what problems they see with them.

Their responses showed that the interview participants agreed that the WCAG criteria are well documented and that there is plenty of supporting material available to help implementing them. However, they criticized that the guidelines mainly cover the needs of visually impaired people, such as the use of screen readers and keyboard (E2, E3, E5, E6, E8). But they also pointed out that the latter is also helpful for people with motor disabilities. In contrast, cognitive and hearing impairments in particular are neglected. In this context, the experts also explain that web content largely addresses visual perception, which is why the focus is also on visual requirements. Furthermore, the WCAG define testable criteria that can be exposed to an objective test procedure, e.g. by means of software tools, to ensure compliance with standards (E3, E5, E8). Requirements for the needs of cognitive or hearing-impaired people are less technical and therefore more difficult to test, e.g. easy language, comprehensibility, simple navigation and layout or sign language. However, the participants also point out that it is difficult to define a standard that addresses all disabilities and limitations, their combinations and different degrees of severity (E4, E5, E7, E8). A compromise is needed and the WCAG are currently the best existing auditable standard. There is nothing better at the moment, even if it is not satisfactory for all people (E6).

Nevertheless, the experts share the view that more needs to be done in this area. They also point out that more can be achieved by implementing the minimum requirements than with marketing features offered individually, such as a button with a read-aloud function (E3). They also recommend that the latest version of the WCAG urgently needs to be translated into German to increase designers' and developers' understanding of the WCAG in Germany (E1, E5, E8).

Conformance Level AA as Sufficient Minimum of Legal Requirements

In its directive, the EU refers directly to the WCAG and calls for its conformity level AA as a minimum legal requirement for public bodies to be compliant with by EU members. In the interviews the participants were asked whether they consider level AA to be sufficiently accessible.

The answers of the experts align with their general criticism of the WCAG. They are of the opinion that compliance with level AA provides sufficient accessibility for blind and visually impaired people, also with regard to the testability of the criteria. However, level AA is not considered as sufficient for the subjective and context-dependent perception of all users. Moreover, too many needs of people with cognitive and hearing impairments are either insufficiently covered or not covered at all. Especially easy language is consistently emphasized as a requirement that should be part of the minimum legal requirements, also because every user can benefit from this (E1-E8).

However, the experts' opinions differ regarding sign language. Some experts would like to see more attention paid to this topic (E2, E5). Others, on the other hand, believe that it would be more useful to help deaf people learn written language than to translate all content into sign language. Those who do not succeed with learning written language should be supported with human assistance (E4, E8).

Evaluation of Conformance Level AAA

As described in the literature analysis, the W3C states that level AAA is not a general policy and is only applicable to certain content. The experts rate this level similarly. According to them, the criteria are a separate specification and are not necessarily stricter than A and AA. They also have a stronger focus on cognitive disabilities, such as readability, abbreviations and unusual words. When asked whether level AAA not only makes applications more accessible but also more usable, the experts replied that this is just the tip of the iceberg and that better solutions must be developed (E3, E4, E6). E4 described AAA as the limit of objective testability. However, there must be more than objectively testable solutions. Even AAA-compliant websites are not necessarily accessible if they were not developed with the good intention of avoiding barriers. The same applies to level AA. E3 shared this opinion and criticized paragraph 3 subparagraph 4 of BITV 2.0, which stated that the "highest level of accessibility" must be implemented for certain content, such as navigation. The expert questioned whether level AAA was meant by this and made it clear that better solutions are needed to make content more

accessible and usable (E5). E8 confirmed the assumption that this paragraph refers to level AAA as the highest degree of accessibility – as standard for legal requirements.

3.2.6 Requirements for Usable Accessibility

The dissatisfaction of the experts with existing criteria leads us to the question of how web content can be made more accessible and usable for all. As in the literature review, the focus is on identifying user requirements that improve the user experience, taking into account usable accessibility.

General Requirements

The experts agreed that accessibility can only be successfully implemented in projects if it is considered an essential attribute right from the start. In fact, it should be treated like other non-functional requirements, such as usability and performance. It is also crucial that project managers and stakeholders work with the good intention of making content more accessible to everyone, especially those who depend on it. It should be avoided that less usable workarounds are developed for people with disabilities (E1-E6, E8).

Furthermore, the experts recommend that only one version of the website or web app should be implemented that covers the needs of all or many people and represents a compromise between design and functionality. This version should allow a certain degree of adaptability to meet specific needs (e.g. visual or cognitive). Participants advise against developing two versions – one original version and one specially for people with disabilities. This would only mean an enormous development and maintenance effort (E3-E6). Furthermore, a special version would only be advantageous for two user groups: deaf and cognitively disabled people, for whom structure and language must be even simpler or translations in sign language are necessary. In general, E5 recommends focusing first on the mobile version of the web content, as this usually offers more simplicity, and then moving on to the desktop version.

The experts also advocated a target-group-oriented design instead of a theme-based design, as this makes orientation and navigation more comprehensible and ultimately easier for users. This is because every user visits a website with a specific intention, e.g. to purchase a certain product or to obtain information. If the design is aligned with such goals and processes, a lot has already been done (E4-E6).

E6 went a little further and explained that barriers also exist in a broader sense. When websites are developed with a high volume due to large images, videos, etc. and many server requests, this affects their performance and requires a certain amount of bandwidth. This is limited in

many Asian countries, or in Africa, Internet use is mostly based on mobile data only. Therefore, a better performance or shorter loading times with low volume and few requests represent a lower barrier for users.

All in all, the experts suggest starting with standard conformity. The leading guidelines point the way along the implementation. It can be helpful to know exactly which criteria address which needs. They also recommend using a well-designed web app as a model or orientation for a new project (E1-E5). Table 14 provides an overview of the general requirements mentioned in this section.

#	**General Requirements**	**Details**
1	Prioritizing accessibility	Giving accessibility the same importance as other non-functional requirements such as usability, performance and maintenance
2	Considering accessibility right from the start of a project	Including accessibility at the end leads to higher amounts of costs and failures
3	Starting with standard conformance	Following international standards to ensure basic accessibility
4	Working with good intention to make web content accessible	Not relying on mere conformance, but working with good intention to make web content more accessible Understanding the needs of users, esp. of people with disabilities; Avoiding less usable workarounds
5	Designing and developing only one version of the web app (general content)	Creating a compromise of design and functionality; Addressing the needs of all or as many people as possible (design for all); Allowing certain degree of adaptability to meet specific needs; Saving efforts in design, development and maintenance by avoiding two versions
6	Proving special versions for easy language and sign language	People who are deaf or have cognitive disabilities requiring special offerings (e.g. content translated in sign language videos, very basic language and design applied to navigation, layout and text)
7	Focusing on mobile version first	Focusing on simplicity of content during design and development
8	Applying a target-group oriented design	Focusing on user needs, tasks and goals while interacting with the product; Avoiding theme-based design
9	Increasing performance of web apps	Avoiding additional barriers due to limited bandwidth or usage of mobile data only, by keeping volume and requests of web apps low

Table 14: General requirements for web accessibility

Implementation Requirements

The experts named numerous requirements that make content more accessible and usable for users. Three requirements were explained particularly often and in detail: *proper HTML structure, simplicity and adaptability*. The total list is shown in Table 15.

The participants explained that a *clear structure with the correct use of HTML* is the basis for an accessible website. HTML elements must be used correctly. This creates a structure and the corresponding semantics that can be recognized and identified by screen readers. This means that there must be a clear concept of headings, areas of the web app must be identified with the appropriate HTML elements e.g. nav, main, footer or tags like heading, p, list, and semantic annotations must be added, e.g. name, role, value. Furthermore, a clear structure in code and design supports the comprehensibility and predictability of content (E2-E6).

The second highlighted requirement is *simplicity*. Reducing complexity in user interfaces and keeping it simple is especially important. According to the experts, all user groups benefit from easy navigation and a clear layout. An abundance of information and elements not only makes orientation and use more difficult for people with cognitive disabilities but also for all people who are less familiar with digital media, e.g. older people or new users. They recommend avoiding unnecessary clutter and decoration and instead focusing on a simple, clear and responsive design (E1, E2, E4-E6, E8).

Several experts described *adaptability* as one of the most fundamental requirements for accessibility, if not the most important. It is not possible to satisfy all the needs of all users at the same time, but it is possible to give them the opportunity to make adjustments that reduce or ideally eliminate barriers or better meet their needs. It is therefore crucial to at least give users the power to decide on changes (E3-E6). These customizations include, for instance, sizes of text and buttons, colors and contrasts, or whether to open a new page in the same tab or a new tab. When it comes to implementing adaptability, the experts agree that such functions should generally be left to the web browsers instead of incorporating their own widgets in the web app that change the font size and color. Browsers offer standardized functions or add-ons that make these changes, e.g. adjust font size or contrast, assess form fields, remove clutter and decoration by reader mode, etc. Specially developed widgets that are built into web apps are often not as stable and serve more as marketing features, such as buttons with a read-aloud function (E3, E6). However, the experts also acknowledge that such widgets can be advantageous for people who are not familiar with browser functionalities or do not have their own interaction techniques, e.g. people with short-term disabilities such as a broken arm or situational barriers (e.g. strong sunlight on the screen), but also for people with cognitive

disabilities or those who are not familiar with technologies. E4 explained offering widgets to change the alignment of text on a page, e.g. from single column left alignment to multi-column format. Despite everything, such widgets should not leverage the functionality of browsers. For example, a button that increases font size by 200 % should not be given as an absolute unit (e.g. 18 pixels) but rather as a relative one (e.g. 10 % of normal text size). Otherwise, the browser function for enlarging does not work anymore. In addition, it must always be checked after coding adjustments whether all contents are still readable and elements do not overlap. Consequently, the experts advocate relying on browser functionalities and incorporating widgets, if desired, as an additional service, but not as the only option (E3-E6).

In addition to these three requirements, the use of *easy language* has been repeatedly mentioned as an important criterion for more accessible and usable content (E1-E8). The experts agreed that less use or avoidance of jargon, long complicated words and sentences, foreign words and abbreviations would help all users. In particular, people with cognitive disabilities benefit from easier language. But also, deaf people, whose mother tongue is sign language but not written language, will find it easier to understand text. E3 recommends explaining unusual words and abbreviations always in a glossary. E7 rates easy language as essential but unfortunately underrepresented in accessibility guidelines and laws. As a translator for easy language, the expert recommends following the guidelines of the Network Easy Language (‘Netzwerk Leichte Sprache’) and providing two versions of web content, one original and one in easy language, so that users can consume what they need.

In connection with this, the experts also repeatedly mentioned the necessity of *sign language* for the deaf (E2, E4, E5, E8), at least for essential contents. Even though the experts E4 and E8 consider it more reasonable to support this user group in learning the written language than to translate all content to sign language, as explained in the previous section about the WCAG.

Another topic discussed was captions as *alternative or supplementary text* for visual and audio content in the form of headings, subtitles, transcripts or semantic annotations of images, icons, tables, graphs, etc. The experts tried to stress the importance of alternative texts. They explained that it was not only about the mere existence of such additions, but also about the meanings they conveyed (E1-E4). It must be checked whether the visual or auditory content (e.g. image, graph, table) has an aesthetic or illustrative, sensory or informative character. Because depending on this, the alternative text must be formulated in order to convey the correct meaning (E3). This applies not only to alternative texts for the use of screen readers but also to subtitles and audio descriptions for multimedia content as well as all kinds of captions.

E4 was also in favor of *supplementing symbols with labels*, as this would improve general comprehensibility. The participant gave the example that the floppy disk is used as a symbol for saving data, but young generations probably do not know what a floppy disk is or have never held one in their hands. There are also cultural differences which make it difficult to interpret symbols commonly. The expert pleaded for making this feature customizable: icons only, text only or both in combination.

The participants also stated that *control via keyboard* is essential for barrier-free use. In this context, special attention must be paid to the *focus management*, ensuring that all elements and functions are controllable and that the focus order is logical (E1-E3, E5). This is best tested during and after development with keyboard and screen reader. In this context it is also helpful to allow the use of *standardized shortcuts* (E3, E5).

Screen reader users also benefit from *skip links* that allow direct navigation to specific content, such as the navigation menu, main content or keyword search (E2, E3, E5). The latter, the *keyword search*, makes navigation easier for all users. However, E5 pointed out that search results must be correctly embedded in HTML in order to be captured by screen readers. Badly implemented keyword searches could not keep up with general search engines.

Moreover, the experts pointed out to consider the correct *choice of colors and contrasts* and the use of *large fonts and buttons*. If possible, *tables, flashing and time-outs should be avoided* (E1-E5).

In terms of links, E3 explained that *link texts in context* would be sufficient if their meaning was recognizable. However, a *speaking link text* is generally better.

Furthermore, E3 warned against the use of *dynamic widgets*, such as tabbed navigation. This is often a source of problems when using keyboard and screen readers. It must be ensured that these elements function properly. For this, the addition of *ARIA* in HTML-elements is necessary. E3 and E4 both described ARIA as a valuable help, but it is often not stable and as long as HTML offers solutions for certain aspects, HTML should always be the first choice.

E6 reported that, as a tester, he/she encountered more and more *accessibility overlays* built into web content. These are small software tools that are built into websites and promise to make the content accessible. But E6 is critical of overlays. They might be able to fix minor bugs like contrast adjustment, but they are not a panacea for accessibility problems. Furthermore, overlays themselves must also be accessible. When testing, it is therefore difficult to judge whether the errors are in the content or in the overlays.

#	Requirements	Details
1	Ensuring proper HTML structure and semantics for better comprehensibility and predictability of content	Using HTML elements correctly for a proper structure and corresponding semantics that can be identified by screen readers and keyboard use; Applying a clear concept of headings; Marking areas by the use of appropriate elements (e.g. nav, main, footer or tags like h, p, list, etc.); Labeling name, role and values of elements
2	Applying simplicity to design and development	Designing a simple and consistent navigation; Designing a clear layout; Applying responsive design; Reducing complexity of user interface; Avoiding overload of information and elements; Avoiding unnecessary clutter and decoration
3	Allowing adaptability / customization of content and design to meet diverse user needs	Such as adjustments for sizes of text and buttons, colors and contrasts or text alignment Providing freedom to decide on adjustments to end-user, e.g. opening a link in the same window or a new tab; Preferred: Ensuring adaptability by browser functions instead of built-in web app features; Offering built-in features/widgets as additional service for people with cognitive disabilities or who are not familiar with techniques, due to temporary or situational barriers or missing knowledge, but without limiting browser functionalities; Ensuring that adjustments do not cover or misalign content
4	Applying principles of easy language	Avoiding jargon, long complicated words and sentences, foreign words, abbreviations; Explaining unusual words and abbreviations in a glossary; Proving an additional version of the original content, translated into easy language for people with cognitive disabilities and non-native speakers
5	Providing sign language	At least for essential content
6	Alternative or supplementary text for visual and audio content	Using headings, subtitles, transcripts or semantic annotations of images, icons, tables, graphs or multimedia; Ensuring to convey proper meaning of visual or auditory content (illustrative, sensory, informative); Supplementing symbols with labels to improve general comprehensibility
7	Ensuring use of keyboard	Ensuring all elements are operable; Ensuring a proper focus management; Enabling standardized short cuts
8	Providing skip links	For easier navigation by use of screen reader
9	Providing key word search	Ensuring results are implemented in HTML elements for use of screen reader
10	Selecting correct choice of colors and contrasts	Using sufficient contrasts; Considering color-blind
11	Choosing large size of fonts	
12	Choosing large size of buttons	

#	Requirements	Details
13	Avoiding tables	If required anyways, applying proper HTML elements and semantics
14	Avoiding flashing	
15	Avoiding time-outs	Or inform end-users about time-out, also especially visually impaired users
16	Making links understandable	Using link texts in context or; Assigning speaking link text
17	Avoiding dynamic widgets	Ensuring proper execution of functions by additional use of ARIA, if used anyways
18	Avoiding accessibility overlays	Ensuring accessibility of overlays themselves, if used anyways
19	Ensuring accessibility of embedded documents	MS Word: Using style templates, alt texts, captions, table formats, “save as”-button (avoiding “print as PDF”); Adobe: complicated to ensure accessibility, training required

Table 15: Accessibility requirements for the implementation

The last topic discussed was the accessibility of documents. E5 recommended to check whether the documents are still needed, especially for existing websites or web apps. If not, they should be removed; if so, they must be made accessible. E3, E6 and E8 recommended that MS Word style templates should be used for e.g. headings and that alternative texts and captions should be inserted in pictures, graphics and tables. It is also important to create the PDF-document using the ‘save as’ function instead of using a PDF printing software. This creates the necessary tags. A lot can be achieved with these few but basic tips. However, the experts pointed out that creating large PDF documents with Adobe is much more complicated and time-consuming. Adobe has a very high training effort in this respect (E3, E5). E8 recommended creating two versions of the documents, one with MS Word and one with Adobe if the design is particularly important. This solution is not popular, but it is a practical way to provide accessible PDF.

3.2.7 Evaluation of Accessibility

During the interviews the participants were also asked about methods and tools for testing accessibility. Their answers covered the three main areas of testing: automated testing, manual testing and user testing. The experts shared the opinion that combining methods and tools is the best way to test accessibility.

In their view, *user testing with real end-users* is the best testing method to provide the most comprehensive overall picture of content accessibility. A scenario-based approach will be used to cover possible interaction behavior and strategies (E4, E5). In order to compensate for

subjective biases, it was recommended to involve several users, if possible, with different disabilities and needs, and to encourage their exchange (E1, E4, E5, E7, E8).

Another important method is *manual testing* by the developers and designers themselves. It should be used in every development, e.g. to eliminate first bugs before user tests or used as the main testing method (E1-E6, E8). On the one hand, the experts recommend reviewing the code itself, paying particular attention to the *Document Object Model* (DOM) and the *Accessibility Tree*. Here, too, they recommend following a scenario-based approach and to test whether each element works as it is supposed to (E1, E3-E5). On the other hand, the experts suggest following existing test procedures that guide the tester along the individual test steps, explaining what needs to be tested, how and why (E1-E6, E8). An example of this is the BIK-BITV test [79], which is based on the WCAG criteria. This test can either be ordered or you can follow the procedure itself. Testers should check the content, especially with the use of a keyboard and screen reader. In addition, several software tools can be used as a supplement. Examples of these tools are browser extensions, plugins like the Accessibility toolbar, Google Light House, headings map for heading concepts, landmarks for landmark elements or bookmarklets, small JavaScript features that check specific aspects. The experts describe these tools as helpful but not sufficient (E3-E6).

The third test method is *automated testing*. Here, software tools are used that independently test websites or web apps (E4, E6, E7). In the latest developments artificial intelligence plays an increasingly important role. However, E4 and E6 point out that modern technology is also reaching its limits here. Software cannot (yet) evaluate whether alternative texts in connection with the visual content make sense and are helpful for the user. Instead, programs mark such content and issue a warning, which in turn must be checked manually. This results in a high number of warnings including false positives. In general, E6 estimates the success rate of automated tests as low, only 30% of all problems can be detected in this way. Furthermore, the experts agree that mere conformity with criteria is not sufficient for usable accessibility. Therefore, manual testing and user tests are the key to success.

3.3 Summary of Expert Interviews

A total of eight semi-structured interviews have been conducted with experts on web accessibility. The purpose of this qualitative research was to obtain insights from practitioners' knowledge and experiences in order to support or refute the results from the systematic literature review. Various topics were discussed in the interview sessions.

In terms of the definition of concept, experts confirmed the literature results: web accessibility as the *unlimited use of web content for all*, with focus on the special needs of people with disabilities. In addition, it is highlighted that accessibility is more than just the functional access, it is about *equality and self-determined participation*. All participants acknowledge the essential role of web accessibility in today's modern world of digital technologies.

Nevertheless, most of the web content is not fully accessible and does not conform to known standards. As a result, people with disabilities rely on personal workarounds and interaction strategies in order to overcome barriers. The main reasons, why accessibility has not yet been established as a standard non-functional requirement are the *lack of awareness* for the concept, for concerned user groups and their needs, the *lack of professional knowledge* about accessibility requirements and their implementation, *the perceived high expenditure of time and money* as well as the *lack of pressure* in the past.

The experts assessed the latest changes to the legal framework in the EU as a relevant step towards more accessible web products. The experts also support the WCAG as international and technical standard. Although, the need for objective testability limits the focus of the guidelines on requirements for visual disabilities, whereas cognitive and hearing impairments are described to be neglected in the standard, especially in the legal minimum.

For addressing accessibility, the experts recommended to *start with standard conformance* and the *good intention for usable and accessible solutions*. In addition, a *target-group-oriented design* that includes the user groups and their needs is essential. *Key requirements* for the implementation are, among others, a proper HTML structure, simplicity and adaptability of the content as well as simple language that serves every user.

In terms of accessibility evaluation, a *combination of methods* was suggested by the experts. Manual testing with the help of automated tools represent the most efficient way in testing standard conformance. Nevertheless, some user requirements are ideally evaluated by end-users themselves in form of user testing.

All in all, the interview results complement the literature and provide important insights in term of the reasons for inaccessible web content, the criticism of the WCAG and user requirements.

4 Merging the Results

This chapter describes the analysis and preparation of obtained results for the composition of the accessibility guide in chapter 5. The guide will be based on the combination of the two methods mentioned in section 1.1: (1) to design and develop accessible web content and (2) to test and fix barriers in web content. As a main step, the previously obtained results are synthesized by merging user requirements identified in the SLR with the implementation requirements from the expert interviews into a comprehensive list of demands for usable accessibility. The results from this step are then compared with the WCAG and partly added to the guidelines to cover the user needs. Beside this extension, the results regarding the definition, general recommendations, key issues and evaluation are synthesized.

4.1 Synthesis of the Results

As a first step in the design of the accessibility guide, the results of the SLR and the interviews are combined: Regarding the definition of accessibility, the findings from the interviews complement the literature review. Furthermore, recommendations are derived from the expert experiences on how to address the key points of accessibility. Afterwards, the user requirements obtained from the literature analysis are assigned to the implementation requirements of the interviews and the overall result is restructured to create a complete list of user requirements for usable accessibility. Afterwards, test procedures are determined.

4.1.1 Definition of Web Accessibility

The first part of the SLR was focused on framing web accessibility compared to usability. The conclusion gained from the selected studies defines web accessibility as an attribute aiming at “the equal access to the web for all – with special focus on people with disabilities”. The understanding of the experts is similar, but in addition they emphasize that accessibility enables self-determined participation of all people in digital technologies. This view expands the above definition and is essential to increase awareness of accessibility and people's needs. Before a topic can be addressed, it must be understood. Therefore, a guide like this one should include a definition of the concept:

“Accessibility enables the self-determined participation in digital technologies by ensuring equal usage of the web and making web content perceivable, understandable, navigable and capable of interactions for all people, especially for people with disabilities, special needs, skills and preferences.”

