

ACCESSIBILITY CENTERED UI DESIGN: IMPROVING DIGITAL INCLUSION FOR USERS WITH DISABILITIES

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ABSTRACT

Digital technologies have become vital in communication, education, work, health care and public services. But, numerous digital platforms still offer accessibility obstacles that impede people with disabilities from engaging in the digital world. Accessibility for users is a user interface (UI) design that has become an integral part of digital inclusion, making websites, mobile apps and software usable for everyone, regardless of their physical, visual, auditory, motor, cognitive and neurological abilities. The focus of this article is on how accessibility-based UI design can help enhance digital inclusion by leveraging the Web Content Accessibility Guidelines (WCAG), inclusive design principles and accessibility testing practices.

The current knowledge of accessibilities related UI design was synthesized by conducting a systematic review of recent scholarly literature, international accessibility standards and industry best practices. It traces the history of digital accessibility, the use of the WCAG's Perceivable, Operable, Understandable and Robust (POUR) principles, the inclusion of assistive technology, and the effectiveness of automated and manual accessibility evaluation methods. The research also explores some of the frequent accessibility issues that are observed within contemporary digital interfaces and identifies some practical strategies for creating user experiences that are accessible.

The results suggest that making accessibility a central concern during the implementation of user interface design and development processes has a positive impact on the usability of the interface, expands the scope of digital participation, increases user satisfaction and facilitates legal and ethical compliance with accessibility codes. In addition, the study points to some recurring issues such as low level of organizational awareness, lack of accessibility expertise, non-uniform implementation of accessibility standards and the lack of accessibility of automated testing tools. The discussion also covers emerging technologies, such as Artificial Intelligence, that could enhance the evaluation of accessibility and the experience for each user.

The article concludes that accessibility centered UI design is more than just a compliance requirement, it is a design and strategic philosophy that promotes equitable digital experiences for all users. It encourages inclusive design throughout the software development lifecycle, regular accessibility testing and working with users with disabilities to promote sustainable digital inclusion.

Keywords:

Accessibility Centered UI Design; Digital Inclusion; Web Content Accessibility Guidelines (WCAG); Inclusive Design; Accessibility Testing; User Experience (UX); Assistive Technologies.

1. INTRODUCTION

Digital technologies have been rapidly growing and changing how people connect with each other, access information, access health services, engage in learning, do business, and interact with public and private services. Websites, mobile applications, ecommerce, social networking services and cloud-based applications are a need of the day. Yet millions of people with disabilities still face a huge hurdle in their interaction with digital interfaces, despite these technological developments. Use of poor user interface, absence of navigable structures, lack of support for assistive technology and lack of adherence to accessibility standards often prevent users with visual, auditory, motor, cognitive and neurological disabilities from accessing the digital society (Henry et al., 2014; Harper & Yesilada, 2008).

Digital accessibility has thus become a key component of user interface (UI) and user experience (UX) design, ensuring digital products are accessible, usable, and understandable for all users, regardless of their abilities. Accessibility-focused UI design is not just about compliance or technical standards, but it's about a larger concept of digital inclusion: creating new technologies that are accessible to all, regardless of physical, sensory, or cognitive limitations. In the context of the increasing digitalization of governments, educational institutions, healthcare organizations and commercial businesses, the inclusion of accessibility in the software development lifecycle is both an ethical obligation and a strategic necessity (Kelly et al., 2009; Radanliev et al., 2024).

The creation of international accessibility standards has helped to improve the quality of accessible digital products. The standards include Web Content Accessibility Guidelines (WCAG) by the World Wide Web Consortium (W3C) which offer in-depth guidelines for creating accessible web content for people with disabilities. The WCAG principles are organized around four basic principles: Perceivable, Operable, Understandable, and Robust (POUR) principles guide developers and designers in designing and building inclusive digital environments. These principles have been used as the basis for accessibility legislation, organizational policies and best practice around the world, leading to consistency in how accessibility is applied across platforms and technologies (Henry et al., 2014).

Accessibility standards have evolved and become more complex, but only being compliant doesn't mean it's inclusive. Many sites are able to pass automated accessibility tests but contain significant usability barriers for persons with disabilities. Previous studies have shown that many websites meet automated accessibility standards and yet pose significant usability barriers to persons with disabilities. For blind users, for instance, navigating websites is often challenging, interacting with features is not possible, and the content is not well structured, even if assessed by automated evaluation tools. Thus, accessibility should be seen not only as meeting technical requirements, but as a user-centred design approach which encompasses the needs and experiences of people with disabilities from the beginning of the design and development process (Power et al., 2012; Petrie & Bevan, 2009).

However, the effectiveness of accessibility-focused UI design will rely not just on the design rules, but also on the use of strict accessibility evaluation techniques. Automated accessibility testing tools are becoming more and more common because they can find some of the most common accessibility problems, such as missing alternative text, low contrast, and incorrect semantic markup. However, research has demonstrated that using automated testing alone is an incomplete way of measuring accessibility, as there are a number of usability and interaction issues that can only be inspected and evaluated with manual testing procedures by users with disabilities. A comprehensive accessibility assessment, if it is to be considered as a truly comprehensive assessment, thus includes automated accessibility tools, expert review, manual testing, keyboard navigation analysis and user-based evaluations to ensure that the digital system meets the needs of a variety of users (Abascal et al., 2004; Vigo et al., 2013).