4.1.2 Recommendations for Key Issues

The results of the interviews reveal several reasons why web pages, web apps, mobile apps and software do not provide sufficient accessibility. At the same time, they also provide suggestions on how to deal with these key issues. Nevertheless, some of the issues need to be addressed on a political and societal level, such as making accessibility a topic of public discussion (awareness), integrating it into curricula of relevant study programs (knowledge) and increasing the legal pressure by means of sanctions. Still, much can be achieved in organizations and individual projects.

The interview findings provide information on how accessibility can be approached in projects in order to overcome existing barriers. Table 16 provides an overview of the key issues to address and respective recommendations. These recommendations will represent the first part of the requirements section of the guide and are explained in the following.

1) By prioritizing accessibility in design and development processes, both awareness and knowledge can be improved. Specific training for practitioners helps in this respect.
2) Accessibility must be considered from the beginning of the project. Late or retrospective requirements lead to increased time and financial expenditure. Awareness is essential.
3) It is advisable to at least follow international standards in implementation to guarantee a minimum of accessibility. This fills respective gaps in practical knowledge.
4) The good intention for accessible solutions is essential and requires knowledge about the user needs.
5) When implementing the product, only one – adaptable – version should be designed and developed, which is a compromise between design and functionality, to address as many users as possible but to minimize time and maintenance efforts (expenditures).
6) An exception is the implementation of simple language and sign language. This content, if necessary, should be made available in an additional version, as it cannot be meaningfully integrated into the original version.
7) To ensure simplicity of navigation and layout, start and focus of the project should be on the mobile version.
8) A target-group-based design should be used to integrate user needs as much as possible.
9) Attention should be paid to the performance by keeping the volume and requests of web apps low. This avoids barriers with limited bandwidth and use of mobile data.

GR#	Key Issues	Recommendations	Details
1	Lack of awareness and knowledge	Prioritizing accessibility	Giving accessibility the same importance as other non-functional requirements such as usability, performance and maintenance; Providing training to practitioners
2	High expenditure of time and money	Considering accessibility right from the start of a project	Including accessibility at the end leads to higher amounts of costs and failures
3	Lack of knowledge	Starting with standard conformance	Following international standards to ensure basic accessibility
4	Lack of awareness and knowledge	Working with good intention to make web content accessible	Not relying on mere conformance, but working with good intention to make web content more accessible; Understanding the needs of users, esp. of people with disabilities; Avoiding less usable workarounds
5	Lack of knowledge; High expenditure of time and money	Designing and developing only one version of the web app (general content)	Creating a compromise of design and functionality; Addressing the needs of all or as many people as possible (design for all); Allowing certain degree of adaptability to meet specific needs; Saving efforts in design, development and maintenance by avoiding two versions
6	Lack of knowledge; High expenditure of time and money	Providing special versions for easy language and sign language	People who are deaf or have cognitive disabilities requiring special offerings (e.g. content translated in sign language videos, very basic language and design applied to navigation, layout and text)
7	Lack of knowledge	Focusing on mobile version first	Focusing on simplicity of content during design and development
8	Lack of awareness and knowledge	Applying a target-group oriented design	Focusing on user needs, tasks and goals while interacting with the product; Avoiding theme-based design
9	Lack of awareness and knowledge	Increasing performance of web apps	Avoiding additional barriers due to limited bandwidth or usage of mobile data only, by keeping volume and requests of web apps low

Table 16: Key issues and general recommendations

4.1.3 User Requirements for Usable Accessibility

Before the international standard, the WCAG, can be extended by the identified user requirements and practical recommendations from experts, a common list of results must be compiled. For this purpose, the 40 user requirements of the literature analysis (*SLR #1-40*) are compared and merged with the 19 implementation requirements of the interviews (*int #1-19*). A total of 32 requirements were defined and supplemented by detailed descriptions. The final

collection was renumbered (*UR #1-32*) and is listed as an overview in Table 17 and accompanied with details in Appendix F.

The consolidation process revealed some differences but mostly similarities in the requirements which show that the insights of the experts mainly confirm the collected results of the SLR. One point of the interview results (int #18 'avoiding accessibility overlays') was not covered by those of the SLR. At the same time, nine of 40 SLR requirements were added to the common list in Table 17 (SLR #: 10, 13, 14, 17, 18, 20, 23, 29, 36).

The consolidation also involved some adjustments in the requirements. Due to different and sometimes more detailed classifications, it was possible to assign several SLR criteria to one int. criterion. In addition, summarized requirements were broken down into their individual parts. For example, SLR #1 'Large and adjustable font size' was split into two requirements, #4 'Allowing Adaptability' and #16 'Choosing large size of fonts'. All elements and design decisions that should be adaptable have been grouped into requirement #4 'Allowing adaptability', but their basic design choices have been defined in individual requirements, such as #13-16 for choice of colors, contrasts, type of font, size of font and size of clickable elements. Moreover, int #1 about (HTML) structure and semantic annotations was separated into two requirements, whereof UR #1 covers all structure related aspects and UR #2 addresses the semantic annotations of elements. Since applying simplicity in design and development was mentioned in different aspects in the SLR as well as during the interviews, all related aspects such as a minimalist layout, simple navigation and consistency are assigned to this requirement #3.

All defined requirements contain a detailed description including recommendations for implementation. These details were extracted from the selected user studies of the SLR as well as from the answers of the interview participants.

The collection of requirements also contains the classification of user groups that will benefit from the implementation of the respective requirements. They are classified according to the main categories of disabilities: vision, hearing, motor and cognition. The elderly form an independent category in this work, as they suffer from gradually declining sensory, physical and cognitive abilities. In addition, ‘general’ is also classified as users without specific disabilities but who may still face barriers, because of situational or temporary conditions, cultural, language or any other aspects. The classification is based on the results of the SLR and is not fully comprehensive. It is intended to help practitioners in using the implementation guide and in better understanding the requirements and their necessity.

UR #	User Requirements	General	Vision	Hearing	Motor	Cognition	Elderly	SLR #	Int. #
1	Ensuring proper (HTML) structure for better predictability of content	x	x			x	x	16, 22, 40	1
2	Ensuring proper semantics for better comprehensibility of content	x	x			x	x	12, 16, 21	1
3	Applying simplicity to design and development	x	x	x	x	x	x	4, 5, 11, 17, 32, 39	2
4	Allowing adaptability / customization of content and design for diverse user needs	x	x		x	x	x	1, 2, 7, 8, 23, 26, 27, 30, 31	3
5	Applying principles of easy language	x	x	x		x	x	3	4
6	Providing sign language	x		x				35	5
7	Alternative or supplementary text for visual and audio (non-text) content	x	x	x		x	x	9	6
8	Ensuring use of keyboard	x	x		x		x	6	7
9	Managing focus	x	x		x		x	19	7
10	Enabling shortcuts	x	x				x	15	7
11	Providing skip links	x	x				x	15	8
12	Providing proper key word search	x	x	x	x	x	x	4, 25	9
13	Selecting correct choice of colors, not as only visual means conveying meanings	x	x			x	x	2	10
14	Selecting sufficient contrasts	x	x		x	x	x	7	10
15	Choosing plain sans serif font		x			x	x	26, 27	/
16	Choosing large size of fonts	x	x			x	x	1	11
17	Choosing bigger size and further distance of clickable / input elements	x	x		x	x	x	8	12
18	Avoiding tables		x					34	13
19	Avoiding flashing	x	x					37	14
20	Avoiding time-outs				x	x	x	28	15
21	Making links understandable		x					21	16
22	Avoiding dynamic widgets		x			x	x	24	17
23	Avoiding accessibility overlays	x	x					/	18
24	Ensuring accessibility of embedded docs	x	x					38	19
25	Providing control elements	x	x	x	x	x	x	10	/
26	Providing user guidance		x			x	x	13	/
27	Providing feedback		x	x	x	x	x	14	/
28	Adding relevant visualization of text in form of symbols, icons, images	x	x			x	x	17	/
29	Making visual content perceivable by other senses		x				x	18	/
30	Highlight manipulated objects	x	x			x	x	20	/
31	Providing clear text alignment	x				x	x	23	/
32	Providing error prevention, error messages		x			x	x	29, 36	/

Table 17: User requirements for usable accessibility

4.1.4 Evaluation of Accessibility

Testing web content on accessibility flaws and on the conformance level as an afterthought is one of the methods to address web accessibility [19].

Three distinct procedures to evaluate web accessibility are presented in literature [20, 21]:

1) Automated testing with software tools
2) Manual testing by accessibility experts
3) User tests with real end-users

Experts confirmed these methods and recommended a combination of them to cover the different aspects of web accessibility. The technical WCAG criteria are testable by partially automated tests and manual testing procedures. Whereas the identified user requirements which are beyond objective testability, such as the principles of easy language, simplicity and adaptability or text alignment and user guidance, require additional evaluations. Therefore, manual testing and user tests with real end-users are needed to get an overall picture of the current state of accessibility.

4.2 Extension of the WCAG

The accessibility guide should support the conformance with minimum legal requirements for accessibility of websites and web apps in order to enable its use in projects of public bodies subject to legal obligations. In the EU this is the standard EN 301 549, which itself refers one to one to the conformance levels A and AA of the WCAG. In addition, this guide should also make it possible to improve the user experience of web content by considering best practices of experts and user studies. Therefore, the WCAG are compared with the previously developed user requirements for usable accessibility (Table 17).

4.2.1 Comparison of WCAG and User Requirements

The structure of the WCAG is based on the four principles ‘perceivable’ (P), ‘operable’ (O), ‘understandable’ (U) and ‘robust’ (R), which in turn are divided into 13 guidelines. Each guideline is more precisely defined by several verifiable success criteria and assigned to a corresponding conformity level (A, AA or AAA). Level A and AA correspond to the legal minimum (50 criteria). Level AAA is not considered as a general policy (additional 28 criteria).

In order to avoid confusions in the following analysis, the terms ‘criteria’ or ‘success criteria’ are used to describe concepts of the WCAG, whereas the results of the SLR and the expert interviews (Table 17) are referred to as ‘requirements’ or ‘user requirements’.

When comparing the WCAG criteria with the results of SLR and interviews, the first step is to determine how the international standard covers the user requirements. Deviations may reveal that the standard does not fully satisfy the needs of people with disabilities and highlight the demand for specific changes or new additions to the guidelines. For this purpose, the requirements from Appendix F are compared with the success criteria and assigned if they match. Due to different levels of detail, individual requirements are sometimes assigned to several success criteria, but also several requirements to one criterion

Table 18 presents the general structure of the WCAG.

Principle	Level	G.#	Guideline	Guideline Description	Criteria #	Success Criteria	Criteria Description
P	A	1.1	Text Alternatives	Provide text alternatives for any non-text content so that it can be changed into other forms people need, such as large print, braille, speech, symbols or simpler language.	1.1.1	Non-text Content	[…]

Table 18: The structure of the WCAG

Principle	Level	Guide-line #	Guideline	Guideline Description	Criteria #	Success Criteria
P	AA	1.4	Distinguish-able	Make it easier for users to see and hear content including separating foreground from background.	1.4.13	Content on Hover or Focus
O	A	2.5	Input Modalities	Make it easier for users to operate functionality through various inputs beyond keyboard.	2.5.1	Pointer Gestures
O	A	2.5	Input Modalities	Make it easier for users to operate functionality through various inputs beyond keyboard.	2.5.4	Motion Actuation
U	A	3.2	Predictable	Make Web pages appear and operate in predictable ways.	3.2.2	On Input

Table 19: WCAG criteria (A, AA) not covered by user requirements

Legal Standard – Success Criteria of Level A and AA

When mapping user requirements to WCAG criteria of level A and AA, four criteria could not be covered. They are listed in Table 19 for reference. Since these criteria are part of the minimum set of accessibility requirements, they are mandatory for compliance.

All other 46 success criteria of the WCAG could be covered by multiple allocation of 20 of the 32 user requirements. This is because some topics are divided into their components and are

described in great detail in individual criteria. In particular, the following requirements were assigned multiple times – please see Table 20 and compare Appendix F for details. It is obvious that the WCAG criteria address some topics particularly thoroughly, such as the structure and semantic annotation of elements, text alternatives for non-text content and focus management. All are essential for the use of screen readers and keyboard control, which in turn cover the basic needs of visually impaired people. Another aspect is error prevention and error messages, which benefits all users by making interaction easier.

A detailed analysis of the allocated user requirements and the matching success criteria still reveals differences in the detailed specification of the aspects. In several cases, the criteria can be supplemented by details of the user requirements that are not even covered by the WCAG techniques. These techniques usually provide “sufficient” or “advisory” guidance for the implementation of each criterion. Nevertheless, the user requirements listed in the left columns of Table 21 contain details that are worth to be added to specific criteria.

Next to the details to be added to existing criteria, particular attention is paid to those user requirements that do not match any of the criteria of level A and AA. The result of the comparison shows that this concerns the following twelve out of 32 requirements which are presented in the right column of Table 21.

UR #	User Requirement	Number of Allocations	Assigned Success Criteria
1	Ensuring proper (HTML) structure for better predictability of content	4	1.3.1, 1.3.2, 2.4.2, 4.1.1
2	Ensuring proper semantics for better comprehensibility of content	7	1.3.5, 2.4.6, 2.5.3, 3.1.1, 3.1.2, 4.1.2,4.1.3
3	Applying simplicity to design and development	3	2.4.5, 3.2.3, 3.2.4
4	Allowing adaptability / customization of content and design to meet diverse user needs	4	1.3.4, 1.4.4, 1.4.8, 1.4.10
7	Alternative or supplementary text for visual and audio (non-text) content	5	1.1.1, 1.2.1, 1.2.2, 1.2.4, 1.2.5
8	Ensuring use of keyboard	2	2.1.1, 2.1.2
9	Managing focus	4	2.4.3, 2.4.7, 3.2.1
14	Selecting sufficient contrasts	2	1.4.3, 1.4.11
25	Providing control elements	2	1.4.2, 2.2.2
26	Providing user guidance	2	1.3.5, 3.3.2
29	Making visual content perceivable by other senses	2	1.2.3,1.3.3
32	Providing error prevention and helpful error messages	5	1.3.5, 2.5.2, 3.3.1, 3.3.3, 3.3.4

Table 20: Multiple allocations of user requirements to WCAG criteria

UR #	To be added to WCAG Criteria: Details of User Requirements	UR #	User Requirements not matching any WCAG Criteria
#3	Applying simplicity to design and development	#5	Applying principles of easy language
#4	Allowing adaptability of content and design to meet diverse user needs	#6	Providing sign language
#8	Ensuring use of keyboard	#12	Providing proper key word search
#10	Enabling shortcuts	#15	Choosing plain sans serif font
#13	Selecting correct choice of colors	#16	Choosing large size of fonts
#21	Making links understandable	#17	Choosing bigger size and further distance of clickable / input elements
#26	Providing user guidance	#18	Avoiding tables
#28	Adding relevant visualization of text in form of symbols, icons, images	#22	Avoiding dynamic widgets
#31	Providing clear text alignment	#23	Avoiding accessibility overlays
		#24	Ensuring accessibility of embedded docs
		#27	Providing feedback
		#30	Highlight manipulated objects

Table 21: User requirements – details to add and requirements not matching

Since the implementation of user requirements, collected in user studies and expert interviews, should improve the user experience through more usable accessibility, the identification of such deviations is valuable for the extension of the WCAG.

It must be noted that no further attention is given to requirement UR #24, because documents embedded in web pages are considered as web content and are therefore also subject to the obligation of accessible design. The standard EN 301 549 dedicates a separate chapter to this topic. In addition, there is a specific PDF/UA standard and the Matterhorn Protocol to follow. Consequently, #24 is not used for the extension of the WCAG but represents a separate area for web accessibility.

Subsequently, the list contains eleven instead of twelve deviations which are analyzed in more detail in the following section.

Success Criteria of Level AAA

In a next step, the user requirements were compared with the success criteria of level AAA, which are complementary to the legal minimum. Here again, not all criteria could be covered by the user requirements. However, the following three criteria represent useful aspects that may apply in individual cases (Table 22). For instance, all users but especially elderly, cognitive impaired or novice users can be distracted by background sounds and hence benefit from the option of turning them off or not having any at all (1.4.7).

Principle	Level	G. #	Guideline	Guideline Description	Criteria #	Success Criteria
P	AAA	1.4	Distinguishable	Make it easier for users to see and hear content including separating foreground from background.	1.4.7	Low or No Background
O	AAA	2.2	Enough Time	Provide users enough time to read and use content.	2.2.5	Re-authenticating
O	AAA	2.5	Input Modalities	Make it easier for users to operate functionality through various inputs beyond keyboard.	2.5.6	Concurrent Input Mechanisms

Table 22: WCAG criteria (AAA) not covered by user requirements

Here too, 20 of the 32 user requirements could be allocated to the remaining 25 AAA criteria. The previously mentioned eleven user requirements that did not fit any of the WCAG criteria (A, AA) could now partly be assigned to the AAA criteria. This applies to four items of the list. Apart from the mere matches, these requirements provide additional information to extend the assigned criteria. Please refer to Table 33 in Appendix F for the details.

- #5 Applying principles of easy language
- #6 Providing sign language
- #17 Choosing bigger size and further distance of clickable / input elements
- #27 Providing feedback

It can be concluded from the analysis that the importance of UR #5 ‘Applying principles of easy language’, which was commonly highlighted by the experts and shown by the highest count of papers in the SLR, is underrated in the WCAG as only being assigned to level AAA. Furthermore, the matching success criteria (3.1.3-3.1.6) only cover the basics of easy language. Above mentioned details provide additional suggestions to improve readability and comprehensibility of text, especially for people with cognitive impairments.

The additional details of UR #17 and #27 extend the existing criteria in terms of an enhanced usability. These aspects support the interaction for all users and thus should be considered.

Nevertheless, a remaining set of seven of the eleven deviating user requirements do not fit any of the WCAG criteria (UR #12, 15, 16, 18, 22, 23, 30). This means that these requirements are relevant to end-users but are neither part of the minimum accessibility requirements nor the complementary level AAA. They are therefore added to the accessibility guide and may support the user experience.

Conclusion of the Comparison

The analysis revealed numerous similarities but also a non-negligible number of differences between the success criteria of the WCAG compared to the user requirements gained from literature and expert interviews.

The success criteria partially overlap with the identified user requirements. In terms of the legal minimum level (A, AA), 46 out of 50 criteria, respectively 92 %, suit the content of 20 user requirements and vice versa, whereof five criteria of level A and five criteria of level AA can be extended with additional details of the user requirements (Appendix F). This results in an extension of 24 % of the legal minimum criteria of the WCAG. In contrast to that, all 28 criteria of level AAA can be matched with 20 user requirements. Almost half of the AAA criteria (43 %) can be extended by additional information of the user requirements. In summary, the user requirements provide added value to 31 % of the criteria, whereof 50 % of the extension is made to level AAA. Table 23 provides an overview of the success criteria which are extended by respective user requirements.

Some of the extending details only provide guidance on how a criterion can be implemented better or what to look for, such as UR #8 (keyboard accessible: pull-down menu only works well if user utilizes mouse) or #10 (keyboard accessible: providing information about shortcuts). Others, however, provide far reaching requirements and detailed information to better address user needs. These include UR #3, 4, 5, 13, 17, 26-28 and 31, which are particularly relevant to the needs of people with cognitive impairments or elderly, according to the SLR classification for disabilities. Similar statements were made by the experts: The WCAG cover mainly the needs of visually impaired people, such as for the usage of keyboard and screen reader (structure and semantic annotations), which are also easier to test. But more must be done regarding cognitive needs. These do not only support cognitive impaired people but also elderly or users who are unfamiliar, tired, distracted, or lack knowledge of language (e.g. foreigners, deaf people) or cultural habits. AAA criteria only make an important step towards the support of cognitive aspects, whereas A and AA do provide just little practical help in this term.

In addition to the extensions, seven user requirements do not fit the WCAG criteria of any level. They represent further aspects from which users with and without disabilities can benefit.

This result of 25 criteria extensions and seven new additions allows the conclusion that much more is needed in terms of accessibility than the current standard covers. It is also evident that much knowledge about user requirements is already known in user studies or from experts. The focus should be especially on incorporating cognitive needs that help all users but are

essential for some. At the same time, the value of the WCAG should not be undermined, as their emphasis on programmatically coded structure and semantics as well as alternative ways to present content, supplemented with detailed descriptions, ensure essential requirements such as using assistive technologies like screen reader and operating by keyboard or switches.

Principle	Level	G. #	Guideline	Criteria #	Success Criteria	New UR #
Perceivable	AAA	1.2	Time-based Media	1.2.6	Sign Language	6
Perceivable	AA	1.3	Adaptable	1.3.5	Identify Input Purpose	26
Perceivable	A	1.4	Distinguishable	1.4.1	Use of Color	13
Perceivable	AA	1.4	Distinguishable	1.4.4	Resize text	4
Perceivable	AAA	1.4	Distinguishable	1.4.8	Visual Presentation	4, 13, 31
Perceivable	AA	1.4	Distinguishable	1.4.10	Reflow	4
Perceivable	AA	1.4	Distinguishable	1.4.12	Text Spacing	31
Operable	A	2.1	Keyboard Accessible	2.1.2	No Keyboard Trap	8
Operable	A	2.1	Keyboard Accessible	2.1.4	Character Key Shortcuts	10
Operable	AAA	2.3	Seizures and Physical Reactions	2.3.3	Animation from Interactions	3, 28
Operable	A	2.4	Navigable	2.4.4	Link Purpose (In Context)	21
Operable	AA	2.4	Navigable	2.4.5	Multiple Ways	3
Operable	AAA	2.4	Navigable	2.4.8	Location	27
Operable	AAA	2.4	Navigable	2.4.9	Link Purpose (Link Only)	21
Operable	AAA	2.4	Navigable	2.4.10	Section Headings	1
Operable	AAA	2.5	Input Modalities	2.5.5	Target Size	17
Understandable	AAA	3.1	Readable	3.1.3	Unusual Words	5
Understandable	AAA	3.1	Readable	3.1.4	Abbreviations	5
Understandable	AAA	3.1	Readable	3.1.5	Reading Level	5
Understandable	AA	3.2	Predictable	3.2.3	Consistent Navigation	3
Understandable	AA	3.2	Predictable	3.2.4	Consistent Identification	3
Understandable	AAA	3.2	Predictable	3.2.5	Change on Request	27
Understandable	A	3.3	Input Assistance	3.3.2	Labels or Instructions	26
Understandable	AAA	3.3	Input Assistance	3.3.5	Help	26

Table 23: WCAG criteria extended by details of user requirements

4.2.2 Allocation of User Groups

In the SLR, user requirements were assigned to the defined user groups (general, elderly or different categories of disabilities). After merging the requirements with the interview results, this allocation was expanded by expert opinions and later applied to the extended list of accessibility requirements (WCAG plus UR). The last step revealed deviations compared to how criteria are allocated to the user groups in the official WCAG. Table 24 and Table 25 show the results of counting the allocations of criteria to user groups.

User groups	**Total** (all criteria incl. new UR)	**Total** (criteria WCAG only)	**A**	**AA**	**A+AA**	**AAA**	**UR Details** (extending)
General	/	29	12	6	18	11	6
Vision	/	60	25	17	42	18	18 (8 AAA)
Hearing	/	17	6	3	9	8	3
Motor	/	27	13	6	19	7	8
Cognitive	/	57	22	14	36	21	19 (11 AAA)
Elderly	/	2	1	0	1	1	2

Table 24: WCAG – allocations of criteria to user groups

User groups	**Total** (all criteria incl. new UR)	**Total** (criteria WCAG only)	**A**	**AA**	**A+AA**	**AAA**	**UR Details** (extending)	**UR (new)**
General	62	58	22	16	38	20	6	4
Vision	82	75	29	19	48	27	18	7
Hearing	26	25	7	5	12	13	3	1
Motor	41	37	15	9	24	13	9	4
Cognitive	67	62	20	18	38	24	21	5
Elderly	74	69	25	19	44	25	22	5

Table 25: SLR – allocations of criteria and user requirements to user groups

Firstly, the WCAG do not provide an overview of which criterion is essential for what kind of disabilities but only explain the beneficials per criteria in text form. Therefore, this information has been included to the tabulated guide of requirements. In the WCAG, it is only described which user groups specifically benefit from the respective criteria, with just rarely pointing out that other users might also profit, such as general users with or without disabilities. The user group of elderly are almost neglected with only two references. In contrast, the SLR classification shows that criteria are also beneficial to all users, especially older people. More attention needs to be paid to the needs of elderly for more accessible web content, especially since society is ageing and their abilities are gradually declining. Acknowledging elderly as a user group with various demands supports the awareness and understanding for their needs. Therefore, it should be pointed out that older people and many times all users benefit from implementing accessibility requirements.

The criteria of the WCAG mostly address visual impairments (highest count of assignments) but being closely followed by cognitive needs. The SLR classification shows similar results which is surprising, because user studies and experts repeatedly mentioned that the WCAG have a strong focus on vision where cognitive demands are neglected. Moreover, the newly added user requirements and the extended criteria are also allocated to be beneficial for mostly elderly, cognitive and visually impaired people. This shows the need for a stronger focus on

these three user groups. The count of assignments for hearing and motor impairments is comparably low for WCAG and SLR allocations.

Nevertheless, it must be stressed that there is no complete set of requirements for individual disabilities. Therefore, it might be possible that hearing and motor impaired people have fewer specific needs than other user groups, which can eventually be covered by a lower number of criteria. Or there are different reasons for the lower number of criteria, e.g. these user groups are underrepresented by research or have a smaller lobby for support. In contrast, web content is mostly characterized by visual presentation and therefore requires various criteria which can cover all relevant aspects. But also, visually impaired people have a bigger and stronger lobby than people with other disabilities which may be a reason that more attention is being paid to the needs of visually impaired people.

Furthermore, being recognized as having the most diverse forms of disabilities, degrees of severity and consequently various needs, the user group with cognitive, learning and neurological impairments require a lot attention, without even reaching a full picture of user requirements. However, addressing accessibility requirements, which are essential for this user group, also support elderly and general users like novice users.

In summary, it can be concluded that a stronger focus on accessibility is required. As shown in the WCAG allocation, it is essential for some user groups, but as revealed in the SLR, it can be useful for a wide range of people, not only limited to the people who rely on accessibility.

4.2.3 Restructuring the Guidelines

The identified user requirements, which supplement and extend the international standard, and the classification to user groups must be incorporated into the guidelines to form the main part of the new guide. It is important to ensure that none of the minimum criteria themselves are changed or contradictory information is added. Furthermore, the structure of the WCAG will be followed. The reason for this is that the WCAG, as an international standard, are regularly updated and supplemented, while still ensuring conformity with older versions. Changing principles, criteria and their numbering would lead to confusion which must be avoided. Additional barriers would be counterproductive to promote the implementation of accessibility. Furthermore, the currently defined criteria provide fundamental contributions for accessible web content to all users, but especially to those who rely on using keyboard and voice output.

Principle	Level	Guideline #	Guideline	Success Criteria #	Success Criteria	Description of Criteria	Details on User Requirements
P	UR	1.4	Distinguishable	1.4.14	Font	/	Choosing plain sans serif fonts, such as Arial, Comic Sans, Verdana, Tahoma, Century Gothic, Trebuchet, Helvetica, dan Sassoon; Avoiding text decorations, such as italics, bold and underlining; Avoiding text in block capitals > using boxes for effective emphasis; Avoiding use of animated text
P	UR	1.4	Distinguishable	1.4.15	Size of Font	/	Using font size of 12-14 point or 14+; Use actual text instead text in graphics; Using larger font size in bold, lower case for headings
P	UR	1.4	Distinguishable	1.4.16	Highlight Objects	/	Highlighting manipulated objects, e.g. by carefully selected color for clicked elements, such as links; Highlighting text, fading text to focus on specific parts, such as reader ruler
O	UR	2.1	Keyboard Accessible	2.1.5	Tables	/	Avoiding tables if possible; If required anyways, applying proper HTML elements and semantics; Tables should not be nested; Tables should be understandable when read sequentially
O	UR	2.1	Keyboard Accessible	2.1.6	Dynamic Widgets	/	Avoiding dynamic widgets or Ensuring proper execution of functions by additional use of ARIA; Avoiding errors of interaction; Dropdown menu appears as single button to screen reader, inaccessible
O	UR	2.1	Keyboard Accessible	2.1.7	Overlays	/	Avoiding accessibility overlays; Ensuring accessible interaction of overlays themselves, if still used
O	UR	2.4	Navigable	2.4.11	Key Word Search	/	Supporting navigation through search; Ensuring search results are embedded into HTML for screen reader

Table 26: WCAG extended by additional user requirements

Instead, an additional column is inserted, that contains expanding details on the criteria derived from the collected user requirements for more usable accessibility. Newly added user requirements will also receive the special label ‘UR’ as conformance level to indicate their importance for an improved user experience. They are assigned to the respective guidelines of the WCAG: UR #15, 16 and 30 are assigned to the guideline ‘distinguishable’ of the principle ‘perceivable’, the last four requirements to the principle ‘operable’, whereof UR # 18, 22 and 23 are allocated to the guideline ‘keyboard accessible’ and UR #12 to ‘navigable’. The numbering of the WCAG criteria will be continued. Table 26 shows the extension of the WCAG by newly added user requirements.

Moreover, six additional columns are added to ensure that each criterion or user requirement is assigned to one or more of the defined user groups. "x" indicates the assignments according to the SLR, whereas the color coding marks those according to the WCAG.

4.3 Summary of the Merge of Requirements

In the first part of the chapter the results of the literature review and the expert interviews are compared, analyzed and combined into one set of components: The definition of accessibility from literature has been extended by the remark that the concept is not only about the access to web content but in particular about the self-determined participation in digital technologies. Moreover, general recommendations have been assigned to key issues of accessibility and the combination of evaluation methods is described as the suggested test strategy. The main part involves the merge of user requirements from literature and interviews into one comprehensive collection.

The second part of the chapter comprises the extension of the WCAG by user requirements. For this purpose, the criteria of the international standard have been compared to the user requirements from literature and experts. The results revealed that most of the requirements are covered by the standard, but several user requirements provide additional details on the WCAG criteria and some are included. These aspects are added to the WCAG and extend the set of accessibility criteria by user requirements identified in user studies and expert interviews. In addition, each criterion respectively user requirement has been assigned to one or more user groups, according to the WCAG and SLR allocation.

5 The Proposed Accessibility Guide

The accessibility guide represents the result of the synthesizing process and the WCAG extension described in the preceding chapter 4. The findings from SLR, expert interviews and the WCAG extension are composed in this chapter into a guideline that fosters the implementation of web accessibility.

5.1 Overview of the Guide

The guide is intended to serve as an introduction to the topic of web accessibility or as a reference work during web development projects. Hence, it needs to deliver answers at the different stages of the project life cycle. For this reason, several components are required to cover the concept of web accessibility from a holistic perspective. They are structured into three layers (Figure 6): First, the foundation layer is established that provides fundamental information and frames the concept in order to raise awareness and understanding of the topic. Secondly, components are needed which provide detailed requirements for the design and development of accessible products. They are composed into the implementation layer. The third and top layer of the guide compromises the evaluation of web accessibility that includes a test strategy as well as supporting tools for test activities. The layers and their components are described in detail in the following sections.

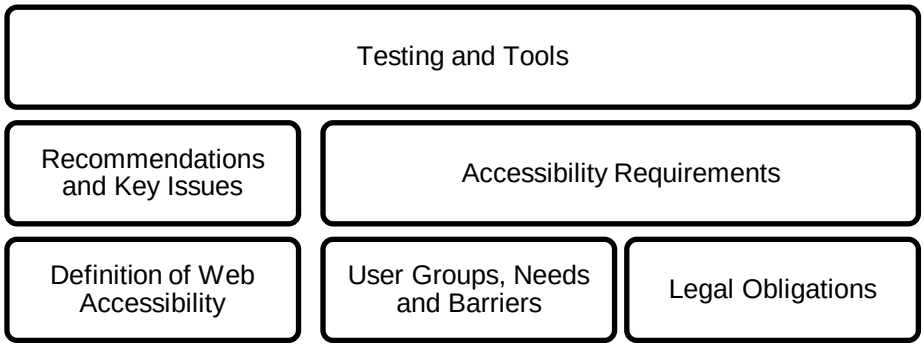

Figure 6: Overview of the accessibility guide

5.2 Components of the Guide

5.2.1 Foundation Layer

As result of the literature and interview analyses, the lack of awareness, knowledge and legal pressure stand out as reasons why web accessibility has not been established as standard attribute in product development and thus this layer supplies a foundation of knowledge about the concept in order to address these reasons.

The first component provides the *definition of web accessibility* in order to create a common understanding. Moreover, the definition of usability is provided, because the goal is to improve the user experience by more usable accessibility and hence, it is beneficial to understand the term usability as well as being able to distinguish between both concepts. It is also highlighted that both concepts are fundamental factors in the design and development of user interfaces and should be understood and treated as equally important non-functional requirements.

As the second component, an *overview of user groups* introduces different beneficials of accessibility, categories of disabilities, barriers that are faced and tools used to overcome them. This summary highlights the specific needs of people with disabilities in regards to the usage of web products and illustrates in contrast to this, that web accessibility also concerns every user, as barriers arise also from other reasons than disabilities, such as situational conditions or age-related characteristics and progressive overarching health impairments. This part plays an essential role in understanding the user requirements for accessibility.

The third component delivers the *legal framework*. Since web accessibility has been uniformly included in the legislation of the EU since 2016 and on national level of member countries since 2018, it is necessary to understand the legal framework when working with public sector clients. Therefore, the guide provides an overview of the applicable regulations at international level that sets the obligations, deadlines and requirements for web accessibility. National specifics are incorporated for the purpose of using the guide in a German based company. Nevertheless, this part can be adjusted and replaced according to the needs of the practitioners.

5.2.2 Implementation Layer

This layer comprises two components that need to be considered during the design and development of accessible web content. In these phases, legal, technical as well user requirements need to be addressed in order to implement accessibility in a way that the product complies to current regulations, meets the technical standards as well as satisfies the various user needs.

The first component provides *general recommendations* that help to tackle accessibility on department and project level. The countermeasures are derived from the professional experience of the interviewed experts and address reasons why most of the web content is still inaccessible, that in turn forces users to deal with various barriers. Moreover, they target different stages of the product life cycle and illustrate the complexity of the concept.

The second component of this layer represents the main section of the guide: the *accessibility requirements*. Their implementation in web and software projects ensures the design and

development of accessible user interfaces. It is of the utmost importance that the real user needs are considered, even though legal requirements must not be disregarded.

The comparison of the success criteria of the WCAG and the identified user requirements revealed the limits of the international standard. Its focus on technical requirements, that are testable and primarily addresses fundamental needs of visually impaired users, neglects further user requirements. In principle, the latter match better with the complementary criteria of level AAA than with the legal minimum (A, AA). Nevertheless, numerous differences have been identified which extend the list of criteria, either as complementary details to existing criteria or as new criteria (UR), and thereby add value for all users, especially for people with cognitive disabilities and older people. The catalogue of criteria has also been expanded to include the classification of user groups according to disabilities, which should help practitioners to understand which criteria are essential for which needs when using the guide.

The final collection contains a total of 85 accessibility requirements, including 78 success criteria and 7 new user requirements, 33 criteria extensions with details on more usable accessibility and the assignment to user groups per criteria. It is recommended to consider not only criteria of level A and AA but also of level AAA and UR for improving the user experience of as many users as possible. Simple and consistent design, easier language, additional and comprehensive assistance as well as flexible options to adapt content is beneficial to all users but essential to some.

5.2.3 Evaluation Layer

Merely implementing accessibility requirements is not sufficient without reviewing the results, therefore a third layer for the *evaluation of web accessibility* completes the guide. The evaluation of web content on accessibility compliance represents a decisive step towards a barrier-free use of digital technologies. It is the only way to determine whether user requirements have been met and what enhancements may be necessary. We consider the evaluation as an essential part of the implementation and an opportunity for continuous improvements. Hence, it is also included in the process of designing and developing products, rather than treating it as an afterthought only.

Based on literature and expert results a *test strategy* is suggested that involves all three procedures of automated tests, manual evaluations and user testing. In addition, a distinction is made according to the timing of the test activities:

1) Development-accompanying tests, that are carried out during the project:
   - Using software tools for identifying obvious barriers (partially) automated, such as browser extensions and bookmarklets
   - (If capacities allow): Conducting user testing based on defined scenarios
   - Testing manually based on defined scenarios, conducting code reviews and using keyboard, screen reader or any additional supportive tools
2) Final tests, that are carried out after the development in order to ensure an accessible and usable product:
   - Testing manually using keyboard, screen reader and code reviews or any additional supportive tools (e.g. screen magnifier, color and contrast picker)
     - following existing test procedures like BIK/BITV-test / WCAG-test which are focused on compliance with accessibility standards
     - based on defined scenarios in order to ensure usable accessibility for user needs
   - Conducting user testing with real end-users for identifying barriers and usability issues
     - based on defined scenarios, such as tasks to perform or goals to achieve
     - ensuring diversity of testers for covering a wide range of disabilities and user needs

As the definition of WCAG criteria is based on objective testability and mainly visual impairments are covered, the test strategy suggested here incorporates multiple procedures in order to evaluate the needs of as many users as possible. This is also necessary due to the identified user requirements which are beyond objective testability, such as the principles of easy language, simplicity and adaptability or text alignment and user guidance. Manual testing and user tests always provide only subjective results, but they represent, especially in combination, reliable methods to ensure the satisfaction of user needs. By involving people with different disabilities, the awareness and focus on other impairments such as learning and intellectual disabilities is also increased.

The different testing methods, that are needed, show the complexity of accessibility, but also emphasize on the necessity to prioritize and consider the attribute from the start of a project.

Tools and assistive technologies are suggested in the guide in order to support the evaluation during and after the product development. The list does not represent a comprehensive collection because of the number and variety of existing tools but it comprises screen readers, keyboard, browser extensions, bookmarklets and individual software tools. New technologies may arise and can be added to the collection of tools.

5.3 Modus Operandi

The accessibility guide is composed in form of a work sheet with six tabs containing the components, as shown in Figure 7. For the purpose of this work, the guide is stored on GitHub and can be accessed via the following URL: https://github.com/Resl411/MA_prototype1.0

The guide can be used as a holistic approach for the introduction to the concept. In this case, it is advisable to follow the chronological order of the components from left to right. This ensures that the users of the guide first understand the concept, potential users and legal obligations, before detailed accessibility requirements and a test strategy are conveyed.

Figure 7: Tabs in the work sheet of the accessibility guide

However, it is also possible to use the guide as a reference work. For this purpose, individual components can also be used independently of each other. This is supported by short descriptions of the content for each tab. Moreover, a legend with instructions on how to understand and use the information presented is added to the component ‘accessibility requirements’, as presented in Figure 8. Here, filters can be used to improve clarity, e.g. to display only minimum legal requirements, or to search for requirements that help a certain user group like cognitive impaired people or concern a specific topic such as keyboard navigation. This tab is the most comprehensive one and serves as a reference for designer, developers and testers during different stages of the product life cycle. It is recommended to gain a good understanding of web accessibility before working with the tab ‘accessibility requirements’.

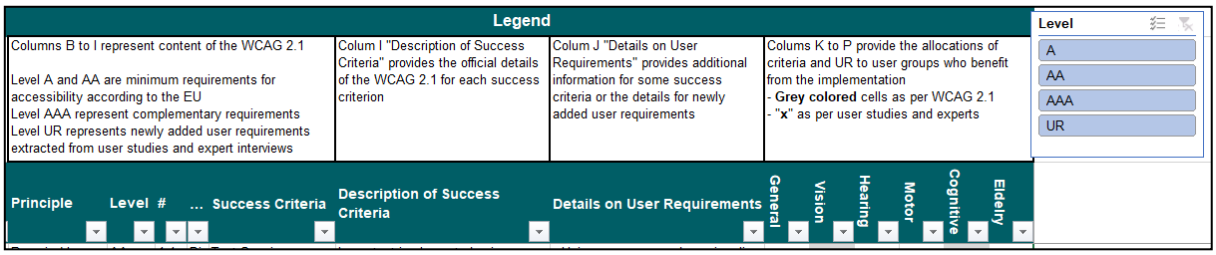

Figure 8: Legend and filter of 'accessibility requirements'

6 Demonstration of the Accessibility Guide

This chapter addresses the first part of the research validation by demonstrating the use of the accessibility guide in a case study. This step is essential to show that the proposed guide is applicable for organizations regarding the implementation of accessibility in web development projects and the improvement of the user experience of the developed products.

For this purpose, an internal project of CONET Solutions GmbH has been selected as use case and applied to the guide. The case as well as the demonstration are described in detail in the subsequent sections.

6.1 Case Description

The case study has been provided by CONET Solutions GmbH in order to test the guide in use and learn from its application. As a provider for IT consulting services and software products, the company intends to integrate web accessibility in its processes in order to improve the user experience and address the current needs of clients in the public sector. Details about the organization and its interests in the concept can be found in section 1.1 (Case Study Company).

CONET has made its company homepage available for the demonstration of the accessibility guide. For the purpose of validation, the application has been limited to two pages of the website only. As the main content targets technically-oriented users, the career landing page and its subsection for initiative applications have been chosen as general content that is applicable to a wider range of users. The career page represents the landing page for all career or job-related matters with which the company intends to attract and inform potential applicants.

The two pages exist as desktop and as mobile versions. Both are considered in this case. Furthermore, the pages consist of three parts: a header, the main content and a footer. Header and footer are the same on both pages. The header contains the logo, the main navigation and other elements such as links or buttons to the search form, the contact form, newsletter registration and the option to display content in English. The navigation consists of a menu that can be unfolded twice into its sub-levels. The second submenu level contains the item 'initiative application' for accessing this page. The footer hosts complementary content such as contact details and links to the newsletter registration, social media accounts and to continuing pages.

The main part of the career page is divided into three sections. The first one is the introductory text with page heading and a subtitle. After that, three boxes follow which are links to sub-topics and contain pictures, headlines and text. The last section is a list of current job offers in tabular form with a filter function. The embedded PDFs were excluded from the case study.

In contrast to that, the main part of the page ‘initiative application’ contains a page heading and an extensive form with an accompanying legend. The form’s subsections are personal data, job details and file upload.

In the following sections, the two pages are analyzed and improved in terms of accessibility by using the proposed guide. Only applicable components have been employed, such as the evaluation of accessibility, recommendations and accessibility requirements – keeping in mind the needs of the different user groups. The goal is to demonstrate how the accessibility guide can be used in order to support the implementation of accessible and usable user interfaces.

6.2 Accessibility Evaluation

This case does not represent a new development project but the improvement of an existing web application. Therefore, the first step includes an analysis of the as-is state of the two web pages in terms of the current degree of accessibility. The *test strategy* of the guide has been used in order to identify inaccessible design choices and elements that may cause barriers to end-users. A combination of manual test activities, such as code reviews and interaction tests, as well as the usage of automated software tools were applied as evaluation procedure. As assistive technologies, the following tools have been used: the screen reader NVDA, navigation by keyboard (desktop) and touch gestures (mobile), browser extensions such as color contrast analyzer (ColorZilla and WebAim Contast Checker), reader mode and headingsmap as well as the evaluation tool Wave.

The evaluation revealed several barriers that users face when visiting the web pages:

- Keyboard navigation:
  - [header] The focus does not follow a linear order in the header. It jumps from the logo on the left to the element group on the right and afterwards to the start of the menu back to the left.

Figure 9: Inaccessible dropdown menu

- [header] The double foldable dropdown menu is not operable by keyboard, except for the main items. Sub-items on both levels are inaccessible (Figure 9).
- [header] The focus follows the structure at the end of the header into two elements (search field, search button) which are not displayed.
- The cookie banner is not controllable by keyboard.

- Screen reader usage:
  - [header] The screen reader follows the non-linear order as the keyboard does.
  - [header] It announces the two invisible elements (search field, button).
  - [main career] In case filter elements of the list are controlled by the keyboard, the screen reader does not announce the accompanied labels.
  - [main career] The table rows are read out without any context to table headers.
  - [main initiative application] Required input fields are only marked with an asterisk. Not all screen readers announce this symbol.
  - [main initiative application] Two labels for input fields are abbreviations that the screen reader cannot announce in an understandable manner (“Nr.”, “PLZ”).
- Structure and semantics:
  - Role and title attributes for the semantic identification are missing.
  - Landmarks are used insufficiently for the navigation and identification.
  - [main career] A clear heading concept is missing.
  - [main initiative application]: Input fields are all marked with the type attribute ‘text’, regardless of the required content, which prevents the operating system in mobile devices from showing the respective keyboard, e.g. numbers only.
- Content:
  - [header] The sublevels of the dropdown menu contain up to 14 items (complexity).
  - [header] The right element group hosts repeating content of the footer.
  - [main career] No headline or introduction is provided to the list of job offers.
  - [main career] No direct link is provided in order to fill out an initiative application if the user could not find a matching job offer.
- Layout and design choices:
  - Content cannot be resized by touch gestures in mobile version.
  - The font color of some text elements shows insufficient contrasts considering the background color, font size and font weight.
  - The font size of some text elements is insufficient considering the font weight, color and background color.
  - The size of some target elements is too small.