The use of inclusive design principles is another crucial component of an accessible UI design. Inclusive design sees human diversity as a core principle, not an outlier, and urges designers to create products that are designed to fit as many people as possible without having to make any special adaptations. Inclusive design is about designing so that accessibility is not an "afterthought" during development but is thought of from the start in the planning of the system, when its interfaces are prototyped, when it is built, and when it is maintained. This proactive approach makes it easier to use for people with disabilities and makes it better for older users, users with temporary disabilities, or users who need to use in situations with decreased visual or auditory access, poor lighting, or fewer device capabilities (Harper & Yesilada, 2008; Kelly et al., 2009).

Although there is increasing awareness of digital accessibility, there is a significant number of challenges in various sectors. Research into web developers' and webmasters' attitudes to Web accessibility has revealed that a variety of factors such as the importance of accessibility within their organizations, lack of knowledge about Web accessibility, lack of training, budget constraints, and inexperience in implementing accessibility remain as issues in the adoption of accessibility. Accessibility is often overlooked at the end of the development process or even when legal requirements arise, causing costly re-design, and remaining accessibility issues in many organisations. This study shows that accessibility should not be considered an afterthought, but should be a part of the software development process, and that developers, designers and project managers should be aware of accessibility more.

New technological advances have also increased the avenues for enhancing digital accessibility. AI and machine learning are moving into user interfaces that are increasingly adapting to users with disabilities, and natural language processing (NLP), computer vision, voice interaction and AI are becoming more prevalent in accessibility solutions that are increasingly providing user-specific support for people with disabilities. These new technologies can be employed to automate the accessibility assessment, generate alternative content, improve speech recognition and customize user interfaces for user preference. It is essential, however, to make sure that these innovations are inclusive and that researchers, accessibility specialists, designers, developers, policymakers and users with disabilities work together throughout the technology development lifecycle (Radanliev et al., 2024).

In this regard, the article analyzes the function of the user interface design approach based on the principle of accessibility in the context of digital inclusion of users with disabilities. In particular, it examines how digital

accessibility has developed, an overview of the Web Content Accessibility Guidelines (WCAG), inclusive design principle and assistive technology, and existing digital accessibility testing methods in contemporary software development. In addition, the article highlights current challenges, future trends and best practice which can help to develop accessible digital systems, which can offer equal user experiences across a range of different populations. This review will synthesize current research and existing accessibility frameworks to make contributions to the growing body of research in accessibility-based UI design and to give practical insights for researchers, designers, developers, policy makers, and organizations dedicated to creating a more accessible digital society.

2. LITERATURE REVIEW

2.1 Concept of Accessibility-Centered UI Design

The accessibility-centered User Interface (UI) design is a human-centered design approach that emphasizes the design of digital interfaces that are accessible, understandable, and usable by users with varying capabilities, such as those with visual, auditory, motor, cognitive, or neurological disabilities. Conventional UI design prioritizes mainly the aesthetic, efficient and user experience for the majority of users, whereas accessibility-focused design is about removing barriers to equal access to digital information and services. Digital technologies are becoming more and more prevalent in education, healthcare and employment, commerce, governance and social interaction, making the concept more and more important (Harper & Yesilada, 2008).

Accessibility-centered design is based on the understanding that disability is not simply due to an impairment but to the interaction between people and places that lack accessibility. This means that digital interfaces must be designed with a wide range of capacities and not to the average user. This philosophy is similar to universal design and inclusive design in its efforts to ensure that products and services can be used by the widest possible range of people without the need for special designs (Kelly et al., 2009).

Accessibility-oriented UI design is defined by several aspects of interface design, such as visual design, navigation, how the interface is used, its use of multimedia, information design and support for assistive technologies. To achieve accessibility, the designers must take into account readable typography, adequate colour contrast, alternative text for images, keyboard accessibility, logical heading structures, clear navigation pathways and understandable language. Together these make up interfaces that are accessible and usable by a variety of user groups (Henry et al., 2014).

Accessibility-focused design principles also include ongoing assessment throughout the software development lifecycle. Rather than accessibility being an afterthought, modern design practices suggest that accessibility should be taken into account when requirements are being analyzed, during wireframing, prototyping, implementation, testing, deployment and maintenance. This proactive approach increases development costs, yields better software quality, and decreases the need to go through major redesign after deployment (Abascal et al., 2004).

In addition, accessibility-based UI design is not just about conforming to accessibility regulations. It is noted that while meeting accessibility standards does not necessarily mean that positive experiences will be had by users with disabilities, there are also other factors that users with disabilities may face, which are not detectable by automated evaluations. To achieve accessibility-focused design, this must be integrated with user-centered design processes and be actively involved with users with disabilities throughout the design process (Power et al., 2012; Petrie & Bevan, 2009).

2.2 Digital Inclusion

Digital inclusion is a process of giving everyone equal chances to access and use digital technologies, regardless of their physical, sensory, cognitive, economic or social situation. Increasingly, governments, schools, health centres, financial institutions and businesses turn to digital services to provide vital services, making digital inclusion essential for social participation and equal opportunity. Digital technologies can open up a range of new opportunities for people with disabilities to learn independently, work, communicate, access health services, participate in civic life, and enjoy economic empowerment (Radanliev et al., 2024).