- [footer] Color is used as only visual means to convey the existence of links.

The identified barriers are addressed in the following section by applying components of the guide's implementation layer.

6.3 Resolving the Accessibility Deficits

For the purpose of ensuring accessibility and improving the user experience of the web app, basic principles of the guide components *general recommendations* and *accessibility requirements* with focus on complementary user requirements are applied. The scope of the case study does not rely on standard conformance and therefore it is not intended to implement every legal criterion.

6.3.1 Selection of Accessibility Requirements

As a first step, principles and requirements need to be selected that are applicable to the use case. Consequently, recommendations related to new development projects or those criteria which are required for standard conformance are neglected due to absence of legal obligations for this web application. Same applies to requirements for time-based media, such as audio and video, which are not present.

Furthermore, the general purpose of a career landing page is to address potential applicants and future employees. Thus, the target group of end-users can represent a wide range of people with different knowledge, abilities and impairments. Accordingly, the needs of the users vary and as many as possible should be addressed.

In terms of *recommendations*, the following principles are considered during the improvement:

- Prioritizing accessibility
- Working with good intention to make web content accessible by understanding user needs and avoiding less usable workarounds
- Developing only one version of the web app as a compromise of design and functionality, addressing the needs of many users while allowing adaptability
- Focusing on the mobile version in order to ensure simplicity
- Applying target-group oriented design and avoiding theme-based design

As the main goal of the demonstration is to show how the application of the guide can support the improvement of the user experience, several *accessibility requirements* are selected to resolve the identified barriers and enhance the web application with previously extended or newly added user requirements (Table 27).

Principle	Level	Guideline	Criteria #	Success Criteria	General	Vision	Hearing	Motor	Cognitive	Elderly
Perceivable	A	Adaptable	1.3.1	Info and Relationship	x	x		x	x	x
Perceivable	A	Adaptable	1.3.2	Meaningful Sequence	x	x		x	x	x
Perceivable	A	Adaptable	1.3.3	Sensory Characteristics	x	x	x		x	x
Perceivable	AA	Adaptable	1.3.4	Orientation	x	x		x	x	x
Perceivable	AA	Adaptable	1.3.5	Identify Input Purpose		x			x	x
Perceivable	AAA	Adaptable	1.3.6	Identify Purpose	x	x			x	x
Perceivable	A	Distinguishable	1.4.1	Use of Color	x	x			x	x
Perceivable	AA	Distinguishable	1.4.3	Contrast (Minimum)	x	x		x	x	x
Perceivable	AA	Distinguishable	1.4.4	Resize text	x	x			x	x
Perceivable	AAA	Distinguishable	1.4.6	Contrast (Enhanced)	x	x		x	x	x
Perceivable	AAA	Distinguishable	1.4.8	Visual Presentation	x	x			x	x
Perceivable	AA	Distinguishable	1.4.10	Reflow	x	x		x	x	x
Perceivable	AA	Distinguishable	1.4.11	Non-text Contrast	x	x		x	x	x
Perceivable	AA	Distinguishable	1.4.12	Text Spacing	x	x			x	X
Perceivable	UR	Distinguishable	1.4.14	Font	x	x			x	x
Perceivable	UR	Distinguishable	1.4.15	Size of font	x	x			x	x
Operable	A	Keyboard Accessible	2.1.1	Keyboard	x	x		x		x
Operable	AAA	Keyboard Accessible	2.1.3	Keyboard (No Exception)	X	x		x		x
Operable	A	Navigable	2.4.1	Bypass Blocks	x	x				x
Operable	A	Navigable	2.4.3	Focus Order	x	x		x		x
Operable	A	Navigable	2.4.4	Link Purpose (In Context)		x			x	x
Operable	AA	Navigable	2.4.5	Multiple Ways	x	x	x	x	x	x
Operable	AA	Navigable	2.4.6	Headings and Labels	x	x			x	x
Operable	AAA	Navigable	2.4.8	Location	x	x	x	x	x	x
Operable	AAA	Navigable	2.4.9	Link Purpose (Link Only)		x			x	x
Operable	AAA	Navigable	2.4.10	Section Headings	x	x		x	x	x
Operable	UR	Keyboard Accessible	2.1.5	Tables		x		x		

Principle	Level	Guideline	Criteria #	Success Criteria	General	Vision	Hearing	Motor	Cognitive	Elderly
Operable	UR	Keyboard Accessible	2.1.6	Dynamic Widgets		x		x	x	x
Operable	AAA	Input Modalities	2.5.5	Target Size	x	x		x	x	x
Understandable	AAA	Readable	3.1.4	Abbreviations	x	x	x		x	x
Understandable	AAA	Readable	3.1.5	Reading Level	x	x	x		x	x
Understandable	AA	Predictable	3.2.3	Consistent Navigation	x	x	x	x	x	x
Understandable	AA	Predictable	3.2.4	Consistent Identification	x	x	x	x	x	x
Understandable	A	Input Assistance	3.3.2	Labels or Instructions		x			x	x
Understandable	AAA	Input Assistance	3.3.5	Help		x			x	x
Understandable	AAA	Input Assistance	3.3.6	Error Prevention (All)		x			x	x
Robust	A	Compatible	4.1.2	Name, Role, Value	x	x		x	x	x

Table 27: Accessibility requirements selected for the improvement of the prototype

A total of 37 requirements have been selected from the set of 85 criteria. The other 47 requirements were either not applicable to the use case or in parts already implemented in the original version. Only those requirements have been taken into account which address the identified barriers or match with the content. 18 criteria of the selection were previously extended by additional details for more usable accessibility (see chapter 4.2.1). Four other criteria represent newly added user requirements, assigned with level ‘UR’. The remaining 15 criteria are used in their original version of the WCAG. Nevertheless, all of the 37 requirements were part of the user requirements identified in the SLR and expert interviews. Therefore, their implementation can now be tested during the demonstration and their overall influence on the user experience will be tested in chapter 7.1.

Table 27 lists the selection of the 37 accessibility requirements which are implemented in the next step. 21 criteria belong to the minimum level for accessibility (A, AA), 17 criteria are complementary (12x AAA, 4x UR) and are supposed to create a higher degree of accessibility.

6.3.2 Implementation of Accessibility Requirements

During the evaluation of the original web page, several barriers and accessibility issues have been detected that makes it difficult or even impossible to use for some users. In this section,

the implementation of the of essential requirements for improving the usage is described. Each adjustment indicates the applied requirements by its number used in the guide (e.g. 1.3.1). The guide and code of the prototype can be accessed via this link: Guide and Code. The prototype can be accessed directly via this URL: https://ma-prototype.000webhostapp.com/index.html

General Issues

As a first step, general issues of the pages are addressed. Therefore, structural as well as content-related changes have been made in the source code.

- In order to enable users to zoom into the content by pulling two fingers apart (gesture), a meta tag in the code was substituted by a tag ensuring responsive design: <meta name="viewport" content="width=device-width, initial-scale=1"> (1.3.4, 1.4.8, 1.4.10).
- The navigation of keyboard and screen reader users has been enhanced by marking the content areas of the pages with correct role attributes, e.g. the navigation with the HTML element <nav></nav> and the respective role =”navigation”; the additional text below the main part with the element <aside></aside> and the role =”complementary”. This allows users to navigate by landmarks (1.3.1, 1.3.6, 4.1.2).
- The role attribute has been added to several HTML elements ensuring the semantic identification and consequently the correct announcement by screen readers (4.1.2).
- The cookie banner was previously not controllable by keyboard and screen reader, hence a ‘tabindex=0’ has been added which enables the focus of the element (2.1.1, 2.1.3, 2.4.3; Figure 10). In addition, the content has been improved: The link text is changed from “learn more” (German “Erfahren Sie mehr”) to a speaking link text “learn more about our data protection” (“Mehr zu unserem Datenschutz”; 2.4.9). It is also underlined, because otherwise color was the only means of showing the function of the element (1.4.1). Furthermore, color contrasts, font size, weight and word spacing are enhanced (1.4.3, 1.4.4, 1.4.6, 1.4.12, 1.4.14, 1.4.15).

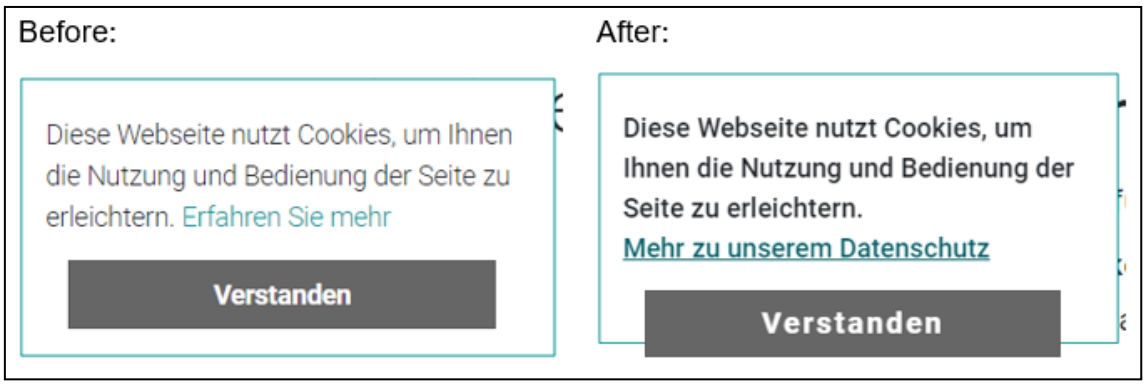

Figure 10: General – cookie banner before and after

Header and Footer

Next, accessibility deficits in the header of the pages are resolved:

- The structural position of the navigation menu has been switched in the code with the right placed group of elements. The visual presentation remains the same, but users of keyboard and screen reader benefit from a linear focus order through the header from left to right (1.3.2, 2.4.3).
- The double foldable dropdown menu, that is not accessible by keyboard, has been eliminated, as user requirements suggest avoiding dynamic widgets because of their inaccessible characteristics (2.1.6). Another reason is that the number of up to 14 menu items exceeds the recommendation of two to seven items by far (3.2.3). As an alternative navigation to the sublevel items, a new matrix menu with six boxes has been implemented into the main part of the career landing page and is discussed later.
- In the right placed group of elements, the legal notice (“Impressum”) and the button to the newsletter registration (message icon) have been removed in order to reduce the number of functions presented in the header (Figure 11). Both are repetitive and already part of the footer. In addition, the contrast of the legal notice is too low and the message icon may be confusing for the newsletter registration, as it usually represents a message or email (1.4.3, 3.2.4). The remaining elements are adjusted by increasing the target size and distance (2.5.5). Furthermore, title attributes have been added to them in order to ensure the proper semantic identification by screen readers (1.3.1, 4.1.2). The foldout search mask (icon of magnifying glass) has also been changed by increasing the contrast of colors for background and font as well as the font size, font weight and letter spacing (1.4.3, 1.4.4, 1.4.6, 1.4.11, 1.4.12, 1.4.14, 1.4.15). Before applying this change, the placeholder attribute was barely noticeable. The text of the placeholder has also been formulated more clearly by saying “insert search term” (“Suchbegriff eingeben”) instead of only “search term” (“Suchbegriff”; 1.3.5, 3.1.5, 3.3.5). Here again, the size of the input field and the search button has been adjusted to a bigger size (2.5.5).

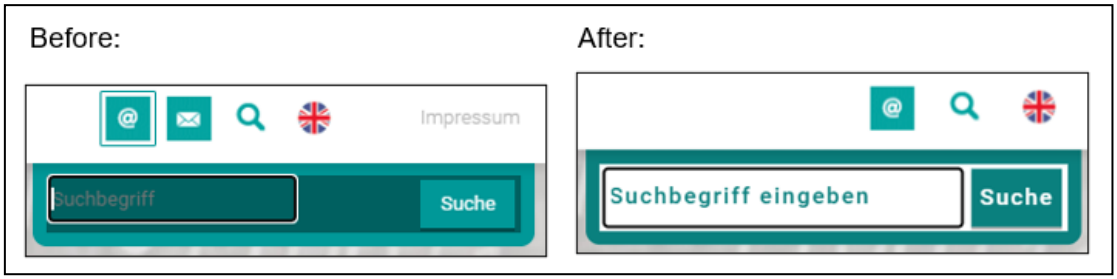

Figure 11: Header – group of elements and search mask before and after

- At the end of the header, keyboard and screen reader focus followed two elements of the search mask (input field and button), even though they were not displayed. This caused the focus to disappear and the screen reader to announce the invisible elements. Adjustments in the JavaScript functions resolved this issue. Now, the search mask is only focused if it is folded out by clicking the icon of the magnifying glass and the focus jumps from the last element of the header to the main part (1.3.2, 2.4.3).
- In order to improve the navigation for keyboard and screen reader users, a skip link has been placed to the beginning of the header for bypassing its elements (Figure 12; “Zum Hauptinhalt springen”). This leads the user directly to the main part. The element is hidden and only becomes visible if it receives keyboard focus (2.4.1, 2.4.3).

Figure 12: Header – skip link for navigating to the main part

The changes to the *footer* are limited. Mainly visual adjustments have been made. The font size, weight and word spacing was increased. The contrast was improved in order to better distinguish the font from the background color; and links received a decoration of style ‘underline’ to make them more noticeable than by color only (1.4.1, 1.4.3, 1.4.4, 1.4.6, 1.4.11, 1.4.12, 1.4.15).

Main ‘Career’

The main part of the career page has undergone several changes to structure and content:

- The breadcrumb has been expanded by a complementary text “You are here” in front of the listed path which informs unfamiliar or cognitive impaired users about their location within a set of web pages (“Du bist hier”; 1.3.6, 2.4.5, 2.4.6, 2.4.8, 3.3.5).
- As explained above the sublevel of the navigation has been newly implemented as a submenu in form of a matrix with six boxes (Figure 13). The boxes contain a picture and a headline as description. They represent links to the sublevel items from where additional details can be accessed. This layout is keyboard accessible and the total number of six items prevents an overload of functions and information. In addition, the simplified navigation supports the avoidance of deep hierarchies compared to the double foldable dropdown menu. Previously, only three boxes were shown which do not reflect the entire first sublevel of the navigation. The boxes also contained advertising text which has been removed for more clarity and missing menu items have been added (2.1.1, 2.1.3, 2.1.6, 2.4.3, 2.4.6, 3.2.3).

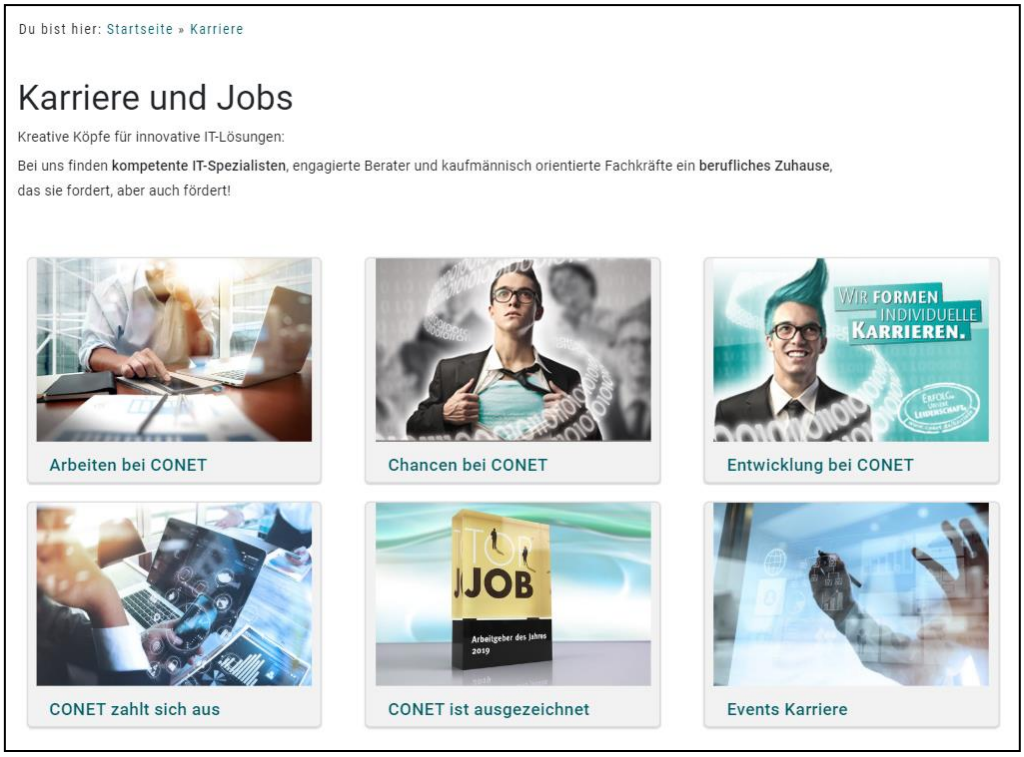

Figure 13: Main ‘career’ – submenu after

- The mobile version contained an own submenu in form of a dropdown list. This one has been removed since the matrix menu is also available there. It adapts to the screen size accordingly (1.3.4, 1.4.10).
- A clear heading concept has been added that enhances the keyboard and screen reader navigation and generally structures content which is beneficial for every user. In addition to the top heading level (h1; “Career and Jobs” or “Karriere und Jobs”), two headings on the lower level h2 have been inserted (Figure 14; “Current Job Offers at CONET” respectively “Aktuelle Stellenangebote der CONET-Unternehmensgruppe” and “Initiative Application” respectively “Initiativbewerbung”). The submenu items (matrix) have been marked as h3 (1.3.1, 2.4.6, 2.4.10).
- Both headlines of level h2 and accompanying text have newly been added to make the content more understandable (3.3.5; Figure 14). Previously, neither an introduction for the list of job offers nor information regarding initiative applications were provided to the users. They were left alone in understanding the presented content and figuring out how to use it. This change also fosters target-group oriented design according to user needs (*general recommendation*).

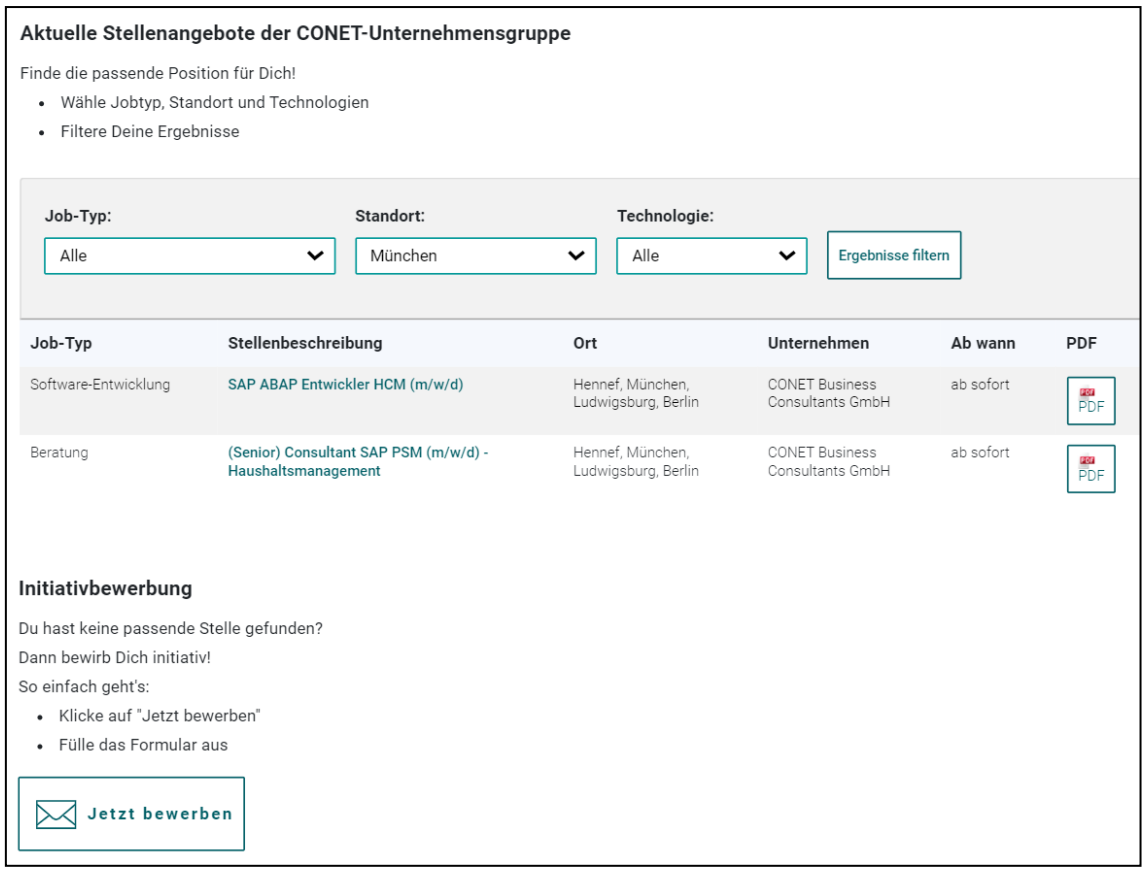

Figure 14: Main ‘career’ – content after

- The accompanying text represents information and instructions on how to proceed with job offers and initiative applications. The text is formulated in short, understandable sentences. Each one begins in a new line. Additionally, instructions are listed by bullet points improving the clarity (1.3.3., 3.1.5, 3.3.2). The font, its size, weight and line height have been enhanced (1.4.8, 1.4.12, 1.4.14, 1.4.15; Figure 14).
- The elements of the filter function for job offers have been adjusted in the code. The combo boxes are now connected with the respective labels for announcing the names (1.3.1, 4.1.2).
- The filter button “filter” has been extended to “filter results” for a better understanding and its target size has been increased (“Ergebnisse filtern”; 2.5.5, 3.3.5; Figure 14).
- The most extensive change has affected the list of job offers presented in a tabular form. The guide suggests avoiding tables or to apply proper HTML elements and semantics (UR). Therefore, it has been decided to keep the overall design due to its clear layout but to programmatically change the structure from list elements into table elements (1.3.1, 2.1.5). This step makes the list of job offers accessible and ensures that screen readers announce a summary of the table content and reads the table rows

in context with the respective table headers. Further code changes ensure the adjustment of the table into the mobile version (1.3.4, 1.4.10).