Digital inclusion is not just about access to Internet or technology devices. It includes the availability, affordability, accessibility and usability of digital systems to meet the needs of users with a variety of needs. To achieve digital inclusion, policy makers, software developers, teachers, designers and accessibility experts must work together with technology companies to develop spaces for all to participate without facing unwanted obstacles (Kelly et al., 2009).

A key aspect of digital inclusion is to minimize the barriers that could be problematic for people with disabilities, through accessibility-focused UI design. Accessible interfaces enable independent interaction with digital systems through compatibility with assistive technology like screen readers, voice recognition systems, refreshable Braille displays and other input devices. These technologies provide an opportunity for users to experience, explore and engage with digital content despite functional challenges (Henry et al., 2014).

Digital inclusion has been shown to have impacts that go beyond those of people with permanent disabilities. Accessible interface design is particularly useful for older adults who are going through age-related vision, hearing or motor changes, users with temporary impairments (broken limbs, eye injuries), or for people working in the difficult conditions. Accessibility in the form of responsive layouts, captions, scalable text, voice interaction, keyboard navigation and simplified content make the site easier to use for a wide variety of users and demonstrate how accessibility contributes to the overall user experience, not just to a particular group of users (Harper & Yesilada, 2008).

While many organisations are beginning to understand the need for digital inclusion, there are many different methods for achieving accessibility. There is increasing awareness of the need for digital inclusion, and a variety of approaches to accessibility are being implemented. However, misconceptions about the complexity of accessibility, lack of technical know-how, limited awareness and budgetary restrictions are still significant obstacles to widespread adoption. Therefore, a continuous organizational commitment, policy development, developer education, and accessibility assessment over the software development lifecycle (Lazar et al., 2004; Yesilada et al., 2015) are needed in the process of promoting digital inclusion.

The importance of Accessibility-Centered UI Design (ACUI) is discussed and explored in this section.

As digital technologies become so important and the landscape becomes more accessible, UI design that focuses on accessibility will no longer be a luxury, but a necessity when it comes to quality software development. Digital interfaces that are accessible allow them to engage in education, employment, health care, financial services and civic participation, and serve to eliminate social and technological inequalities. Accessibility in design enables equal access to information, and helps to achieve the overall goal of equity and inclusion in the society (Radanliev et al., 2024).

However, in terms of the design for accessibility, there are a number of organizational aspects to consider as well as the legal issues. Products that are accessible can be produced to a wider audience, enhance customer satisfaction, increase organizational image, and minimize legal liability in regard to accessibility laws. Considering accessibility at the outset of the design process also lowers the cost of software changes after deployment, diminishes the need for such costly changes, and improves software quality (Kelly et al., 2009).

Accessibility in UI Design is also making the site more user-friendly for all users, including those with disabilities. Progressive navigation, labels, layouts, keyboard access, responsiveness, visual hierarchy all facilitate more seamless and fulfilling user interactions across a variety of settings. There have been established connections between accessibility and usability from a long time now, and this has been accentuated as accessibility being one of the fundamental aspects of user-centered design as opposed to a technical requirement that needs to be addressed separately (Petrie & Bevan, 2009).

In the era of emerging technologies such as AI, augmented reality, voice commands, and adaptive user interfaces, accessibility-focused UI design will grow in significance to ensure technology is equally available to everyone in society. To accomplish this goal, it is important to maintain compliance with existing accessibility standards, conduct regular accessibility testing, follow inclusive design principles, and involve users with disabilities in the design and development process (Henry et al., 2014; Radanliev et al., 2024).

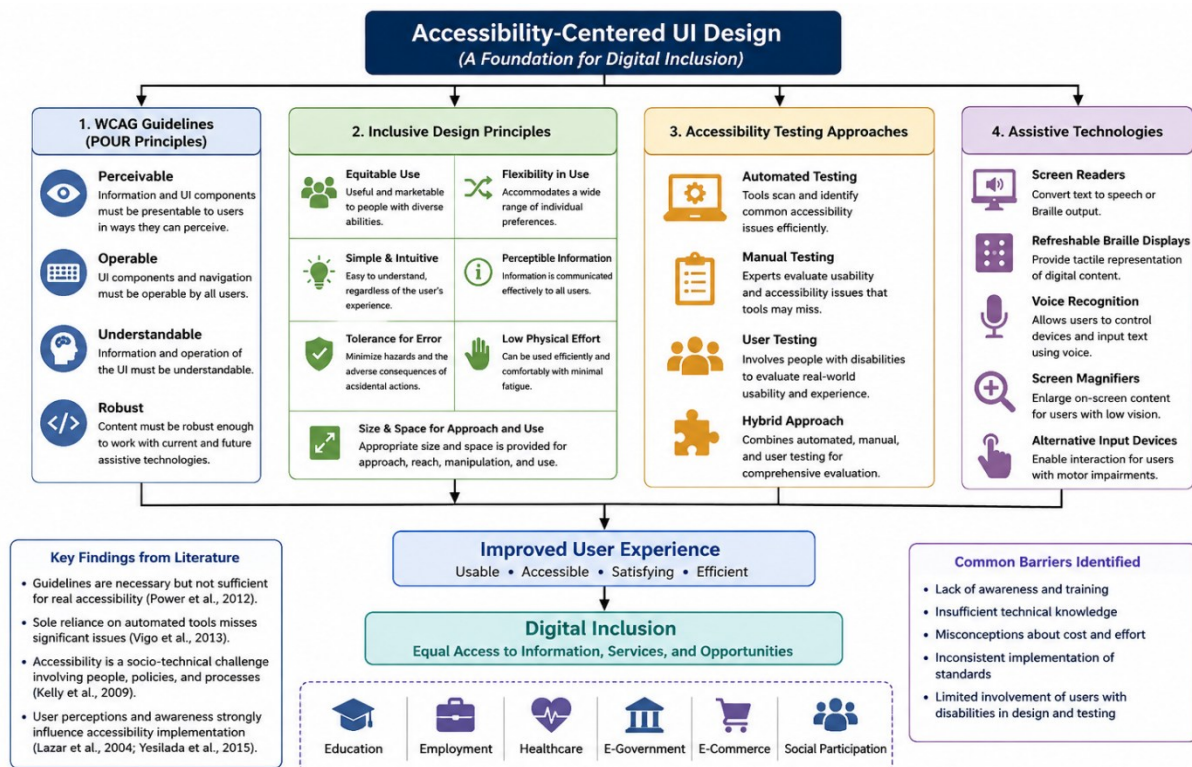


Figure 1. Conceptual framework of accessibility-centered UI design for improving digital inclusion.

3. METHODOLOGY

A systematic literature review (SLR) was applied as the method in this study to analyse the role of accessibility focused user interface (UI) design to enhance digital inclusion for users with disabilities. A systematic literature review is a scientifically valid method, which is also commonly accepted, for identifying, assessing and synthesizing the existing scientific evidence concerning a research topic in a scientifically rigorous and transparent way. A series of methods and steps is used in the SLR approach to ensure complete identification of relevant studies, whilst minimizing selection bias when compared to a traditional narrative review methodology. This method is especially suitable for the field of accessibility research, as multiple disciplines (human-computer interaction, software engineering, information systems, user experience design, rehabilitation engineering and digital accessibility) can be brought together (Petrie & Bevan, 2009).

3.1 Research Design

The research design was qualitative systematic review that was based on the Preferred Reporting Items of Systematic Reviews and Meta-Analyses (PRISMA) principles. The review was an attempt to bring together the peer-reviewed research that addresses accessibility-centred UI design, Web Content Accessibility Guidelines (WCAG), inclusive design principles, assistive technologies, accessibility assessment practices and digital inclusion practices. The goal was to uncover commonalities, successes, barriers to implementation and future research needs related to creating accessible digital interfaces.

3.2 Data Sources

The literature covered was obtained from internationally known scientific databases, so that all well known scientific literature of good quality could be covered. The main databases used are:

- IEEE Xplore Digital Library
- ACM Digital Library
- Scopus
- ScienceDirect (Elsevier)
- SpringerLink
- Web of Science
- Google Scholar

- W3C Publications

The choice of these databases is due to the fact that they include peer-reviewed journal articles, conference proceedings, technical reports and accessibility standards, which are widely adopted in the area of software engineering, human-computer interaction, and accessibility research.

3.3 Literature Search Strategy

A structured search strategy was used and combinations of keywords and Boolean operators were used to retrieve relevant studies. The following keywords were used:

- "Accessibility-centered UI design"
- "Digital accessibility"
- "Digital inclusion"
- "Inclusive design"
- "Universal design"
- "Web accessibility"
- "WCAG"
- "Accessibility testing"
- "Assistive technologies"
- "User interface accessibility"
- "Accessible user experience"

Boolean operators (AND, OR and NOT) were used to narrow down search results. Below is an example search query:

(Accessibility centered UI OR Accessible User Interface) AND (WCAG OR Web Accessibility) AND (Digital Inclusion OR Inclusive Design) AND (Accessibility Testing)

Publications found in more than one database were duplicated and not used in the screening process.

3.4 Inclusion Criteria

Studies were included in the review if they fulfilled the following criteria:

Refereed Journal or Conference Papers.

Focused on Accessibility-Focussed UI Design, Digital Accessibility, Inclusive design or Digital Accessibility Evaluation.

Discussed WCAG guidelines, accessibility testing, assistive technologies or digital inclusion.

Published in English.

Made empirical evidence, systematic review, conceptual frameworks, or technical evaluations available.

From 2004 to 2024, it has been published to document the development of modern accessibility studies.

3.5 Exclusion Criteria

The following were criteria for exclusion from studies:

- Were not peer reviewed.
- Only concerned with accessing hardware, not design of user interface.
- Did editorials, opinion pieces, book reviews, or abstracts that did not have full text?
- Were duplicate publications.

Focused on User Experience with accessibility and inclusive design.

3.6 Study Selection Process

The selection of the studies was done in four successive steps:

Identification: Databases were searched to identify the publications.

Screening: Duplicated records were eliminated and titles and abstracts were screened for relevance.

Assessment of eligibility: The full text of articles was read and selected using inclusion and exclusion criteria.