- A button has been implemented forwarding the user directly to the page ‘initiative application’. It contains a message icon and a descriptive text “Apply now” (“Jetzt bewerben”; 1.3.6, 1.4.11, 2.4.4, 2.5.5, 3.3.5; Figure 14).

Main ‘Initiative Application’

The final step of the improvement concerns the main part of the page ‘initiative application’.

- The introduction text has been formulated more clearly and separated from the form by a greater distance. Its heading has been highlighted in bold (1.4.14, 3.1.5, 3.2.4, 3.3.5).
- The form was already divided into three main parts. For the improvement of visual clarity, the distance between them has been increased (3.2.4).
- Legends and labels have been formulated in a more understandable way and by avoiding abbreviations that are inaccessible to some users or to screen readers, such as “house number“ instead of only “no.” (“Hausnummer”, “Nr.”), or “postal code” instead of “PLZ” (“Postleitzahl”) or “insert personal data” instead of only “personal data” (“Persönliche Daten eingeben”; 3.1.4, 3.1.5, 3.3.2, 3.3.5; Figure 15).

Figure 15: Main ‘initiative application’ – form after

- Furthermore, the respective type attribute has been added to seven input fields in order to support users using mobiles devices in entering the data in the required format (postal code, phone number, mobile phone number, e-mail address, birth date, job entry date, intended salary). This way operating systems recognize which type of keyboard should be displayed, e.g. only numbers or e-mail address with ‘@’, and additionally helps to prevent input errors (1.3.5, 3.3.2, 3.3.5, 3.3.6).

- All mandatory input fields have been extended in the code by the attribute ‘required’. Screen readers are able to identify and announce this attribute in contrast to asterisks. If the application has been submitted with an empty value for a required field, the user is prompted to this field in order to enter data (1.3.5, 3.3.2, 3.3.5, 3.3.6).

6.4 Testing the Prototype

The implementation of the guide’s accessibility requirements has led to the creation of a new prototype of the existing web application which was selected for the case study. Without the evaluation of the new version, it is not possible to judge whether the previously identified barriers have been resolved by the measures deployed.

For this reason, the components of the *test strategy* described in the accessibility guide have been used once more. Development-accompanying tests were continuously conducted during the improvement activities. Manual testing with code reviews, keyboard and the screen reader NVDA was the main procedure applied. Newly implemented changes, even though they concerned only one element, were tested with the respective tool right away. Software tools, like a color contrast analyzer, were used to check the contrast level and to define colors with a high and sufficient contrast. Browser extensions and developer tools helped to identify existing issues and to switch between desktop and mobile versions.

Upon completion of the development, final tests were conducted manually. The same tools and assistive technologies were used as before. In contrast, this test session did not focus on single implemented enhancements, but rather followed a scenario-based procedure. One scenario was defined that involved several tasks.

Scenario: The user is looking for a job and is interested in CONET as an employer. Therefore, the user visits the career landing page for the first time. Until then, the user is not familiar with the content and layout of the web application.

The user intends to perform the following tasks on the page:

1) The user tries to find his way around the site. To do this, the user explores the navigation, structure and basic content of the page.
2) The user would like to inform himself about the development possibilities at CONET.
3) The user searches for a suitable job ad and filters the results of the list.
4) The user would like to search for a specific content and uses the keyword search.
5) The user hasn’t found a suitable job offer and would like to make an initiative application.
6) The user fills out the form for an initiative application.

The scenario and tasks are applicable for the desktop as well as the mobile version.

Following this scenario, while considering the identified barriers and applicable user requirements, the result of the test session was overall positive. All known deficits have been resolved: All controlling elements are now accessible for keyboard navigation. The screen reader is able to identify and announce the elements and content, including the table. Inaccessible dynamic widgets are removed and replaced by accessible solutions. The navigation has been improved by restructuring content and removing repetitive elements. Same applies in terms of clarity, simplicity and understanding. Therefore, additional information and instructions have also been added and formulated in short, clear and easily understandable sentences. Responsive design ensures adaptability (e.g. zooming). Links are highlighted by color and style (underline). Contrasts are enhanced from partly below a relation of 3:1 to at least 4.5:1 and mostly 7:1 for essential text (from #009898 to #005E66). Fonts are increased to at least 14 px, mostly 16 px or larger. Font weight, line height and word spacing are enhanced to a layout that supports users in distinguishing and understanding the content. Based on this result, it can be assumed that people with various disabilities or restrictions can now use the web app better than before.

6.5 Conclusion of the Demonstration

The accessibility guide has been applied to the use case of CONET. Different components of the guide helped in addressing accessibility in the selected web application. The *evaluation* component accompanied the entire process, from the determination of the current status, through the development to the final test. While the different user needs were kept in mind, the *general recommendations* as well as the *requirements* for the definition and implementation of the measures were decisive.

The final test session showed an overall positive result and it should be highlighted that the identified barriers have been resolved by applying the accessibility requirements of the guide. Nevertheless, this procedure depends on the subjective perception and evaluation of the examiner. It can provide important insights but does not promise a 100 % confirmation of accessibility. This is not only due to the necessarily subjective assessment of a person but also because accessibility and user experience depend on the perception, knowledge and skills of each individual end-user. Therefore, the guide also recommends combining several evaluation methods.

7 Research Validation

This chapter represents an essential step in the DRSM process model. The evaluation of the designed accessibility guide aims to observe and measure the performance of the artifact in providing a solution to the problem. Therefore, the results from demonstrating the artifact in use and the guide itself are compared to the objectives defined in chapter 1.3 in order to determine the quality of the proposed design.

Within the scope of this work, the validation is carried out by means of 1) user testing and 2) semi-structured interviews. As it could be seen in the next subsections, these two means are chosen because of their suitability to the research context of this graduation project.

The user testing is conducted with the goal of evaluating the user experience of the improved prototype (chapter 6) with regard to the implemented accessibility requirements and the resolved barriers. This activity focuses on validating the extension of the WCAG by additional user requirements extracted from literature and expert interviews. In addition, semi-structured interviews are conducted with practitioners in web development and software projects in order to evaluate the accessibility guide as a holistic approach.

7.1 Evaluation of User Requirements

7.1.1 Evaluation Method

Since accessibility as well as user experience strongly depend on individual knowledge, abilities and needs, it is recommended to involve users of the target group in the evaluation. Therefore, user testing was chosen as a method to evaluate the prototype regarding its changed degree of accessibility and the user experience influenced by it.

In this method, users are asked to use the prototype and interact with it in order to reveal how they perceive the components and interaction behavior of the application. Although the focus of this work is on accessibility, applying the method may also uncover problems related to usability or other constructs of user experience. The method is likely to identify barriers and accessibility deficits. However, due to the case-related implementation of requirements, the small number of participants and the subjective assessment of users, the results may be valuable for this work but do require additional testing to strengthen their validity and in turn, form some more generalizable claims.

7.1.2 Execution of the Evaluation

First, users were recruited who fit to the context of the case study and who are part of the target group. Due to the general orientation of the context, it was possible to select people with

different experiences, knowledge and skills. The focus was on people with disabilities in order to evaluate how the user experience has been influenced by resolving accessibility deficits with the implementation of user requirements. For this purpose, three persons (UT1, UT2, UT3) agreed to participate in the user test. UT1 and UT2 have visual disabilities. UT3 suffers from several disabilities, such as motor, visual and cognitive disabilities. In addition, UT3 is over 60 years old and hence belongs to the user group of 'elderly'.

The user tests were conducted in individual sessions, whereof the tests with UT1 and UT2 were conducted remotely via phone. The session with UT3 took place in a personal meeting. UT2 requested to perform the test by himself/herself before discussing his/her test experience. The reason for this request was due to the fact that UT2 is blind and had to let the screen reader read out the content first. In contrast, the other two users did not have any preparation time.

As in the manual test, described in chapter 6.4, a scenario-based approach was applied in the user tests, too. The same scenario and the defined tasks were used which are presented in Table 28. The participants were required to perform the given tasks while being asked to describe their actions and to think aloud. In addition, users were advised to use the assistive technologies and devices they are familiar with. As a first step, the participants should perform the tasks with the original version of the web app to test whether and to what extent the barriers identified in chapter 6.2 apply to them. Afterwards, the prototype was evaluated in the same manner. Each test session including the discussion lasted in average about 60 minutes.

Scenario: The user is looking for a job and is interested in CONET as an employer. Therefore, the user visits the career landing page for the first time. Until then, the user is not familiar with the content and layout of the web application.	
No.	**Tasks**
1)	The user tries to find his way around the site. In order to do this, the user explores the navigation, structure and basic content of the page.
2)	The user would like to inform himself about the development possibilities at CONET.
3)	The user searches for a suitable job and filters the results of the list.
4)	The user would like to search for specific content and uses the keyword search.
5)	The user has not found a suitable job offer and would like to make an initiative application.
6)	The user fills out the form for an initiative application.

Table 28: Test scenario and tasks

7.1.3 Results of the User Tests

User Test 1

The first participant (UT1) is aged 30 to 39 years old and works as job advisor at an employment agency. UT1 is blind in one eye and has only 15 % vision in the other. This impairment limits the visual abilities and the user relies on optical magnification. Therefore, UT1 needs assistive technologies in order to make use of digital technologies, such as screen magnifier or accessibility aids of the operating system. In general, the user prefers to use mobile devices rather than laptop or desktop computers, as content is displayed in a more compressed form. That is why, UT1 performed the user test on a smartphone with the mobile version of the web application.

On the first view, UT1 declared for both, the original and the prototype, that the overall font size was too small without magnification. Using the original version of the web app, UT1 reported the lack of a zooming option by the touch gesture of pulling to fingers apart and therefore it was necessary to use the more complicated aid of the operating system (to zoom by tapping three fingers, to move by sliding two fingers). The zooming gesture has been enabled in the prototype (replaced meta tag) and rated by UT1 as very helpful and more intuitive, because this gesture requires only two fingers instead of three for zooming and one finger instead of two for scrolling. Nevertheless, UT1 prefers a feature in the web app to increase the font size that adjusts the alignment of the content as well. Because zooming itself does show focused elements bigger but requires the user to move the focus around in order to grasp the entire content. In addition, the font and background colors (grey with turquoise), their contrast and the light font weight represented a general barrier in the original, because the text was badly distinguishable from the background. This concerned the submenu, general text and the search mask. UT1 was not able to notice the placeholder in the search input field. In the prototype, these barriers were mostly resolved, and elements were much better perceivable for UT1, except for the submenu text which had a sufficient contrast but insufficient font weight. The adjusted layout (contrast, colors, alignment) of the table in the prototype was clearer, more distinguishable and understandable.

Next to contrasts and sizes in the original, which partly prevented UT1 from noticing content at all, the user faced a major barrier with task 5 (Table 28), navigating to the page ‘initiative application’. First, UT1 searched for a link or button on the career landing page and afterwards clicked the burger button of the mobile menu in the header. The navigation folded out showing the main items, such as ‘career’. UT1 had to zoom in very closely in order to read the labels. Clicking on each item or row just opened the respective landing page. Due to the zoomed view,

the arrow icons for folding out the sublevel items were out of sight. The layout and navigation tree were too complicated, overloaded with items and not understandable for UT1 to locate the requested page. The user was not able to perform task 5 in the original version, but highly appreciated the changes in the prototype: Replacing the inaccessible dropdown menu by the matrix submenu and adding an introduction for initiative applications below the list of job offers supported the navigation and comprehensibility of the content.

On the page ‘initiative application’ in the prototype, UT1 rated input fields, correctly marked by type, as helpful, because operating systems offer input-oriented keyboards with less keys in a bigger size. However, browser dependent features for input types limited the freedom of the user, such as on how to enter a date, e.g. only by selecting from a calendar widget instead of typing numbers.

Overall, UT1 evaluated the improvements in the prototype as ‘very positive and helpful’ but suggested some changes in the way certain requirements were implemented.

User Test 2

The second participant (UT2) is aged 30 to 39 years old and is currently doing his/her PhD. As a child, UT2 was able to see but lost his/her vision gradually until age 13. Because of the blindness, the user is dependent on assistive technologies and uses the screen reader JAWS as well as keyboard navigation. This user test was performed on a laptop with the desktop version of the web application.

Initially, UT2 perceived the original career landing page as accessible, but admitted that it was impossible to perform task 5 (Table 28), because the user was not able to locate the form for an initiative application. Due to the inaccessible dropdown menu (header navigation), neither the screen reader nor the keyboard identified the sublevels of the navigation. Thus, UT2 was not aware about any additional hierarchies. In contrast to the original, the user evaluated the prototype as excellent to use and explained that a lot more elements were operable. Moreover, UT2 appreciated the well-structured page layout based on the heading concept and stressed the need for structural elements such as headings, lists, tables, landmarks, graphs, forms and buttons for a screen reader and keyboard accessible navigation.

Regarding the list of job offers (task 3), UT2 reported that the table in the prototype is more accessible than the list in the original, because the screen reader announces a summary of the content and relates the rows to the headers. Both is not the case if HTML list elements are used instead of table elements. The user also warned that tables can quickly change from a

structured overview to a time-consuming and complex presentation for blind users. However, UT2 admitted that a table makes sense for this purpose of presenting the list of job offers.

Testing the form ‘initiative application’ in the prototype (task 6), the user described the announcement of required input fields as very helpful, because the textual addition of an asterisk in the label is not mentioned by every screen reader and blind users are not informed about mandatory fields. Moreover, after pressing the submit button, the ‘required’ attribute also brings the focus back to a mandatory field which has not been filled out properly. UT2 appreciates this feature but prefers a textual summary of missing data, such as in the original version, because otherwise a blind user ends up with a trial-and-error process of detecting every field with missing data one by one. Furthermore, input fields, correctly marked by type, support the user in entering the required data format. In the original, all fields are marked as ‘text’.

Overall, UT2 evaluates the prototype as more accessible and easier to use than the original. The participant highlights that clarity in structure and additional instructions make the interaction with web content more comprehensible and usable for screen reader and keyboard users.

User Test 3

The third participant (UT3) is aged 60 to 69 years old and an early retiree since the age of 36 due to the consequences of a left hemisphere stroke. These effects concern cognitive impairments such as problems with speech and understanding language (aphasia), memory problems, impaired ability to organize, reason and analyze items as well as to read write and learn new information. As an additional consequence, UT3 has a right-sided weakness in the body and paralysis of the right arm (motor disability). Therefore, as a native right-handed person, UT3 had to learn to do everything with the weaker left arm and hand at age 36. This impairment restricts UT3’s fine motor skills. Furthermore, the participant has limited visual abilities. By means of special lenses, UT3 achieves 80 % vision in the right eye and 50 % vision in the left eye. The user wore these lenses during the test session. Nevertheless, UT3 used a mechanical magnifying glass whenever necessary. The test was performed with the user's smartphone, as UT3 does not use computers.

Unlike the other two participants, UT3 is not an experienced user of digital media and mainly uses messenger services or websites and mobile apps, e.g. for news or audio books, with which UT3 is familiar with. As a new user as well as a person with various, especially cognitive, disabilities, UT3 provides insights from a new perspective.

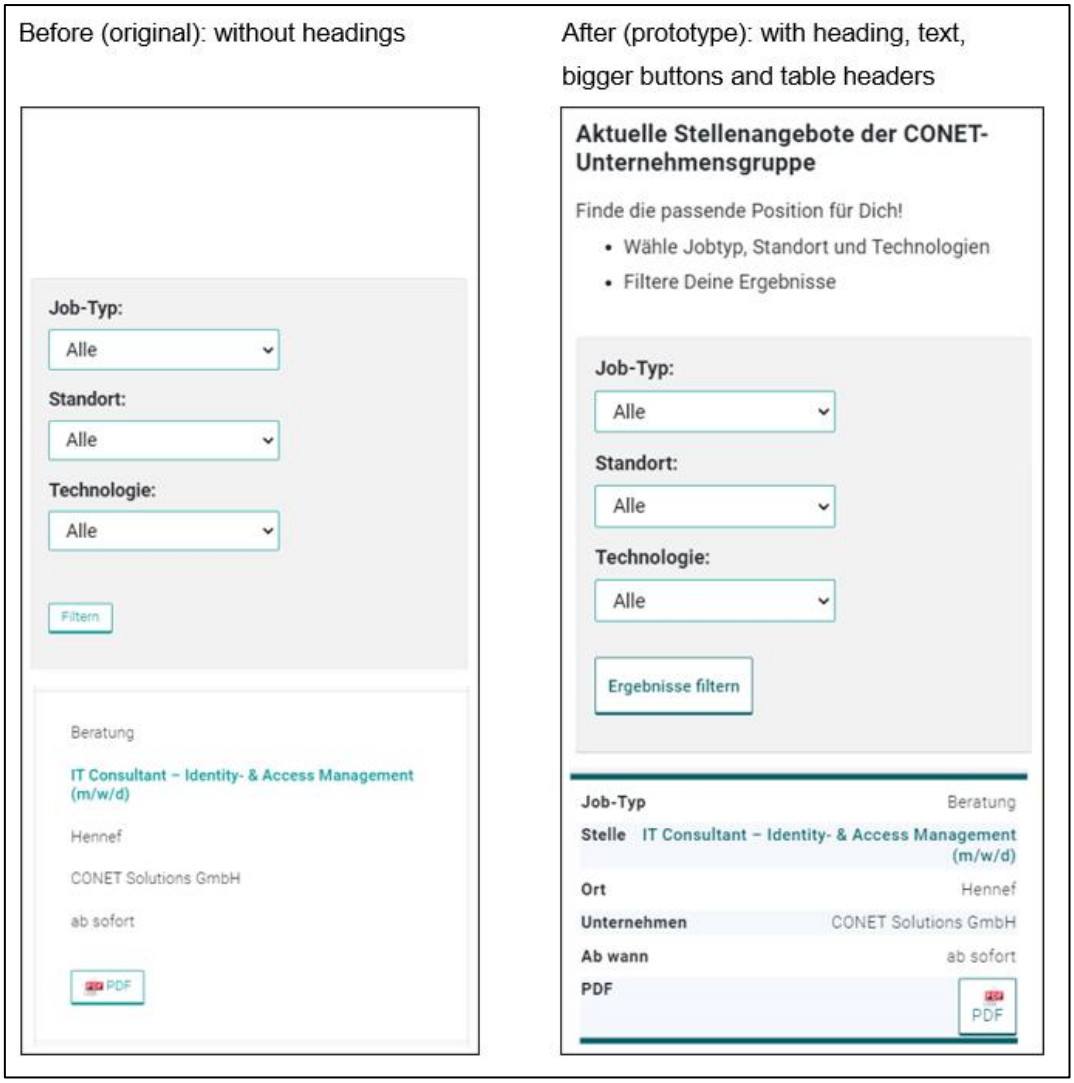

Figure 16: Main – mobile version of job list before and after

During the test, the user showed basic difficulties in identifying the purposes of elements and using control functions. UT3 took some time to explore the content and read texts several times in order to grasp the meaning. In many cases the participant used the trial-and-error principle and scrolled up and down in order to complete the tasks assigned. Dropdown lists such as the quick start menu (only available in the mobile version of the original application) or the filter function of the job list with three choices were not known to UT3 (task 3, Table 28). This became clear in task 2, among others. In the original web app, UT3 could not find the navigation element 'Development at CONET' at first. Due to the boxes of the matrix menu, UT3 had less problems finding the item in the prototype. In task 1 and 3, it was noticed that UT3 first interpreted the list of job offers in the original page as the company's scope of activities. In contrast, the user understood the content in the prototype correctly, since the entire section is introduced by an

informative heading with supplementary instructions and the table rows are directly marked with table headers (Figure 16).

Task 4 could not be completed by the user without help, neither in the original nor in the prototype version of the web app. The reason was that UT3 could not identify the icon of the magnifying glass as a symbol for search. Furthermore, the user was not able to see the placeholder label in the search mask because of the low contrast of the font. A similar problem regarding the interpretation of icons occurred with task 5. UT3 did not recognize the icon of a burger menu as a controllable element for a cascading menu (original). Labels would have helped the user to understand the function and purpose of the icons. In addition, it was not possible for the participant to understand the navigation tree and to locate the menu item ‘initiative application’ in the second sublevel of the mobile menu, even with some help. These difficulties show how complex navigation structures prevent users with cognitive disabilities or novice users without prior knowledge from using web content or at least make it difficult to use. Whereas in the prototype, UT3 was able to find the link to the page 'initiative application' without help. However, it took some time, as the position of the table kept the user several times from scrolling down any further. At the same time, the new heading and the keyword-like instructions proved to be very helpful and guided the participant to the correct button.

Filling out the form for submitting an initiative application (task 6), UT3 did not face any major barriers. However, the user highly appreciated the adapted keyboard according to the required data format in the prototype. This made the input very easy und improved the user’s understanding. UT3 also preferred the functionality of the prototype that focus is brought back to missing mandatory fields, compared to a text summary in the original.

Overall, the user had difficulties to perceive visual content, such as text and labels, clearly and distinctly in the original version at times. This was due to low contrast levels, small font sizes and low font weights. UT3 confirmed that these aspects were not a problem in the prototype. The content was easier to recognize and more readable.

All in all, UT3 evaluated the original version as very complex, confusing and difficult to perceive and understand to the content and its layout. In contrast, the prototype was assessed as easier to use and more barriers were resolved, especially visual aspects, compared to the original. In terms of cognitive abilities, the potential for improvement regarding comprehensibility, clarity and simplicity has yet not been exhausted.

7.1.4 Discussion of the Test Results

All participants of the user tests confirmed that the implementation of accessibility requirements in the prototype of the web application has improved their user experience compared to the original version. Resolving the barriers, identified in chapter 6.2, represented a significant enhancement for the users.

In terms of design and layout, UT1 and UT3 benefited the most from visual changes concerning the color of font and background, contrast levels, line height, word spacing, font sizes and weight as well as increased target sizes – the bigger the adjustments, the better the assessment (compare Table 27 in chapter 6.3.1, criteria 1.4.1, 1.4.3, 1.4.4, 1.4.6, 1.4.8, 1.4.11, 1.4.12, 1.4.14, 1.4.15, 2.5.5).