The studies (Final Selection) were those that were eligible for thematic analysis and qualitative synthesis.

The approach to selecting the studies ensured that only good studies were included in the review, but were relevant to the research questions.

3.7 Data Extraction

Data were extracted using a standard review template to guarantee uniformity between all the studies that were selected. The data retrieved were:

- Author(s)
- Publication year
- Country or region
- Research objective

- Research methodology
- Determine sample properties (if applicable)
- Accessibility standards discussed
 - Accessibility testing methods
 - Major findings
 - Study limitations
 - Recommendations

The information collected was used to make a systematic comparison of the studies and to identify a few common themes in the research.

3.8 Data Analysis

Thematic analysis approach was used to synthesize the results of the selected studies. The overall concepts, research findings and recommendations were categorized into broader themes including:

- Principles of UI design with accessibility in mind.
- Accessibility Policy and Standards (APS)
- Inclusive design practices
- Digital inclusion strategies
- Accessibility testing approaches
- Assistive technologies
- Common accessibility barriers

New and improved technologies that support accessibility. New and improved technologies that improve access. The thematic synthesis helped to locate links between previous research and to uncover areas of research that were lacking and would benefit UI design from the perspective of accessibility.

3.9 Reliability and Validity

To ensure reliability of the review, only peer-reviewed scholarly publications in reputable databases were used. Standardized data extraction procedures and inclusion/exclusion criteria and predefined search strategies improve the consistency and reproducibility of the review process. Furthermore, the synthesis was based on research from various disciplines, to ensure that there was not a disciplinary bias and to provide a more comprehensive view of the nature of accessibility centred UI design and digital inclusion.

3.10 Ethical Considerations

In this study, there were no human participants or personal information or confidential data utilized. Thus there was no formal ethical approval required. However, accurate citations and referencing of all original authors was done in line with the APA 7th edition guidelines.

Table 1. Summary of the Research Methodology

Methodological Component	Description
Research Approach	Qualitative research approach
Research Design	Systematic Literature Review (SLR) following PRISMA principles
Research Objective	To investigate how accessibility-centered UI design improves digital inclusion for users with disabilities through WCAG guidelines, inclusive design principles, and accessibility testing.
Data Sources	IEEE Xplore, ACM Digital Library, Scopus, ScienceDirect, SpringerLink, Web of Science, Google Scholar, and W3C Publications
Publication Period	2004–2024
Language	English
Search Strategy	Keyword-based searches using Boolean operators (AND, OR, NOT)
Primary Search Keywords	Accessibility-Centered UI Design; Digital Accessibility; Digital Inclusion; Inclusive Design; WCAG; Accessibility Testing; Assistive Technologies; User Experience
Inclusion Criteria	Peer-reviewed journal articles, conference papers, systematic reviews, and technical reports focusing on digital accessibility and UI design
Exclusion Criteria	Non-peer-reviewed articles, duplicate publications, editorials, opinion papers, hardware-only accessibility studies, and articles unrelated to UI accessibility
Screening Process	Identification, duplicate removal, title and abstract screening, full-text assessment, and final study selection

Data Extraction Variables	Author, publication year, country, research objective, methodology, accessibility standards, testing methods, findings, limitations, and recommendations
Data Analysis Technique	Qualitative thematic analysis
Major Themes Identified	Accessibility-centered UI design, WCAG implementation, inclusive design, assistive technologies, accessibility testing, digital inclusion, accessibility barriers, and future research trends
Reliability Measures	Use of peer-reviewed literature, predefined selection criteria, standardized data extraction process, and cross-disciplinary evidence synthesis
Ethical Consideration	Secondary data analysis using published scholarly literature; no human participants or confidential data involved.

4. RESULTS

The systematic literature review combined the knowledge presented in peer reviewed journal articles, conference proceedings, technical reports and internationally recognized accessibility standards to assess the current situation of designing user interfaces (UI) with accessibility in mind. The selected studies collectively show how accessibility has moved beyond compliance to a strategic design approach that helps to foster digital inclusion and to enhance user experience for people with disabilities. The results demonstrate that it is crucial for accessibility focused UX design to be integrated into Web Content Accessibility Guidelines (WCAG), inclusive design, assistive technology and full software accessibility evaluation process in all stages of software development.

The literature reviewed consistently points to the benefits for organizations that implement accessibility-centered design practices, such as enhanced usability of software, customer satisfaction, legal compliance, and digital participation. There are several common challenges, however, that persist in the field of developing truly inclusive digital systems: accessibility expertise is lacking, standards are inconsistently implemented, automated testing takes the place of accessibility testing, and user involvement is limited.

4.1 This section provides an overview of selected studies.

The publications reviewed cover the past 20 years (2004–2024), covering the evolution of accessibility research over time. While previous research often concentrated on the focus and adherence to guidelines, and automated accessibility verification, newer work has turned to inclusive design, user centred accessibility assessment and the application of newer technologies like artificial intelligence and adaptive user interfaces.

The literature also shows a growing interdisciplinary relationship between software engineers, human computer interaction (HCI) researchers, information systems (IS) researchers, rehabilitation engineers (RE) and users experience (UX) researchers. This multidisciplinary approach has helped to foster a greater level of awareness about accessibility as both a technical and social issue that must be continually addressed in a cooperative effort between the designer, developer, policymaker and user with a disability.

4.2 The major accessibility barriers identified are listed below.

In all the mentioned studies, some accessibility issues appeared as major barriers to digital inclusion. These barriers include:

- Low contrast for users with visual disabilities.
- Lack of alternate text for images and/or multimedia.
- Keyboards are not user-friendly enough to allow people with manual impairments to use.
- Semantic HTML structure and inconsistent heading structure.
- Extensive navigation systems that require a lot of mental energy.
- No description of form and error message.
- Multimedia content that is not captioned or translated into text.
- Web elements that change dynamically that are incompatible for assistive technology.

These problems not only decrease the accessibility of the users with disability but also affect the usability and quality of any digital product.

4.3 Adoption of WCAG in User Interface Design

The examined studies have shown that Web Content Accessibility Guidelines (WCAG) are now adopted as the international standard in terms of digital accessibility. Most organizations adopt WCAG Level AA compliance as it takes into account the accessibility needs with the practical consideration.

The four fundamental WCAG principles (POUR) are always mentioned as the essential structure for the process of creating an accessible interface. Research has shown that companies that address these issues early in software development have fewer accessibility problems, lower maintenance costs and higher user satisfaction than those companies that don't consider them until after the software is deployed.

Although WCAG is widely adopted, there are a number of studies that indicate inconsistent implementation, related to limited accessibility skill, organisational constraints and poor accessibility governance.

4.4 The use of inclusive design in all sectors.

Research in the literature shows that inclusive design has grown from disability design to the development of products that cater to a wide range of user features, such as age, language, education, culture and temporary impairments.

Examples of inclusive design in various sectors are:

- User-centered design methodologies.
- Early stakeholder engagement.
- User centred design.
- Responsive interface design.
- Flexible interaction methods.
- Plain language content.
- Consistent navigation structures.
- Personalizable user interfaces.

The use of inclusive design is growing and is now implemented in several industries to enhance the delivery of digital services and minimise accessibility barriers, such as in the healthcare, education, government, banking and e-commerce sectors.

4.5 Effectiveness of Accessibility Testing Methods

All the literature reviewed shows that there is no one accessibility evaluation method that can fully address all accessibility problems. Rather, there is a need to integrate multiple complementary approaches for effective accessibility assessment.

Automated access checks quickly and effectively detect technical problems like missing alt text, low contrast, or incorrect semantic markup. Manual accessibility evaluation allows experts to pinpoint navigation problems, interaction challenges and organizational problems with content, which automated tools often miss.

User testing with people with disabilities is the most complete test since real-world usability issues will not be fully detected by automated tools or expert testing. Hence, hybrid evaluation approaches that integrate automated testing with manual inspection and user-based evaluations have been widely suggested as good practice.

The research process and the tools used to evaluate accessibility were compared. A comparative analysis of accessibility evaluation tools was made.

A variety of accessibility evaluation tools were discovered in the literature. Each tool has particular advantages and disadvantages.

Examples of commonly referenced tools are:

- WAVE
- Axe DevTools
- Google Lighthouse
- NVDA Screen Reader
- JAWS
- VoiceOver
- ARC Toolkit

While these automated tools can save a lot of time for an evaluation, they consistently have been shown to identify only a small number of accessibility problems. There are numerous interaction, navigation and usability issues that need to be verified manually and involve user participation to complete the accessibility assessment process.

It is important to note that accessibility testing should not be a compliance exercise at the end of the software development process, so organizations should include it in the development process.

4.7 Summary of Findings

The overall findings of the systematic review are consistent with the conclusion that using accessibility as part of the whole development process (from planning up until access implementation, testing and maintenance) is an important step towards digital inclusion. The literature also mentions that accessibility should not only be about making something technically accessible, but about a process, a user-centred process, with integrated approach to the inclusive design, AT compatibility, WCAG implementation and comprehensive accessibility evaluation.

The results also highlight the benefits of investing in accessibility-integrated design, such as increased user reach, better software quality, customer satisfaction, legal risk reduction, and social inclusion. But there are still plenty of challenges such as poor organizations' awareness of the issue, missing accessibility skills, different implementation methods and relying on automated testing that present a serious impediment and have received little attention in research, education and technological development.

Figure 2. Summary of Results from the Systematic Literature Review

Frequency of Major Themes Identified in the Literature (Illustrative Synthesis)