UT2's perception relied only on the programmatically determinable structure and semantic annotations of elements due to the usage of screen reader and keyboard navigation. This need was supported by the respective accessibility requirements 1.3.1, 1.3.2, 1.3.5, 1.3.6, 2.1.1, 2.1.3, 2.3.1, 2.4.3, 2.4.10, 2.1.5, 2.1.6, 3.2.3 and 4.1.2.

Furthermore, the user test revealed that consistency and simplicity in layout and navigation pave the way towards improved access to web content for every user, especially unfamiliar and cognitive impaired users. Among others, this was particularly evident in task 5, finding a way for accessing the page 'initiative application'. It represented a critical barrier in the original version to all three users which none of them could overcome due to the complex nesting of elements, the deep navigation structure, dynamic widgets, the unclear symbols for additional menu levels and the lack of related information and instructions. By restructuring elements, shortening navigation routes and supplementing additional descriptions and instructions in the prototype, the users were able to complete this task (1.3.5, 2.4.6, 2.4.9, 2.1.6, 3.1.4, 3.1.5, 3.2.3, 3.2.4, 3.3.2, 3.3.5).

It was also particularly revealing that today's common use of icons as buttons or links can be a critical barrier for unfamiliar or cognitively impaired users, such as the magnifying glass for the search mask or the hamburger icon for the mobile menu. This finding came as a surprise, as businesses generally think of icons as a way to enhance user experience [80]. Based on these results, we acknowledge, that in such a case, icons should be supplemented with labels or the possibility should be given to at least show captions if required for a basic understanding of users.

Finally, it should be mentioned that the users had partially different needs and opinions about the way some requirements should be implemented, such as resizing text (zoom, browser

functions or special buttons within the website) or error prevention (summary of missing mandatory input fields compared to focus shift to the first missing field). This goes in line with the fact that some users require more support or different type of help than others. One version can barely meet the needs of all possible users, but adaptability may fill some gaps and provide freedom to users to adjust content and layout to their personal needs. Our test findings also show that with the good intention to resolve barriers and ensure accessibility, many people are already better off in using digital technologies.

7.2 Validation Interviews

Semi-structured interviews were selected as qualitative research approach for validating how the proposed accessibility guide stands up to the scrutiny of practitioners. As reference, the approach followed, its advantages and disadvantages are described in detail in chapter 3.1.1.

7.2.1 Planning and Execution of the Interview-based Study

Four semi-structured interviews were conducted during the validation process. In the interview process, explicit attention was paid to the fact that the participants are practitioners who have different backgrounds and experiences with regard to accessibility. They agreed to participate on a voluntary basis. The selection of the sample as well as the individual interview participants are described more in detail in the sections 7.2.2 and 7.2.3.

Three interviews were carried out in individual sessions in form of personal meetings while complying with the current distance regulations of the COVID-19 pandemic. One interview was conducted as a video conference. First, the participants were informed in detail about the objective of this research work and received a letter of information and declaration of consent. Afterwards, the accessibility guide and its components were introduced to them. Questions and comments by the participants were allowed during the entire sessions.

After the initial presentation, interview questions were asked about the guide which were defined up front but adjusted throughout the sessions, considering the structure of the guide as well as the individual background of the participants. This approach ensured the flexibility needed in semi-structured interviews in order to gain valuable insights of the practitioners. The focus of the discussions was on evaluating the guide on its completeness, usability, application possibilities and potential improvements. The participants were asked to assess the guide, explain their understanding, describe what elements should be added, removed or improved in some way. Moreover, their perceived usefulness and usability was discussed. They were asked

for potential application possibilities and their personal intention to use the guide. For reference, the interview questions are provided in Appendix G.

As the participants are native German speakers, the sessions were conducted in German. With their consent, all interviews were recorded as audio files to allow a detailed analysis. The average duration of the interview sessions was 60 minutes. Table 29 describes the professional occupation of the practitioners and the duration of the interview with each of them.

Participants	Profession	Duration of Interview [min]
IP1	Project lead	00:56:00
IP2	User interface designer	00:39:00
IP3	Consultant	01:15:00
IP4	Manager	01:10:00

Table 29: Overview of the interview participants (validation)

7.2.2 Selection of the Sample

As applied for the expert interviews in chapter 3, 'theoretical sampling' was also used as our method to consciously select the participants for the validation interviews. The selection was carefully made in order to maximize the feedback gained from the individual practitioners. The different range of professional backgrounds and job positions of the participants ensured that the accessibility guide was evaluated from different perspectives. This reduces the risk of a one-sided evaluation and increases the validity of this work.

The sample consists of four persons (Table 29) who have been exposed to the topic of web accessibility in different ways, ranging from the first introduction to the topic, over theoretical knowledge building up to practical experience in customer projects. This makes it possible to test the guide for its different requirements in supporting the implementation of accessibility, from the novice to the experienced user.

7.2.3 Participants

The selected participants are employees at the software and consulting company CONET Solutions GmbH. They are part of the same department that delivers digital workplace solutions to its clients and all are actively involved in web and software development projects. Below, each practitioner's background is described in more detail, using the IDs in the first column of Table 29.

IP1 is a project lead with more than 25 years of work experience, including one recent project in which accessibility was a mandatory requirement that had to be implemented according to

legal regulations for public sector bodies. IP1 had to do research and ask colleagues for help to address accessibility properly.

IP2 works as user interface designer in the UX team. In the future, the concept of web accessibility will also be addressed there. IP2 has 19 years of work experience in web design and three years in user experience. The participant has recently gained deep theoretical knowledge about web accessibility, since facing the pressure by clients to design accessible user interface that comply with legal obligations.

IP3 has just started his/her career as consultant for user experience and digital solutions. The participant has gained first experience in the design of user interfaces and the development of mockups. IP3 has little to no knowledge about web accessibility for now. In the future, the participant will be involved in accessibility projects as well.

IP4 works as a manager and has more than ten years of work experience in his/her field of expertise. The main tasks include the responsibility for personnel and cost centers as well as strategy management. IP4 is aware about the importance of web accessibility for the company's clients in the public sector and intends to shift focus on the concept. He/she has a general idea about the subject without detailed knowledge.

The four participants have different levels of knowledge and experiences about the concept of web accessibility. So they are well suited for the validation of the guide, since it should be evaluated how well the guide supports practitioners in addressing and implementing accessibility in web development projects, while considering the required legal information and improving the user experience of the products.

7.2.4 Results of the Validation Interviews

After the presentation of the guide, all participants stated that they had understood the artifact and its components. They rated it as very well structured, clear and comprehensive. In general, the participants assessed the guide as well as the individual components as easily understandable. They confirmed that they do not need any further aids for the use of the guide.

Regarding the components of the guide, the participants agreed that a definition of the concept is required in order to form a common basis and to be able to distinguish between accessibility and usability. In addition, they assessed the combination and scope of the components as very detailed and helpful in understanding the complexity of the subject. IP3 appreciated the illustration of user groups and their barriers as well as the assignment of accessibility requirements to user groups (components 2 and 5). IP2 stated that the guide was an important

step towards establishing accessibility in the organization, its processes and projects. It can be used by employees across different departments and functions, such as IT support, sales, project management, designers and developers (IP2, IP4).

All participants indicated that they would like to use the guide in the future. They agreed that the guide could be applied to familiarize employees with the topic of accessibility. The information available provides the necessary knowledge to be able to advise customers on the concept. Furthermore, the guide could be used as a reference work in projects in case any questions come up or detailed background knowledge is required.

When asked whether content was missing or whether something should be changed, the participants gave different answers. IP2 proposed to assign the requirements also to functions according to their responsibilities, e.g. whether a particular criterion concerns designers or developers only. This could facilitate the coordination of tasks in projects and improve clarity. In addition, IP2 recommended to add hyperlinks to the listed testing tools for easier use. IP2 also suggested that the guide should be supplemented by an argumentation aid for customer consultants, e.g. in the form of a FAQ list (frequently asked questions). But the participant also expressed the concern that this would require some relevant experience already gained or that new projects would have to serve as a basis for such help. IP1 shared this opinion and commented that the guide was too complex in the case of client consulting and that a short version would be helpful. Finally, IP4 pointed out that additional information and instructions would be useful to be able to use the guide independently and without the presentation in chapter 5 in this report. The participant suggested to add details to the component legends. In particular, a clearer distinction between web content and application software in terms of accessibility requirements was appreciated.

All in all, the participants were overly satisfied with the accessibility guide. They gave positive feedback about the structure, layout, scope and content in terms of completeness, usability and clarity. The interviews were rounded off by constructive suggestions for improvement.

7.2.5 Discussion on the Interview Results

Although the interview results indicate that according to the participants our guide adds value and is useful, we are conscious about some validity threats to the findings. First, our interview study includes only four practitioners and these are from the same organization. It is therefore intuitive to assume that including more practitioners would be much beneficial and strengthen our findings. Would this mean that the possibly new insights would change our conclusions? One might speculate that if we include more practitioners with the same job titles as those

already involved, and from the same department in the company, we might well get similar interview responses (and possibly derive similar conclusions). One might expect this because of our explicit focus to involve practitioners with diverse jobs and backgrounds while each practitioner was representing a certain job and work-related perspective. To understand if perspectives vary across departments, a follow-up evaluation research is needed by including IT professionals from other teams, such as development and testing.

Next, a generalizability threat is related to the extent to which the interview findings in one company could possibly be observable in other companies in the same business sector engaged in providing accessible technology to the same client audience. Following the reasoning of Seddon and Scheepers [81], we could possibly expect that our findings might overlap with perceptions and experiences of practitioners in similar companies who have similar processes, goals and values and serving similar clients. Seddon and Schepers [81] argue that similarity of contexts could create similar circumstances in the organization and similar mechanisms which could bring similar experiences and perceptions. Therefore, we would think that it might as well be possible that if we reproduce the evaluation in similar organizational contexts, we might observe findings similar to ours. Of course, more empirical research is required in order to collect solid evidence about the usefulness of our accessibility guide beyond the original context for which it was created.

7.3 Conclusions of the Validation Studies

The interview participants expressed their satisfaction with the accessibility guide. They assessed the components as comprehensive, well-structured and understandable. Nevertheless, potential for improvement concern a suggested extension of the *accessibility requirements* by assigning the requirements to the responsibility of functions such as designer or developer. This may support the coordination of tasks in web development projects. Moreover, one participant proposed to extend the component legends by additional instructions for the usage of the guide. Furthermore, it has been suggested to provide guidance on consulting clients by providing an argumentation aid with frequently asked questions. All in all, the participants commonly declared their intention to use the guide in future, either for introducing web accessibility to non-specialist employees or as reference work for detailed background knowledge. They shared the opinion that the guide will help to establish accessibility in the organization, projects and processes.

The user testing showed that the user experience of applications can be improved by resolving barriers through the implementation of accessibility requirements. Thus, it is essential to keep

the various user groups in mind and work with the good intention to provide usable accessibility. Among others, the case supported the need for a clear structure, a consistent and simple layout and navigation as well as adaptability. Latter ensures the freedom of users and bridges the gap between general and special user requirements. The test also showed contradictory preferences of users regarding the detailed implementations. It should be mentioned that all needs can never be addressed at the same time, but accessibility is essential to some and concerns everybody to some extent.

8 Discussion and Conclusion

This chapter discusses the results of the thesis in regard to the main research question as well as the sub-questions defined. In addition, contributions to theory and practice are elaborated under the consideration of applicable limitations. Finally, directions for future research are presented and with the intention to provide further inspiration for the topic.

8.1 Discussion

The objective of this research is to create a guide that helps practitioners in organizations in implementing accessibility in web applications and improving the user experience while considering the legal framework. With this in mind, the goal was defined in the form of the main research question.

How can accessibility be implemented to meet regulatory requirements while improving the user experience of web applications?

The answer to this question is the result of the present research: An artifact has been developed that is intended to serve organizations as a guide for web accessibility. Six components support practitioners during the implementation. The first three components lay the foundation by defining and distinguishing accessibility from usability, giving an overview of user groups, their needs and barriers, and introducing legal requirements. Two more components provide recommendations and requirements on how to address and implement web accessibility in web development projects. Moreover, both of them support usable and accessible solutions by considering identified user requirements. The sixth component compromises a test strategy in order to evaluate accessibility during and after the development.

The design of the guide was only possible by dividing the research objective into detailed sub-research questions. These were then gradually addressed and processed using various research methods.

8.1.1 Underlying Research

A systematic literature review (chapter 2) and semi-structured interviews with experts in the field (chapter 3) have been carried out in order to explore the concept of web accessibility and answer the following sub-questions.

RQ1. What are the definitions of accessibility and usability and their relation?

It is required to define the term ‘accessibility’ in context of the web in order to shape a common understanding and be able to distinguish the concept from usability. Different definitions were

found in literature describing the equal and unlimited access to the web for people with disabilities or for all people with focus on impaired people. Others define the concept as the usability for people with disabilities. Latter can be neglected when considering the definition of usability as an attribute addressing the quality of use and accessibility as an attribute ensuring the equal access to the use of the web. Both concepts should go hand in hand. Experts pointed out that the definition of accessibility should not be limited to access alone but should rather be considered in a broader sense, ensuring the self-determined participation of people facing any kind of barriers. In addition, further research confirmed that accessibility concerns and benefits everybody but is essential to some.

RQ2. What are the guidelines and regulations for web accessibility?

The literature review resulted in an extensive list of laws, guidelines and checklists for web accessibility. The most mentioned one were the Web Content Accessibility Guidelines (WCAG 2.1) of the W3C, a set of technical criteria assigned to three conformance levels (A, AA, AAA), for the implementation of accessibility covering various disabilities. The review revealed that the majority of national laws refer to these guidelines which are acknowledged as international standard. The EU did the same and enacted a law that requires public authorities of member countries to meet at least the conformity levels A and AA of the WCAG 2.1 in web and mobile apps. The interviews confirmed that the WCAG are currently the most appropriate guidelines to follow, although they are not free from criticism. For instance, they are criticized for their limitation to objectively testable criteria and the focus on visual disabilities which result in a lack of coverage regarding the needs of people with cognitive and hearing impairments, in particular for level A and AA.

RQ3. What are the user requirements for accessibility in web applications?

This question aimed to explore the needs of end-users, with and without disabilities, and determine requirements for more accessible and usable user interfaces. The literature review delivered an extensive list of user requirements that were merged with the results of the interviews into one collection. The insights of the experts confirmed the requirements extracted from user studies. The essential aspects comprise criteria which improve the perception, comprehensibility and predictability of the content as well as the interaction with elements. Among others, these include a proper (HTML) structure and the use of semantics, simplicity, consistency and adaptability in terms of design and layout, the use of easy language as well as alternative and supplementary texts for non-text content. The use of assistive technologies, such as screen reader and keyboard navigation, needs to be ensured. While deciding about

design and layout choices, keeping the visual perception in mind, attention needs to be paid to rich color and contrast levels, clear fonts, text alignment, sufficient target sizes, font sizes and weights, word spacing and line height. Furthermore, novice, unfamiliar and cognitive impaired users benefit from labels, instructions, help or guidance, proper feedback to interactions, error prevention and the avoidance of information overload. The identified user requirements are diverse and numerous, but they support every user and provide essential access to people with disabilities who rely on them.

RQ4. What are the reasons that prevent practitioners from ensuring accessibility?

In order to address web accessibility, it is required to understand the reasons that prevent practitioners from considering this concept in the development of web and software products. Possible explanations involve the lack of awareness and understanding of accessibility, of the concerned user groups, their needs and the barriers they face. This may be because people with disabilities are viewed as a minority and people believe accessibility concerns only disabled people, resulting in the neglect of unfamiliar users, elderly, people with situational barriers, different cultural and language backgrounds and many more. In addition, the concept is hardly an issue in public discussions. Another reason and a consequence of the lack of awareness is the lack of professional knowledge on how to design and develop accessible user interfaces. This may also be caused by the fact that accessibility is not taught and integrated into the curricula of relevant study programs. Furthermore, practitioners associate accessibility with high financial and time expenditures. This may be the case but can be reduced or avoided if accessibility is considered from the beginning of a project in the product life cycle. Moreover, the lack of legal pressure in the past enabled actors to ignore accessibility. However, this might change in the future in terms of public sector bodies due to the latest changes in the legal framework in the EU and other countries.

8.1.2 Design and Development

Research questions 5 and 6 have been answered by incorporating the underlying research into design and development activities of the artifact.

RQ5. How can the WCAG be extended in order to make web content not only accessible but also more usable?

The criticism of the technical standard called for an inspection in detail. The comparison with identified user requirements revealed that the latter are mainly covered by the WCAG but nevertheless, some differences exist. Therefore, the list of WCAG criteria has been extended

with user requirements into a collection of accessibility requirements: 23 out of 78 criteria were expanded by additional details of the user requirements and seven user requirements have been newly added to the list of criteria, marked with the conformance level ‘UR’. This activity aimed to ensure more usable accessibility due to the consideration of user requirements extracted from user studies and expert interviews.

RQ6. How can web accessibility be addressed in development projects?

This question focused on the composition of gained information, accessibility requirements, and testing procedures in order to design a guide for implementing web accessibility. The guide consists of three layers and six components. The foundation layer provides fundamental knowledge about the concept, in particular its definition, user groups and needs as well as the legal framework. The second layer represents the implementation layer with general recommendations and accessibility requirements. Finally, the third layer (evaluation), which presents a test strategy with different test procedures. This guide should support practitioners in addressing the concept in web development projects by understanding, applying and assessing web accessibility.

8.1.3 Demonstration and Validation

The final question has been answered by demonstrating the proposed artifact in use and evaluating its design and application through a case study, user tests and interviews.

RQ7. Does the composed accessibility guide hold up in practice?

Several components of the guide, including the user groups, general recommendations, accessibility requirements and the test strategy, have been applied to a case study, a web application of CONET. Identified barriers have been resolved by implementing accessibility requirements. The final prototype has been evaluated in comparison to the original version through manual and automated test procedures as well as user testing. Three participants with different disabilities assessed the prototype as more accessible and its user experience as significantly better. However, it also became apparent that there is still further potential for improvement with regard to the detailed implementation of requirements as well as personal preferences. Although it is impossible to satisfy every user, the needs of many users can be addressed with a few changes. Clarity and structure as well as simplicity and adaptability proved to be extremely important.

Furthermore, the guide as a holistic approach has been evaluated through semi-structured interviews with four practitioners from CONET. All participants have been satisfied with the

proposed artifact in terms of structure, comprehensibility, completeness and usability. Suggestions for improvement included the assignment of requirements to the responsible functions, such as designer or developer, and the addition of an argumentation aid for client consultations. It has also been recommended to add more details and instructions to the component legends for the use of the guide. Nevertheless, the practitioners confirmed their intention to use the guide in the future and that it will help to establish accessibility in the organization, its projects and processes.

8.2 Contributions to Research, Practice and Teaching

This work was motivated by the industry need for addressing web accessibility in web development projects due to the latest changes in the legal framework of the EU and subsequently in the national laws of its member states concerning web and mobile applications of public sector bodies. Due to the complexity of the concept of web accessibility in terms of legal, technical and user-related requirements, a guide was needed which covers the topic in its entirety and supports practitioners in the implementation. With this goal in mind, several contributions have been made as a result of this work.

8.2.1 Research

The contributions to the research are manifold. First, the concepts of accessibility and usability have been defined and differentiated from each other. This lays the foundation for a more focused scientific discussion on accessibility. Other researchers are now provided with a deeper conceptual understanding of what accessibility includes and how it relates to seemingly similar non-functional requirements, such as usability. Secondly, current laws, leading guidelines and checklists for web accessibility have been ascertained which provide an overview of the state of the art in the field to researchers and practitioners. To the best of our knowledge, such a consolidation of the existing normative references has not been done before. Third, user requirements of end-users for accessible user interfaces, such as of people with different disabilities and elderly, are identified from user studies and expert interviews. They have been gathered in an extensive collection which may help to understand the needs of end-users better and to foster user-centered design approaches. Fourth, the international standard, the WCAG, has been reviewed and compared with the user requirements. The result is an extension of the standard, that can help in the implementation of accessibility but also shows potential for improvement of the WCAG. Especially with regard to the legal minimum, its limited focus on visual impairments and the neglect of other needs were highlighted. It may also help to develop future standards and best practices further. Finally, the proposed

accessibility guide brings together the single components that need to be considered for addressing web accessibility. It supports researchers in outlining the concept as a whole and increases the awareness and the understanding for accessibility. Single components can form the focus of further research, such as the elaboration of reasons that prevent the concept from becoming established in practice. This can provide a new starting point for researchers.

8.2.2 Practice

The contributions to practice comprise the accessibility guide, that supports organizations in establishing accessibility as a standard non-functional requirement in the design and development of web and software products. It may serve for the introduction and training of practitioners who are new to the topic or as a reference work for specialists.

Specifically, the component *user groups* increases the awareness and understanding for users who rely on the concept, the barriers they face and the needs they have. In addition, *general recommendations* support organizations in introducing accessibility in projects and processes by addressing the key issues of the concept. The extended list of *accessibility requirements* provides an overview of criteria that should or have to be considered. Moreover, the *test strategy* represents a procedure to assess the as-is or the practitioners' efforts in implementing accessibility. Finally, this work shows that accessibility does not need to result in plain design and limited functionalities but instead may improve the user experience of web applications.

8.2.3 Teaching

This thesis makes a contribution to the area of Requirements Engineering (RE) teaching. Existing Requirements Engineering textbooks used in universities (such as the one use at the University of Twente [82]) discuss well-established non-functional requirements that have a long history of being researches, for example usability, performance and reliability. Almost nothing has been reported in such textbooks about accessibility in general, and from the perspective of users with disabilities in particular. We consider the accessibility requirements reported in this thesis to possibly serve as a convenient starting point for RE teachers interested in teaching requirements as applicable to web and software development as well as assistive technologies. One of the supervisors serves as a RE teacher at the UT and found this thesis' work worthwhile considering for inclusion in RE teaching. Moreover, Computer Science and Information Technology students beyond those at the UT, who follow a Requirements Engineering course and consider a career in the field of web and software development or assistive technology, might consider the accessibility requirements and the accessibility guide as a starting point to inform themselves in this IT sub-field.

8.3 Limitations

Considering the design and execution of the empirical research in this thesis, several limitations in terms of validity and generalizability must be acknowledged.

An extensive systematic literature has been carried out in order to explore the underlying research of web accessibility. Although the search process has been documented in detail in order to ensure its repeatability to other researchers, several aspects limit the validity. Four scientific databases with relevance to software engineering were used to identify significant papers. However, other search engines might have delivered additional results. Moreover, several filters were applied, and the time range of publications was limited to the years of 2010 to 2020 in order to extract latest developments in the field. This also influenced the search results. In addition, the search strings evolved along the process involving the trial-and-error principle as well as a snowball search for obtaining the most relevant results and achieving completeness. The final selection of papers was made by the author which indicates the influence of a certain degree of bias. This has been addressed by the detailed documentation of the research process as well as the definition of inclusion and exclusion criteria. In addition, the results of the literature review have been followed up through the qualitative research conducted in form of semi-structured interviews with experts in the field of web accessibility.

The experts confirmed the literature results and provided additional insights. Although, the number of eight interviews limits the generalizability of the input. In addition, the contributions of the experts are drawn from their personal and professional experiences, opinions and specializations and thus influenced by bias. Therefore, explicit attention was paid to the selection of participants with the purpose of guaranteeing different backgrounds and expertise.

Furthermore, the guide and its components are based on literature and expert interviews. Consequently, their threats to validity have been transferred to the artifact. This concerns specifically the extension of the WCAG by relying on the international standard and expanding it with identified user requirements. The latter do not represent a comprehensive list of user requirements, but rather an excerpt only. This is because the needs of people with and without disabilities are dependent on individual abilities, knowledge and preferences and, in some cases, not sufficiently researched, such as cognitive impairments. Therefore, this collection is based on the existing user studies and expert experiences.

The proposed guide has been validated through user tests and semi-structured interviews. Both validation studies were conducted with a relatively small number of participants – three and four respectively. This number limits the generalizability of the guide. The three participants

of the user testing had different disabilities in order to evaluate various aspects of accessibility. However, this situation could have been influenced by bias because of personal experiences and abilities. Furthermore, the four participants of the validation interviews were all employees of CONET with limited expertise in accessibility, although attention was paid to involve persons with different levels of experience, from beginner to advanced knowledge. Therefore, more efforts should be made in evaluating the proposed guide, its components and effects. For this purpose, additional user testing could be carried out with a larger number of end-users with different disabilities and knowledge. In terms of interviews, experts in accessibility, such as developers, should be involved in further validation in order to review the guide on its practical contribution.

8.4 Future Research

The accessibility guide has been developed in the first iteration of the DSRM process model by Peffers et al. [1]. The next step should include further iterations in order to improve the guide and incorporate the suggestions for improvement obtained from the validation interviews. These are among others the development of an argumentation aid for client consulting on web accessibility as well as the addition of allocating requirements to the responsible functions, such as developer or designer. The latter supports the coordination of tasks in development projects. Another recommendation referred to the component legends and their extension by additional instructions in order to use the guide without the details of this report. In the course of further iterations, additional tests such as more case studies or user tests and interviews with a larger number of participants should be carried out in order to increase the validity and improve the generalizability of the conclusions.

Further research should also focus on the integration of web accessibility in organizational processes. The single components of the guide need to be incorporated into project management frameworks, such as the agile methodology Scrum, used in web or software development projects within organizations. General recommendations and accessibility requirements concern design and development activities, such as usability has been doing for years, as an established non-functional requirement. Moreover, test procedures for the evaluation of accessibility need to be part of the iterations, too.

As a main part of this work, the identification and analysis of user requirements revealed differences to the criteria of the international standard, the WCAG. The comparison showed that criteria of conformance level AAA reflect relevant requirements of users and that some are not included at all. In addition, experts and literature criticized the focus on visual impairments

due to the objective testability of respective criteria and the neglect of cognitive and hearing disabilities. Thus, future efforts should reassess the WCAG in regard to the defined legal minimum requirements and shift the focus of further research on additional user needs and new test strategies that go beyond objective testability or utilize new technologies such as artificial intelligence.

Finally, web accessibility should be established in public discussions and in the curricula of relevant study programs in order to address the lack of awareness, understanding and professional knowledge in the future.

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Appendix

Appendix A: User Groups and Disabilities, Barriers and Tools

Disability	People "without Disability"	People with Disability	Elderly	Examples of Barriers	Tools
Vision	Users who are driving or moving in the dark	Blindness – substantial, uncorrectable loss of vision in both eyes	Including reduced contrast sensitivity, color perception, and near-focus, making it difficult to read web pages	▪ Images, controls, and other structural elements that do not have equivalent text alternatives. ▪ Text, images, and page layouts that cannot be resized, or that lose information when resized. ▪ Missing visual and non-visual orientation cues, page structure, and other navigational aids. ▪ Video content that does not have text or audio alternatives, or an audio-description track. ▪ Inconsistent, unpredictable, and overly complicated navigation mechanisms and page functions. ▪ Text and images with insufficient contrast between foreground and background color combinations. ▪ Websites, web browsers, and authoring tools that do not support the use of custom color combinations. ▪ Websites, web browsers, and authoring tools that do not provide full keyboard support.	Keyboard or touch, screen reader, braille device, screen magnifier, increased text size, inverted colors, text-to-speech, modified contrasts, zooming tool or speech input, human assistance
Vision	Users who are using a device with a small display	Low vision – incl. poor acuity (vision that is not sharp), tunnel vision (seeing only the middle of the visual field), central field loss (seeing only the edges of the visual field), clouded vision			
Vision	Users who are using a device with small display and are exposed to sunlight	Color blindness – incl. difficulty distinguishing between colors (e.g. red and green, or yellow and blue) and sometimes inability to perceive any color			
Hearing	Users who are in silent environments (library) or using music players with headphones	Deafness – substantial, uncorrectable impairment of hearing in both ears	Incl. difficulty hearing higher-pitched sounds and separating sounds, making it difficult to hear podcasts and other audio, especially with background music	▪ Audio content, such as videos with voices and sounds, without captions or transcripts. ▪ Media players that do not display captions and that do not provide volume controls. ▪ Media players that do not provide options to adjust the text size and colors for captions. ▪ Web-based services, including web applications, that rely on interaction using voice only. ▪ Lack of sign language to supplement important information and text that is difficult to read.	Visual access to aural information, captioning + subtitles (speed issue); sign language translation, virtual characters to translate
Hearing	Users who are in noisy environments	Hard of hearing – mild or moderate hearing impairments in one or both ears			

Disability	People "without Disability"	People with Disability	Elderly	Examples of Barriers	Tools
Physical / Motor	Users who are on a moving and/or unstable vehicle, e.g. train, or Users who are wearing tight clothes, protective clothing, overalls, workwear, gloves	Motor impairments – weakness and limitations of muscular control (such as involuntary movements including tremors, lack of coordination, or paralysis), limitations of sensation, joint disorders (such as arthritis), pain that impedes movement, and missing limbs	Including reduced dexterity and fine motor control, making it difficult to use a mouse and click small targets	▪ Websites, web browsers, and authoring tools that do not provide full keyboard support. ▪ Insufficient time limits to respond or to complete tasks, such as to fill out online forms. ▪ Controls, including links with images of text, that do not have equivalent text alternatives. ▪ Missing visual and non-visual orientation cues, page structure, and other navigational aids. ▪ Inconsistent, unpredictable, and overly complicated navigation mechanisms and page functions.	Keyboard shortcuts, switch, gaze tracking, speech input. screen magnification to increase target sizes, personalization of keyboard and mouse configurations
Cognitive, learning, neuro-logical	Users who are tired, fatigued, sleepy, worried, distracted, drunk Users who lack knowledge of the language, dialects, symbols, culture, traditions	Users with limited abilities to process and memorize information, to learn, to perform intellectual tasks, to take decisions – e.g. language, learning and intellectual disabilities such as Aphasia, Dyslexia and Down Syndrome, Autism Spectrum Disorder	Including reduced short-term memory, difficulty concentrating, and being easily distracted, making it difficult to follow navigation and complete online tasks	▪ Complex navigation mechanisms and page layouts that are difficult to understand and use. ▪ Complex sentences that are difficult to read and unusual words that are difficult to understand. ▪ Long passages of text without images, graphs, or other illustrations to highlight the context. ▪ Moving, blinking, or flickering content, and background audio that cannot be turned off. ▪ Web browsers and media players that do not provide mechanisms to suppress animations and audio. ▪ Visual page designs that cannot be adapted using web browser controls or custom style sheets.	Text simplification (structure, grammar) > wider benefit to other web users like visual impaired people; Text layout and presentation to create readable web content

Table 30: User groups and disabilities, barriers and tools [2, 83, 84]

Appendix B: Papers Used in the Literature Review

P1	S. Abou-Zahra, "WAI-ACT: Web accessibility now," in WWW'12 - Proceedings of the 21st Annual Conference on World Wide Web Companion, 2012, pp. 215-218, doi: 10.1145/2187980.2188012. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84861085166&doi=10.1145%2f2187980.2188012&partnerID=40&md5=f67b38df8f8c6b8bbe5f8ab6cf4f477e
P2	G. Anand, S. Geethamsi, R. V. R. Chary, and C. Madhu Babu, "Email access by visually impaired," in Proceedings - 2013 International Conference on Communication Systems and Network Technologies, CSNT 2013, 2013, pp. 597-601, doi: 10.1109/CSNT.2013.128. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84880894191&doi=10.1109%2fCSNT.2013.128&partnerID=40&md5=4d35c9ca10b0c3f7d3a4d897b880b881
P3	M. Anjos et al. How to overcome the challenges of developing responsive and accessible websites – a case study, Advances in Intelligent Systems and Computing, vol. 972, pp. 260-270, 2020.
P4	H. L. Antonelli, R. A. Igawa, R. Pontin, M. Fortes, E. H. Rizo, and W. M. Watanabe, "Drop-down menuwidget identification using HTML structure changes classification," ACM Transactions on Accessible Computing, Article vol. 11, no. 2, 2018, Art no. 3178854, doi: 10.1145/3178854.
P5	H. L. Antonelli, S. S. Rodrigues, W. M. Watanabe, and R. P. De Mattos Fortes, "A survey on accessibility awareness of brazilian web developers," in ACM International Conference Proceeding Series, 2018, pp. 71-79, doi: 10.1145/3218585.3218598. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85061404714&doi=10.1145%2f3218585.3218598&partnerID=40&md5=2599608f87cfb7d8515c9739f8b211bf
P6	L. O. d. Avelar, G. C. Rezende, and A. P. Freire, "WebHelpDyslexia: A Browser Extension to Adapt Web Content for People with Dyslexia," Procedia Computer Science, vol. 67, pp. 150-159, 2015/01/01/ 2015, doi: https://doi.org/10.1016/j.procs.2015.09.259.
P7	F. A. Aziz, H. Husni, and Z. Jamaludin, "Translating interaction design guidelines for dyslexic children's reading application," in Lecture Notes in Engineering and Computer Science, 2013, vol. 2 LNECS, pp. 977-980. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84887968308&partnerID=40&md5=69fdf1074ce7add1f9785f190898cc9d. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84887968308&partnerID=40&md5=69fdf1074ce7add1f9785f190898cc9d
P8	I. S. Baazeem and H. S. Al-Khalifa, "Advancements in web accessibility evaluation methods: How far are we?," in 17th International Conference on Information Integration and Web-Based Applications and Services, iiWAS 2015 - Proceedings, 2015, doi: 10.1145/2837185.2843850. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84967016903&doi=10.1145%2f2837185.2843850&partnerID=40&md5=aa3256079088cf039e2c1a47a67a66d6
P9	I. Basdekis, I. Klironomos, I. Metaxas, and C. Stephanidis, "An overview of web accessibility in Greece: A comparative study 2004-2008," Universal Access in the Information Society, Article vol. 9, no. 2, pp. 185-190, 2010, doi: 10.1007/s10209-009-0166-z.
P10	J. L. Bele, D. Bele, S. Hauptman, I. Kožuh, and M. Debevc, "eCampus as a platform for ubiquitous learning," in 2014 IEEE Global Engineering Education Conference (EDUCON), 3-5 April 2014 2014, pp. 1-7, doi: 10.1109/EDUCON.2014.7130486.
P11	T. J. Bittar, L. A. Do Amaral, F. B. Faria, and R. P. De Mattos Fortes, "Supporting the developer in an accessible edition of web communications: A study of five desktop tools," in ACM International Conference Proceeding Series, 2012, pp. 3-9, doi: 10.1145/2311917.2311919. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84864029122&doi=10.1145%2f2311917.2311919&partnerID=40&md5=c0df528676390caebc0828a93209d52d

P12	T. J. Bittar, L. A. Do Amaral, and R. P. D. M. Fortes, "AccessibilityUtil: A tool for sharing experiences about accessibility of web artifacts," in SIGDOC'11 - Proceedings of the 29th ACM International Conference on Design of Communication, 2011, pp. 17-24, doi: 10.1145/2038476.2038480. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-80054782035&doi=10.1145%2f2038476.2038480&partnerID=40&md5=c4e12f6e50a6afd57eb95e211332bb71
P13	A. Bocevska, S. Savoska, B. Ristevski, N. Blazheska-Tabakovska, and I. Nedelkovski, "A comparison of accessible e-learning projects for improving of digital health literacy," in CEUR Workshop Proceedings, 2019, vol. 2464. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85073514638&partnerID=40&md5=922348a022363ba714c4815ccbf5407f. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85073514638&partnerID=40&md5=922348a022363ba714c4815ccbf5407f
P14	M. C. Buzzi, M. Buzzi, E. Perrone, and C. Senette, "Personalized technology-enhanced training for people with cognitive impairment," Universal Access in the Information Society, Article vol. 18, no. 4, pp. 891-907, 2019, doi: 10.1007/s10209-018-0619-3.
P15	J. O. Connor. User testing of google reader and RIA complexity - A warning, Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), vol. 6179 LNCS, pp. 444-448, 2010.
P16	D. Costa and C. Duarte, "Visually impaired people and the emerging connected TV: a comparative study of TV and Web applications' accessibility," Universal Access in the Information Society, Article vol. 16, no. 1, pp. 197-214, 2017, doi: 10.1007/s10209-016-0451-6.
P17	R. G. Crespo, J. P. Espada, and D. Burgos, "Social4all: Definition of specific adaptations in Web applications to improve accessibility," Computer Standards & Interfaces, vol. 48, pp. 1-9, 2016/11/01/ 2016, doi: https://doi.org/10.1016/j.csi.2016.04.001.
P18	A. Darejeh and D. Singh, "A review on user interface design principles to increase software usability for users with less computer literacy," Journal of Computer Science, Article vol. 9, no. 11, pp. 1443-1450, 2013, doi: 10.3844/jcssp.2013.1443.1450.
P19	A. Darvishy, H. P. Hutter, and O. Mannhart. Web application for analysis, manipulation and generation of accessible PDF documents, Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), vol. 6768 LNCS, pp. 121-128, 2011.
P20	S. M. A. de Lara, R. P. M. Fortes, C. M. Russo, and A. P. Freire, "A study on the acceptance of website interaction aids by older adults," Universal Access in the Information Society, Article vol. 15, no. 3, pp. 445-460, 2016, doi: 10.1007/s10209-015-0419-y.
P21	R. C. De Oliveira, A. P. Freire, D. M. B. Paiva, M. I. Cagnin, and H. Rubinsztejn. A framework to facilitate the implementation of technical aspects of web accessibility, Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), vol. 8516 LNCS, pp. 3-13, 2014.
P22	J. Dekelver, M. Kultsova, O. Shabalina, J. Borblik, A. Pidoprigora, and R. Romanenko. Design of mobile applications for people with intellectual disabilities, Communications in Computer and Information Science, vol. 535, pp. 823-836, 2015.
P23	A. L. Dias, R. P. D. M. Fortes, and P. C. Masiero, "Increasing the quality of web systems: By inserting requirements of accessibility and usability," in Proceedings - 2012 8th International Conference on the Quality of Information and Communications Technology, QUATIC 2012, 2012, pp. 224-229, doi: 10.1109/QUATIC.2012.33. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84878860324&doi=10.1109%2fQUATIC.2012.33&partnerID=40&md5=5e4c3ef2c7f9b2f099912ffefc7351da
P24	A. L. Dias, R. P. D. M. Fortes, P. C. Masiero, W. M. Watanabe, and M. E. Ramos, "An approach to improve the accessibility and usability of existing web system," in SIGDOC 2013 - Proceedings of the 31st ACM International Conference on Design of Communication, 2013, pp. 39-48, doi: 10.1145/2507065.2507074. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84887284763&doi=10.1145%2f2507065.2507074&partnerID=40&md5=598e6712ab628ba3224bb806bc53fd3e

P25	L. Doblies, D. Stolz, A. Darvishy, and H. P. Hutter. PAVE: A web application to identify and correct accessibility problems in PDF documents, Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), vol. 8547 LNCS, pp. 185-192, 2014.
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P27	M. Elias, S. Lohmann, and S. Auer. Fostering accessibility of OpenCourseWare with semantic technologies – A literature review, Communications in Computer and Information Science, vol. 649, pp. 241-256, 2016.
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P29	G. Farrelly, "Practitioner barriers to diffusion and implementation of web accessibility," Technology and Disability, Article vol. 23, no. 4, pp. 223-232, 2011, doi: 10.3233/TAD-2011-0329.
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P60	S. S. Rodrigues, P. E. Scuracchio, and R. P. d. M. Fortes, A support to evaluate web accessibility and usability issues for older adults (Proceedings of the 8th International Conference on Software Development and Technologies for Enhancing Accessibility and Fighting Info-exclusion). Thessaloniki, Greece: Association for Computing Machinery, 2018, pp. 97–103.
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P72	T. Watanabe, "International and national standard harmonization and achievement effort of web accessibility in Japan," SIGACCESS Access. Comput., no. 104, pp. 30–42, 2012, doi: 10.1145/2388818.2388821.
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P76	Y. Yesilada, G. Brajnik, M. Vigo, and S. Harper, "Understanding web accessibility and its drivers," in W4A 2012 - International Cross-Disciplinary Conference on Web Accessibility, 2012, doi: 10.1145/2207016.2207027. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84860994975&doi=10.1145%2f2207016.2207027&partnerID=40&md5=64b5c2bec500e38b767f2718554b7335
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P78	S. A. Youngblood, "Communicating Web Accessibility to the Novice Developer: From User Experience to Application," Journal of Business and Technical Communication, Article vol. 27, no. 2, pp. 209-232, 2013, doi: 10.1177/1050651912458924.
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P82	E. Zitkus et al. Accessibility and usability of websites intended for people with disabilities: A preliminary study, Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), vol. 9747, pp. 678-688, 2016.

Table 31: Papers used in the literature review

Appendix C: Quality Assessment of Selected Papers

Paper	Q1	Q2	Q3	Q4	Q-Count	Sum	Score [%]
P1		0.5		1.0	2	1.5	75
P2			1.0	0.5	2	1.5	75
P3		1.0	1.0	1.0	3	3.0	100
P4		1.0		1.0	2	2.0	100
P5	0.5			1.0	2	1.5	75
P6			1.0	1.0	2	2.0	100
P7			1.0	1.0	2	2.0	100
P8		1.0		1.0	2	2.0	100
P9		0.5		1.0	2	1.5	75
P10	1.0			1.0	2	2.0	100
P11		1.0		1.0	2	2.0	100
P12		1.0		1.0	2	2.0	100
P13		1.0		1.0	2	2.0	100
P14			1.0	1.0	2	2.0	100
P15		0.5		1.0	2	1.5	75
P16		1.0		1.0	2	2.0	100
P17		1.0		0	2	1.0	50
P18			1.0	1.0	2	2.0	100
P19		1.0		0	2	1.0	50
P20	0.5		1.0	1.0	3	2.5	83
P21		1.0		1.0	2	2.0	100
P22			1.0	0.5	2	1.5	75
P23	1.0	1.0	1.0	0.5	4	3.5	88
P24	0.5			1.0	2	1.5	75
P25		1.0		0.5	2	1.5	75
P26		1.0		1.0	2	2.0	100
P27	0.5	1.0		0.5	3	2.0	67
P28	1.0			1.0	2	2.0	100
P29		1.0		1.0	2	2.0	100
P30		1.0		1.0	2	2.0	100
P31	1.0		1.0	1.0	3	3.0	100
P32		1.0		1.0	2	2.0	100
P33		1.0		0.5	2	1.5	75
P34		1.0		1.0	2	2.0	100
P35		1.0		1.0	2	2.0	100
P36			1.0	1.0	2	2.0	100
P37	0.5	0.5		1.0	3	2.0	67
P38		0.5		1.0	2	1.5	75
P39			1.0	1.0	2	2.0	100
P40	0.5	0.5		1.0	3	2.0	67
P41	1.0	0.5		1.0	3	2.5	83

Paper	Q1	Q2	Q3	Q4	Q-Count	Sum	Score [%]
P42		1.0		1.0	2	2.0	100
P43			1.0	1.0	2	2.0	100
P44	1.0	1.0		0.5	3	2.5	83
P45			1.0	1.0	2	2.0	100
P46		1.0		1.0	2	2.0	100
P47	0.5			0.5	2	1.0	50
P48		1.0		0	2	1.0	50
P49			1.0	0.5	2	1.5	75
P50		1.0		1.0	2	2.0	100
P51			1.0	0	2	1.0	50
P52			1.0	0.5	2	1.5	75
P53			1.0	1.0	2	2.0	100
P54	0.5			0.5	2	1.0	50
P55		1.0		0	2	1.0	50
P56			1.0	1.0	2	2.0	100
P57			1.0	1.0	2	2.0	100
P58			1.0	0	2	1.0	50
P59			1.0	0.5	2	1.5	75
P60			1.0	0.5	2	1.5	75
P61			1.0	0.5	2	1.5	75
P62		1.0		1.0	2	2.0	100
P63		1.0	1.0	1.0	3	3.0	100
P64		1.0		1.0	2	2.0	100
P65			1.0	0	2	1.0	50
P66	1.0			1.0	2	2.0	100
P67		1.0		1.0	2	2.0	100
P68		1.0		1.0	2	2.0	100
P69		1.0		0	2	1.0	50
P70			1.0	1.0	2	2.0	100
P71		1.0		0	2	1.0	50
P72		1.0		0	2	1.0	50
P73		1.0		0.5	2	1.5	75
P74			1.0	1.0	2	2.0	100
P75			1.0	1.0	2	2.0	100
P76	0.5			1.0	2	1.5	75
P77	1.0			1.0	2	2.0	100
P78	1.0	1.0		0	3	2.0	67
P79		1.0		0	2	1.0	50
P80			1.0	0.5	2	1.5	75
P81			1.0	0	2	1.0	50
P82	1.0		1.0	1.0	3	3.0	100

Table 32: Quality assessment of selected papers

Appendix D: Interview Guide (Experts)

This set of questions was used to guide the course of the interviews to the main topics as the definition of web accessibility, personal experiences and opinions, legal obligations, the WCAG, user requirements and accessibility evaluation. Depending on the individual conversations, the questions or the order, in which they were raised, were adjusted as necessary.