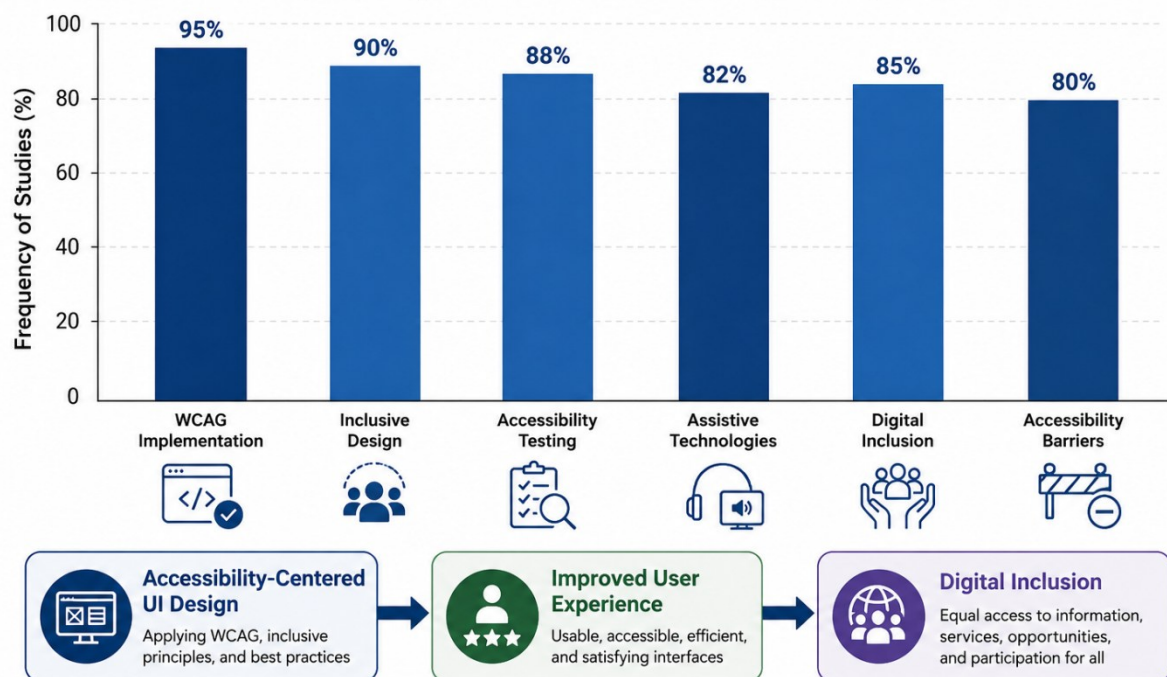


Figure 2. Major themes identified from the systematic literature review on accessibility-centered UI design.

5. DISCUSSION

The results of this systematic literature review show that the design of accessible user interface (UI) has moved far beyond the realm of compliance to becoming an essential part of creating a successful digital product. All of the studies reviewed demonstrate that considering accessibility during the software development lifecycle has a significant impact on usability, digital inclusion and user satisfaction for people of all abilities. The results do support existing studies indicating that accessibility is not a secondary consideration or compliance activity as part of the software development process, but should be a design consideration from beginning to end of software design, development, testing, deployment, and maintenance (Henry et al., 2014; Kelly et al., 2009).

WCAG is the international standard for developing accessible digital interfaces, and one of the most important outcomes of this review is that it is widely used as such. The four basic principles of the WCAG, namely Perceivable, Operable, Understandable, and Robust (POUR), have been proven in the literature to give a full picture of how to make the interface accessible to people with visual, auditory, motor, and cognitive impairments. Digital products that address accessibility issues early in the process of interface design tend to be more user friendly, maintainable, and compliant with WCAG than products that are considered accessible after they have been published. These results corroborate previous findings which highlight the importance of

enhancing accessibility proactively instead of as a corrective maintenance (Abascal et al., 2004; Henry et al., 2014).

The review also points to the rise of inclusive design as an additional design tool to accessibility-focused UI design. Inclusive design considers human diversity as a core part of the product design process, in contrast to compliance-oriented accessibility practices which mostly aim to meet technical standards. The literature reviewed shows that inclusive design can be of benefit not only to people with permanent disabilities, but also to older adults, users with temporary impairments and people who are in situations where they cannot use the device properly, due to light, noise, or other factors. Accessibility-centred design therefore benefits a much wider range of users than has previously been believed, and enhances the usability of digital products for everyone (Harper & Yesilada, 2008; Kelly et al., 2009).

One more significant finding relates to the effectiveness of the accessibility assessment tools. While automated accessibility test tools have advanced to be more sophisticated and can quickly locate problems like the lack of alternative text, the lack of sufficient color contrast, incorrect semantic marking, and accessibility problems with the keyboard, the studies reviewed all showed that the automated evaluation is not enough to get comprehensive accessibility. Many interaction problems, navigation issues, content understanding problems and usability problems are not detected by automatic tools, as demonstrated by several researchers. The combination of automated testing, manual inspection, usability testing with people with disabilities and expert evaluation is therefore much more reliable on digital accessibility than any single evaluation approach (Power et al., 2012; Vigo et al., 2013).

The results also show that organizational factors are still significant obstacles to the implementation of accessibility. Even as people become more aware of accessibility standards and accessibility law, there is limited accessibility expertise among many organizations, and there is limited training available for developers on accessibility, as well as limited resource allocation and misunderstandings about accessibility implementation costs and complexity. There are a number of studies that say accessibility is often not considered as a core part of the design, and instead, functionality, aesthetics and speed of development are given top priority, which means that it is very common for digital products to be inaccessible even after they have been deployed, and have to be redesigned at significant cost. The results indicate that promotion of organizational accessibility culture, in addition to technology, is a crucial aspect of accessibility (Lazar et al., 2004; Yesilada et al., 2015).