1) Please introduce yourself briefly.
2) What does web accessibility mean to you? How would you define web accessibility?
3) According to the information on your website, you yourself have gone blind. How do you act on the internet and which tools do you use? Please describe your interaction with and use of web applications on a desktop computer and on mobile devices!
4) What are your personal experiences with accessible or inaccessible web content?
5) Accessibility of information technology is not a new topic. The BITV has been demanding its implementation by public authorities for years. How do you estimate the current degree of implementation of accessibility for web applications / websites of public authorities?
6) How do you assess the legal situation regarding the introduced regulations EN 310 549, the amendment of BITV 2.0 and WCAG 2.1 in order to improve accessibility?
7) As an accessibility consultant/developer, you also test websites for compliance on the WCAG. What are the biggest issues or rather, what criteria do you see the most problems with regarding their implementation?
8) Conformance level AA of the WCAG is the minimum requirement under BITV 2.0. Do you consider level AA compliant design to be (sufficiently) accessible?
9) How do you rate level AAA, does it contribute to more accessibility and usability?
10) If this is not the case, which additional aspects should be considered to ensure accessibility from the user's point of view in the web application? (your personal and professional experience)
11) In your opinion, what other requirements need to be considered to make web applications not only accessible but also more usable for end-users?
12) Which methods and software tools do you think are best suited for testing accessibility?
13) What other tips, tricks or best practices are there for implementing accessibility?

Appendix E: Summaries of Expert Interviews

Expert 1

The participant E1 works as front- and backend developer for web and software projects. The participant has more than 20 years for work experience in this field. However, E1 has no practical experience with web accessibility and has just started to learn about the topic: The participant understands the concept of web accessibility as an attribute that gives access to web content for people with any kind of impairment in order to read, work or just interact. E1 sees several reasons why web content is mainly inaccessible. First, responsible parties like clients / owners of web content do not know what accessibility means and what is legally required. In addition, E1 believes that the implementation takes a lot of efforts and re-launches may be necessary in some cases, but clients are not willing to pay for additional efforts. Two other reasons, that E1 explained, are that people with disabilities represent a minority and it is difficult to fully understand the needs of blind people or anyone with disabilities. Although, as a developer it is essential to be sensitized to understand the user needs.

In general, the participant is aware about the legal obligations in the EU and in Germany, but lacks detailed knowledge, such as deadlines. E1 sees issues in missing German translations of the international standard WCAG.

E1 mentioned several accessibility requirements, such as avoiding tables if possible, using a simple navigation and layout, leaving out unnecessary clutter, using easy language, choosing correct colors and contrasts, avoiding flashing, checking keyboard and focus management as well as adding alt texts for images, graphs and tables.

Regarding evaluation, E1 suggests using supportive tools, like browser extensions, but he/she admits that tools are not sufficient. It is necessary to test by yourself, e.g. with screen reader, look at images from distance, decrease sizes, check tab navigation. Then one should test with real end-users.

In summary, E1 suggested to follow guidelines to guide the way along the implementation and to avoid frames because they are inaccessible. The participant thought it is helpful to know that criteria cover several needs of different disabilities and to have samples of accessible web apps as role models.

Expert 2

The participant E2 has been a front- and backend developer for more than 30 years with first experience with web accessibility in 2003. E2 also trained colleagues and clients on the topic

and worked on an accessibility project in 2017. The participant defines accessibility as access to web content for people with disabilities. He/she acknowledges the importance of the concept but stresses that clients only care about the topic if it is mandatory by law. E2 also admits the high effort during development and points out that costs are too high, and that accessibility has not yet been recognized as standard attribute like usability or performance.

E2 is familiar with legal obligation and views them as good but doubts that it is realistic to make all existing software and content accessible. In terms of the WCAG, the participant expresses the focus on visual disabilities and the fact that not all disabilities are covered properly. According to E2, the WCAG as of version 2.0 are also vaguer than 1.0 because they are intended to be neutral regarding technologies.

As requirements for accessibility, E2 mentioned skip links, the importance of sign language and easy language, alternative texts, keyboard navigation and focus management, language tag, to avoid flashes and to utilize ARIA if necessary.

The participant suggested to test accessibility manually by following a test guide such as the German BIK/BITV test or the WCAG-test in order to comply with the standard criteria.

In general, E2 points out to consider accessibility from the start of a project and to approach real end-users for support. In terms of consultants, he/she suggested for them to get awareness and understanding of the concept, to check if a re-launch or new development is necessary and to be very cautious about a general requirement saying only that the product has to be accessible. This must be clarified and defined in detail to avoid misunderstandings.

Expert 3

The participant E3 is blind and has gained professional experience as accessibility consultant and tester for more than 18 years. E3 has written books and blog posts about the topic. He/she defines the term mainly in regards of audits and evaluations with the conformance of required standards as the WCAG 2.1. E3 points out that accessibility compliance is more important than ‘nice to have’-elements in web content. As tools, the participant uses screen reader and keyboard only. If the usage or interaction is not possible due to inaccessible elements, E3 refuses to try any further. This experience can be very frustrating. Web content always has issues, such as a missing structure and problematic dynamic elements, because accessibility has not been taken seriously for now. According to E2, other reasons for inaccessible content are a too small target group, missing knowledge of developers how to code accessible websites, partly missing awareness and understanding of responsible people in software projects, low budgets and that accessibility is often considered too late during projects.

However, E3 perceives the latest legal obligations as positive change that creates more pressure and that the concept is taken more seriously. Still, the participant considers the goals and deadlines as not realistic.

E3 criticizes the focus of the WCAG on visual impairments and the lack of coverage for other disabilities such as hearing, cognitive and learning, but he/she also points out that the criteria for keyboard navigation also supports motor impairments. E3 explains the focus by the need for objective testability of criteria for measuring the conformance. In addition, the participant discussed some criteria and their interpretations and stressed that level AAA would not represent the highest level of accessibility. It would only be the tip of the iceberg, but better solutions need to be found for more usable accessibility.

In general, E3 recommended to start with standard conformance by ensuring a proper structure, semantic annotations and keyboard navigation. Furthermore, dynamic widgets should be avoided, unless they are fully accessible, and easy language should be applied. E3 highlighted to focus also on adaptability.

In terms of evaluation, E3 suggested to check the DOM, review code and test with screen reader and keyboard. He/she also referred to the accessibility toolbar in web browsers and assistive extensions.

All in all, E3 recommended to think about target users, their needs and interaction behaviors from the start of a project. Another important topic concerns PDF which need to be accessible, because they represent a source for many barriers.

Expert 4

The participant E4 is a web developer for a federal agency, a book author and a consultant for web accessibility with almost 20 years of professional experience. According to his/her understanding, accessibility is about self-determined participation. It enables people to make their own decisions and includes people in society and work life by eliminating barriers. E4 highlights the need to comply with accessibility standards and to meet the needs of the end-users, but 95 - 98 % of web content is not fully accessible, as per WCAG definition. This does not mean that people with disabilities cannot make use of the content but that it is exhausting and frustrating to deal with non-usable workarounds.

E4 blames a lack of legal pressure and control mechanisms for public sector bodies as well as the absence of obligations for privately-owned companies. Other reasons are the fact that users

who benefit the most from accessibility represent minorities and due to a lack of awareness, many people do not understand the added value it brings for everybody.

The participant considers the latest legal regulations, introduced by the EU and Germany, as important for increasing awareness and forcing the implementation of accessibility, but also questions whether sanctioning is possible in order to create more pressure.

E4 acknowledges the difficulty of defining a standard that addresses all disabilities and accompanying needs. A compromise must be found that will help everyone. The WCAG are well documented and provide lots of supporting material. But E4 also criticizes that the minimum level does not meet the needs of all, especially people with hearing and cognitive disabilities are left alone. Whereas visually impaired people can use AA-compliant web content well. The participant also stresses that people who require rely on sign language, should rather be supported to learn written language or get human assistance than translating all websites into sign language.

Moreover, E4 highlights the need for adaptable content that allows customization by browser functionalities. Also, easy language is essential for some and useful for all. Other suggestions included to supplement icons with captions and vice versa, to create a proper heading concept, to provide higher contrasts and bigger sizes of elements and also to find a compromise between design and functionality, that results in one adaptable version for all.

In terms of evaluation, E4 suggests testing accessibility manually, by using screen reader, keyboard and supportive browser tools. Test guides like BIK/BITV can be a helpful guidance to know what and why elements are being tested. In addition, the participant stresses that mere conformance with criteria is not enough, but scenario-based user tests can help to make content more accessible.

In summary, E4 recommends considering accessibility as early as possible and to focus on creating additional value for all users. He/she suggests putting yourself in the other person's shows and always work with the good intention to enable people with disabilities to access web content.

Expert 5

The participant E5 is blind and works as consultant for web accessibility for more than ten years. Before learning about the concept of accessibility, E5 focused on the mere possibility to use web content as a blind person. Nowadays, he/she considers the concept as wider and more essential. It is about ensuring the self-determined participation in digital technologies, the

possibility to gain information, to communicate in the modern world, to perceive digital opportunities and to handle personal matters, from online shopping to financial transactions.

E5 relies on the usage of a screen reader and the keyboard. If content is not fully accessible, the participant uses the reader mode of a browser to remove unnecessary clutter and decorations and he/she prefers native apps over web app, because they are simpler in terms of navigation and layout. Reasons for inaccessible web content are among others the lack of awareness and understanding of accessibility and user needs, the lack of knowledge how to make documents and websites accessible, the lack of motivation to deal with the topic, missing German translations of guidelines and supportive documents as well as a limited budget for getting external support. Additionally, the market is not big enough because only a part of the ten million people with disabilities in Germany really rely on web accessibility.

In terms of legal obligations, E5 considers the latest changes as necessary update and as an improvement that the EU focuses on fostering an international standard by referring to the WCAG. Regarding the guidelines, E5 confirms that they are more technical and the criteria need to be testable. Therefore, their focus is on visual rather than cognitive user need. However, the participant criticizes that simplicity of user interfaces, hearing as well as cognitive user requirements are not sufficiently addressed. Especially simplicity is beneficial for every user, same applies to easy language. E5 also suggests ensuring a proper structure, adaptable design choices, standardized keyboard shortcuts, a properly implemented search function, transcripts for audio and video and a time-out option to avoid stress during interactions.

The participant relies on code reviews and scenario-based test procedures that include manual testing with assistive technologies as well as user tests.

All in all, E5 recommends implementing only one version for all users that is characterized by being adaptable for specific user needs, simple in terms of navigation and layout and clear due to a proper structure.

Expert 6

The participant E6 is a web developer and founder of an advertising and web design agency. In 2012, E6 started to work with accessibility and since then has become an active member of the community. Growing demands for consulting and testing of accessibility has shifted his/her focus more and more to web accessibility. E6 understands the concept as ensuring that online content is comfortably usable and accessible for all, not only for people without disabilities and not only for people with disabilities. It should be an equal experience for all with the intention to integrate as many as possible.

According to the expert's opinion, there are no fully accessible websites. This is because of several reasons: Among others, accessibility is still a niche topic and there are just a few specialists in Germany and knowledge is lacking among most designers and developers. Consequently, developers build barriers into the source code in order to make content more dynamic, although HTML by nature is accessible. Moreover, the awareness and understanding for the concept is insufficient and because budgets are low, accessibility is mostly off topic.

As the other experts, E6 considers the latest legal changes as positive updates for creating more pressure by law. The obligation to denouncing oneself publicly in the accessibility statement forces public sector bodies to continuously improve their web content towards fully accessible user interfaces. Furthermore, E6 described the WCAG as the best standard that is available for now. Although they are not sufficient for everybody and all user needs, the intention of the WCAG is to provide a standard that is objectively testable. In addition to that, E6 stressed to shift focus on cognitive impairments and the needs of people who are limited in their ability to process, abstract or remember information, no matter how difficult or subjective the requirements are.

E6 recommended to focus on users' needs and interaction strategies to fully understand their requirements. An essential demand is to allow as much adaptability as possible, preferably by browsers but also by website features. Moreover, E6 warned about accessibility overlays, that are small software tools to be implemented in websites, promise to make pages accessible, but it is only possible to maybe solve little issues, like contrasts. Also overlays need to be accessible in the first place to allow their usage, but it is difficult to test whether the website or overlay causes problems, because no standardized way to deal with it. E6 pointed out that it would be essential that providers such as WordPress should deliver accessible products in order to make the majority of websites accessible.

In terms of evaluation, E6 suggested to test manually with screen reader and keyboard, following test guides such as the German BIK/BITV-test, but also to utilize software tools that detect accessibility flaws.

Expert 7

The participant E7 is a certified translator for easy language with a focus on text content but on request also on web content. According to E7, information should be accessible for most people, ideally for everyone.

As an expert in easy language, the participant takes a critical view of the current legal obligations, because easy language is underrepresented in laws and more needs to be done.

Currently, it is only included in the complementary part of the WCAG (level AAA). In Germany, an additional requirement has been introduced to provide essential content, navigation and summaries in easy language.

For implementing easy language, E7 recommended to follow guidelines which explain how to translate content into an easier wording. In general, it is his/her opinion that everyone benefits from a less complicated language. But in terms of translations into easy language as per definitions, E7 suggested to provide a second version of the web content in addition to the original version. It should be a summary rather than a one to one translation. This offers users to choose what is needed.

Regarding evaluations, E7 explained that easy language always needs to be tested by experts and ideally by real end-users with cognitive disabilities, such as learning disabilities. But in future, new automated tools might support the evaluation by counting word. However, these require testable criteria which are difficult to define for easy language.

Expert 8

The participant E8 is blind and is a specialist for web accessibility in a public authority in Germany. According to his/her understanding, accessibility enables people with disabilities to operate something without human assistance or without enormous efforts, especially in terms of participating in life and society. Therefore, content needs to be perceivable, operable, understandable and robust. E8 considers accessibility and usability as different concepts which intersect partially.

The participant relies on the usage of screen reader and keyboard or preferably touch screens. According to his/her experience, there are no fully accessible user interfaces and native apps are more accessible than web apps, but the WCAG set a high standard. Reasons why content is not accessible range from the lack of awareness and knowledge, because accessibility is not taught at schools and universities, the accompanying efforts regarding time and costs and the absence of sanctioning.

The latest legal changes are considered as an improvement compared to previous regulations, especially because the German regulation BITV sets a higher standard than the EU does. However, E8 estimates the deadlines for implementing accessibility as not realistic and criticizes that there is still no option to sanction parties that do not comply with standards.

Furthermore, the participant considers the WCAG as high standard but has a critical view on the insufficient coverage of hearing and cognitive user needs. At the same time, E8 admits how

difficult it is to include and regulate criteria for language and content, that are objective but not up to any interpretations. In general, he/she has the opinion that deaf people should be supported in learning written language rather than translating all content into sign language. Moreover, E9 suggested to make user of new technologies, such as avatars for sign language.

In terms of evaluation, E8 recommended a combination of different test procedures. The advice included automated tools, manual testing guided by instructed tests and user tests with real end-users.

All in all, E8 highlighted to consider accessibility from the start of a project and to focus on essential tasks, functions and user needs, such as PDF.

Appendix F: User Requirements

UR#	Implementation Requirements	Details	General	Vision	Hearing	Motor	Cognition	Elderly	SLR #	Int. #
1	Ensuring proper (HTML) structure for better predictability of content	Using HTML elements correctly for a proper structure that can be identified by screen readers and keyboard use; Marking areas by the use of appropriate elements (e.g. nav, main, footer or tags like h, p, list, etc.); Using linearly design and structure; Assigning a clear title for every page; Applying a clear heading concept (h1-h6) for structure, using CSS for styling	X	X		X	X	X	16, 22, 40	1
2	Ensuring proper semantics for better comprehensibility of content	Using HTML semantics correctly that can be identified by screen readers and keyboard use; Using language tags for identification of language; Enabling identification of elements, fields, etc.; Labeling name, role and values of elements	X	X			X	X	12, 16, 21	1
3	Applying simplicity to design and development	Designing a clear layout; applying minimalist and consistent design	X	X	X	X	X	X	4, 5, 11, 17, 32, 39	2
4	Allowing adaptability / customization of content and design to meet diverse user needs	Such as adjustments for font type, sizes of font and buttons, font colors, background colors and contrasts or text alignment; Ensuring that adjustments do not cover or misalign other content; Applying responsive design	X	X		X	X	X	1, 2, 7, 8, 23, 26, 27, 30, 31	3

UR#	Implementation Requirements	Details	General	Vision	Hearing	Motor	Cognition	Elderly	SLR #	Int. #
5	Applying principles of easy language	Using standard abbreviations and consistent labels; Explaining unusual words, symbols and abbreviations in a glossary; Proving an additional version of the original content, translated into a simplified language for people with cognitive disabilities and non-native speakers	X	X	X		X	X	3	4
6	Providing sign language	At least for essential content, in form of videos			X				35	5
7	Alternative or supplementary text for visual and audio (non-text) content	Using headings, subtitles, transcripts or semantic annotations of images, icons, tables, graphs, multimedia, etc.; Ensuring to convey proper meaning of visual or auditory content (illustrative, sensory, informative); Supplementing symbols with labels to improve general comprehensibility	X	X	X		X	X	9	6
8	Ensuring use of keyboard	Ensuring all elements are operable (with a few keys), not only by mouse; Web pages should not have programmatic events dependent on a click or mouse movement	X	X		X		X	6	7
9	Managing focus	Ensuring a proper focus management and logical focus order; Ensuring user can control new pop-up window > focus given to the active window	X	X		X		X	19	7
10	Enabling shortcuts	Enabling standardized shortcuts; Enabling users to set their preferences to configure keyboard shortcuts	X	X				X	15	7
11	Providing skip links	For easier navigation by user of screen reader in order to bypass blocks	X	X				X	15	8
12	Providing proper key word search	Ensuring search results are embedded into HTML for screen reader; Supporting navigation through search	X	X	X	X	X	X	4, 25	9
13	Selecting correct choice of colors, not used as only visual means for conveying meanings	Not using only color for conveying meaning; When links are underlined (or otherwise differentiated) as well as colored, this ensures that color blind users will be able to notice them	X	X			X	X	2	10
14	Selecting sufficient contrasts	For text and background colors	X	X		X	X	X	7	10

UR#	Implementation Requirements	Details	General	Vision	Hearing	Motor	Cognition	Elderly	SLR #	Int. #
15	Choosing plain sans serif font	Such as Arial, Comic Sans, Verdana, Tahoma, Century Gothic, Trebuchet, Helvetica, dan Sassoon; Avoiding text decorations, such as italics, bold and underlining; Avoiding text in block capitals > using boxes for effective emphasis; Avoiding use of animated text		X			X	X	26, 27	/
16	Choosing large size of fonts	Using font size of 12-14 point or 14+; Use actual text instead text in graphics; Using larger font size in bold, lower case for headings	X	X			X	X	1	11
17	Choosing bigger size and further distance of clickable / input elements	Supporting use of pointing devices, esp. for motor impaired people; Using minimum size of 44 pixels	X	X		X	X	X	8	12
18	Avoiding tables	If required anyways, applying proper HTML elements and semantics; Tables should not be nested; Tables should be understandable when read sequentially		X		X			34	13
19	Avoiding flashing	Or make them optional	X	X			X		37	14
20	Avoiding time-outs	Or inform end-users about time-out, especially visually impaired users; Offering extended or customizable version of time-out		X		X	X	X	28	15
21	Making links understandable	Providing proper identification of links and their actions; Using link texts in context or assigning speaking link text, avoiding ‘click here’, ‘next’, ‘more’		X			X	X	21	16
22	Avoiding dynamic widgets	Ensuring proper execution of functions by additional use of ARIA; Avoiding errors of interaction; Dropdown menu appears as single button to screen reader, inaccessible		X		X	X	X	24	17
23	Avoiding accessibility overlays	Ensuring accessible interaction of overlays themselves, if still used	X	X		X			/	18

UR#	Implementation Requirements	Details	General	Vision	Hearing	Motor	Cognition	Elderly	SLR #	Int. #
24	Ensuring accessibility of embedded documents	Following PDF-UA or Matterhorn-Protocol; MS Word: Using style templates, alt texts, captions, table formats, “save as”-button (avoiding “print as PDF”); Adobe: complicated to ensure accessibility, training required	X	X					38	19
25	Providing control elements	Such as for speed, volume, pitch, play, replay, stop, etc.; Supporting user control freedom	X	X	X	X	X	X	10	/
26	Providing user guidance	Fill out forms: must be indicated which forms to fill, mandatory, what kind of data > color formatting > alternative: asterisk > by a letter; Voice indication to be provided to explain what needs to be done > screen reader only "edit box", label tag to provide instruction for fields		X			X	X	13	/
27	Providing feedback	Such as for interactions or any changes on page, e.g. indicate current location, announce/display current page	X	X	X	X	X	X	14	/
28	Adding relevant visualization of text in form of symbols, icons, images	Avoiding text in images	X	X			X	X	17	/
29	Making visual content perceivable by other senses	Providing audio descriptions, sonographic or haptic feedback	X	X	X		X	X	18	/
30	Highlight manipulated objects	E.g. by carefully selected color; Highlighting text, fading text to focus on specific parts, such as reading ruler	X	X			X	X	20	/
31	Providing clear text alignment	Preferred line spacing of 1.5 point	X	X			X	X	23	/
32	Providing error prevention and helpful error messages	Defining relevant error messages that are simple and easy to follow; Minimizing user input/data entry, using auto-complete; Inhibiting or disabling not valid items in the moment; Providing error recovery, such as undo, cancel operation		X			X	X	29, 36	/

Table 33: Merged list of user requirements with details and user groups

Appendix G: Interview Guide (Validation)

The following set of questions was used to guide the course of the validation interviews to the main topics such as the completeness, comprehensibility, usability and potential improvements of the accessibility guide. Depending on the individual conversations, the questions or the order, in which they were raised, were adjusted as necessary.

Introduction

1) What is your position in the company?
2) What are your main tasks?
3) How familiar are you with the concept of web accessibility?

Discussion after the guide presentation

4) Have you understood the guide and its components?
5) Is there anything missing that you would like to add or highlight?
6) Would you like to change anything?
7) Would the guide help you in fulfilling your task to implement web accessibility?
8) If yes, how and to what extent?
9) How would you assess the understandability of the guide?
10) Do you need any other tools or support for using the guide?
11) Do you intend to use the guide in the future?