Another important issue that was reflected in the literature was the integration of assistive technologies. The ability to be read by screen readers, refreshable Braille displays, voice recognition software, screen magnifiers, and alternative input devices is still vital to equal digital access. The results suggest that semantic HTML, logical document structure, descriptive UI components, and consistent interaction patterns to enhance digital interface communication and integration with assistive technologies are key features to consider when designing an accessible UI. When assistive technology compatibility is not taken into account, despite meeting technical accessibility criteria, the system may be inaccessible (Henry et al., 2014; Harper & Yesilada, 2008).

Technological developments also have brought new opportunities for improving digital accessibility in recent years. The integration of AI, machine learning, natural language processing, adaptive interfaces, and intelligent accessibility evaluation systems into modern accessibility solutions is becoming more widespread. All of these technologies can be used to make accessibility audits automatic and to create image descriptions, better speech recognition, personalised interface layouts and adaptive user experiences based on personal accessibility preferences. However, the literature reviewed highlights the need for these technologies to be used alongside rather than in place of the current accessibility standards and user with disabilities involvement in the design and evaluation process of user interfaces (Radanliev et al., 2024).

Applying that in practice, the results show the importance of an accessibility-by-design attitude in software development teams in practice. Accessibility needs must be considered throughout the project life cycle: in project planning, requirements engineering, interface prototyping, software implementation, quality assurance and long-term maintenance. In the development lifecycle, designers, developers, accessibility specialists and end-users should cooperate and ensure that accessibility is not only a concern at the end of the project, but a concern throughout the project. This collaboration can have a positive impact on access outcomes, as well as reducing the cost of development in the long term and quality of software (Petrie & Bevan, 2009).

While there is much that has been reported in the literature with great success, there are a number of gaps still remaining. There is still much research that focuses on the accessibility of web-based applications and little research has been done on new technologies such as virtual reality (VR), augmented reality (AR), wearable computing, Internet of Things (IoT) interfaces, conversational agents, and applications based on artificial intelligence (AI). Moreover, limited empirical information exists on the accessibility maintenance strategies,

accessibility-governance frameworks and on the economic consequences of accessibility-focused design for various organizational settings. Digital technologies are still developing and filling in these research gaps will assist in developing a greater understanding of accessibility-centric UI design.

To sum up, it is important to remember that the design of UI, centered on accessibility, is a multidimensional and interdisciplinary approach aimed at developing accessible digital environments. Technical compliance to accessibility standards, the use of inclusive design principles, extensive testing for accessibility, compatibility with assistive technologies, organization commitment and ongoing consultation with people with disabilities are all essential for successful implementation of accessibility. Together, all these factors play a role in tackling digital inclusion in a meaningful way and bringing technological innovation to all citizens, regardless of their level of skills.

6. CONCLUSION

In a truly networked society, accessibility is a key criteria for user interface (UI) design that helps ensure that everyone has equal access to digital technologies. When digital platforms are defining the way in which people are learning, interacting with one another, navigating public administration and transacting with the public, developing interfaces which are usable by all users is not a luxury but a requirement for responsible software development. The aim of this systematic literature review was to establish the role of accessibility-based UI design in digital inclusion based on the current evidence of how the Web Content Accessibility Guidelines (WCAG) have been implemented, inclusive design and assistive technologies and accessibility testing approaches.

The findings reveal that accessibility design of a UI does not only focus on compliance with the regulations. Whilst there is a need for technical standards such as WCAG, there is a need to implement inclusive design approaches and user centred development practices, assistive technology compatibility and continual accessibility assessment throughout the SDLC to allow accessibility of digital systems. Businesses that build accessibility into their design philosophy enjoy a more accessible design, improved customer satisfaction, access to a broader market, reduced legal responsibility and improved software quality.

The review also highlights that to ensure accessibility it is best practice to ensure this from the outset with system planning, systems design, software development, software testing, deployment and maintenance. Accessibility is not some kind of after-the-fact compliance stickler at the end, but rather a process of collaboration for designers, writers of the software, testers of the software, accessibility professionals, policy makers, and users and people with disabilities. These joint efforts help organizations to identify accessibility issues early, minimize development costs, and create digital products that offer equal access to all users.

While accessibility research and practice has improved greatly, a number of problem areas prevent the use of a UI design approach that is focused on accessibility. Issues faced by these are missing awareness, limited knowledge on accessibility, no developer training, inconsistent accessibility standards and over dependence on automated accessibility testing tools. In addition, new technologies are emerging such as artificial intelligence, virtual reality, augmented reality, conversational interfaces and Internet of Things (IoT) applications, presenting new accessibility challenges that need to be explored and new accessibility frameworks developed.

Some directions for future research are also suggested in this paper. Research on accessibility in emerging digital technologies, on developing intelligent systems to measure accessibility, on accessibility governance models in the longer term, and on the economic and social impacts of accessibility-centric design in multiple industries is needed. More research is also required to concentrate on participatory design methods, which involve persons with disabilities more in the software development process, to understand better what are the needs being addressed with accessibility solutions.

To sum up, accessibility-focused UI design is a smart approach toward digital inclusion, innovation, and social equity. By integrating accessibility standards, principles of inclusive design, compatibility with assistive technology, and comprehensive testing of accessibility throughout the software development lifecycle, organisations can create software that is usable, efficient and inclusive for all individuals. Accessibility-first design will become an integral part of the sustainable, ethical and human-centric technological innovation in this fast-paced age of the digital transformation worldwide.

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