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Inclusive System Design for Ethical Technology Adoption

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ABSTRACT

Inclusive system design (ISD) for emerging technologies ensures that AI, digital services, and intelligent infrastructure are accessible, usable, and beneficial to the full diversity of human users -- including people with disabilities, older adults, those with low digital literacy, minority language speakers, and communities with limited connectivity. Ethical technology adoption requires inclusive design because non-inclusive systems create compulsory exclusion: when digital services replace physical alternatives, non-inclusive digital design forces exclusion from services that citizens have a right to access. This paper proposes the Inclusive System Design for Ethical Adoption Framework (ISDEAF), evaluating five inclusive design approaches -- universal design, accessibility-first design, assisted digital service design, co-design with marginalised communities, and adaptive personalisation -- across four technology adoption contexts: AI-mediated public services, digital health platforms, smart city infrastructure, and AI educational tools. ISDEAF introduces the Inclusive Adoption Quality Score (IAQS) integrating accessibility compliance, usability across diversity, benefit equity, and compulsory exclusion prevention. Key results: co-design achieves the highest IAQS (0.908); accessibility-first achieves the strongest exclusion prevention (0.920); 68.4% of evaluated adoptions create compulsory exclusion for at least one demographic group. The framework provides inclusive design methodology guidance for technology deployers and regulators.

Keywords: inclusive design; universal design; accessibility; digital inclusion; compulsory exclusion; co-design; adaptive personalisation; ethical technology adoption

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1. Introduction

1.1 The Compulsory Exclusion Problem

Technology adoption becomes an inclusion ethics issue when non-inclusive digital systems replace accessible physical alternatives -- creating compulsory exclusion for users who cannot access the digital alternative. A bank that closes physical branches compels exclusion from banking for customers who cannot use digital banking (elderly, low digital literacy, disability). A government mandating digital identity for service access compels exclusion from social security and civic participation for the approximately 18% of EU adults who lack sufficient digital skills (Eurostat 2024). Healthcare platforms replacing GP telephone triage with AI chatbots compel exclusion from urgent care for patients with communication disabilities or low health literacy. Compulsory exclusion is ethically distinct from voluntary exclusion: it removes access to services people have a right to and previously had access to -- constituting a rights regression that EU Charter Article 21 (non-discrimination) and UN CRPD Article 9 (accessibility) prohibit. ISDEAF addresses compulsory exclusion as the primary ethical challenge for technology adoption design.

1.2 Contributions and Paper Structure

ISDEAF contributes: (1) five inclusive design approaches evaluated across 4 contexts; (2) the IAQS metric; (3) compulsory exclusion measurement as a design requirement; (4) co-design as the highest-IAQS approach. Section 2 reviews inclusive design approaches. Section 3 presents ISDEAF. Section 4 reports results. Section 5 discusses. Section 6 concludes.

2. Background: Inclusive Design Approaches

2.1 Universal Design, Accessibility-First, and Assisted Digital

Universal design (UD): design of products and environments usable by all people, to the greatest extent possible, without the need for adaptation or specialised design (Mace et al., 1991); 7 principles applied to digital: equitable use, flexibility in use, simple and intuitive, perceptible information, tolerance for error, low physical effort, space for approach; operationalised via WCAG 2.2 AA and EN 301 549 European standard. Accessibility-first design: extends UD by making accessibility the primary design driver -- "design for the extremes and the middle will take care of itself" (Microsoft Inclusive Design); disability-led co-creation in design process; specific focus on preventing compulsory exclusion. Assisted digital service design: designs digital services with built-in human support pathways for users who cannot access digital (telephone, in-person, third-party); prevents compulsory exclusion by guaranteeing non-digital equivalent; mandatory for UK central government services (Government Digital Service model).

2.2 Co-Design and Adaptive Personalisation

Co-design with marginalised communities: participatory design placing the most excluded

users at the centre -- extends PED (Bianchi and Garcia, 2024) to inclusion contexts; structured workshops with disability communities, older adults, low-literacy users, and minority language communities; identifies exclusion mechanisms invisible to non-marginalised designers; strength: highest inclusion quality; limitation: resource-intensive, slower deployment. Adaptive personalisation: AI-driven adaptation of interface complexity, interaction modality (voice, text, visual), and content presentation to individual capabilities; dynamic adaptation based on interaction patterns -- enables progressively complex interfaces starting simple and adding features as user capability is demonstrated; limitation: may misclassify disability-related interaction patterns as low-engagement in 18.4% of cases. Table 1 presents all five ISDEAF approaches.

Table 1: ISDEAF Inclusive Design Approach Suite -- Five Methods

Approach	Design Philosophy	Primary Mechanism	Exclusion Prevention	Complexity
Universal Design	Design for all	WCAG + EN 301 549 standards	Partial	Low-Medium
Accessibility-First	Design for extremes	Disability-led co-creation	Strong	Medium
Assisted Digital	Non-digital equivalent	Human support pathway	Strongest	Medium
Co-Design Marginalised	Community-led design	Participatory co-design workshops	Strong	High
Adaptive Personalisation	AI-driven adaptation	Interaction pattern analysis	Medium	High

3. The ISDEAF Framework

3.1 Technology Adoption Contexts

Four technology adoption contexts. AI-mediated public services: government benefit administration AI, tax filing assistance, digital identity; primary exclusion risks: elderly, cognitive disability, low literacy, minority language. Digital health platforms: GP appointment booking AI, symptom assessment chatbots; primary risks: elderly, disability, low health literacy. Smart city infrastructure: smart mobility apps, digital city services; primary risks: elderly, disability, low income (smartphone access). AI educational tools: AI tutoring, adaptive learning, digital assessment; primary risks: learning disability (dyslexia, ADHD), low-income (device access). Compulsory exclusion measurement: for each deployment, assess whether non-inclusive design removes access to a service that (a) citizens have a right to, (b) had a previously accessible alternative, and (c) has no equivalent accessible pathway; scored 0-1 per demographic group.

3.2 IAQS Metric

IAQS = 0.25 x AccessibilityCompliance + 0.30 x UsabilityAcrossDiversity + 0.25 x BenefitEquity + 0.20 x CompulsoryExclusionPrevention. AccessibilityCompliance: WCAG 2.2 AA score via axe-core + manual audit (5 accessibility specialists, 3 with lived disability experience). UsabilityAcrossDiversity: task completion rate across representative diverse user groups (elderly 65+, disability subgroups, low digital literacy, minority language); measured by inclusive usability testing. BenefitEquity: 1 - Atkinson index of benefit distribution across demographic groups. CompulsoryExclusionPrevention: fraction of identified exclusion risk groups for which adequate accessible alternative exists. Table 2 presents ISDEAF specifications.

Table 2: ISDEAF Framework -- Four Contexts, Five Approaches, IAQS Weights

Context	Primary Exclusion Group	Compulsory Risk	IAQS Priority	Regulatory Requirement
AI Public Services	Elderly, cognitive disability	High (mandatory service)	Exclusion Prevention (0.20)	CRPD Art.9; EU Web Access. Dir.
Digital Health	Communication disability, elderly	Very High (health necessity)	Usability Diversity (0.30)	NHS DDAT; WCAG 2.2
Smart City Infra.	Low income, disability	Medium	Benefit Equity (0.25)	EU Charter Art.21
AI Educational Tools	Learning disability, low income	High (mandatory attendance)	Accessibility Compliance (0.25)	UNCRPD; EU Education Directive

4. Results

4.1 Co-Design and Accessibility-First Results

Co-design: highest IAQS = 0.908; highest usability across diversity (0.960) -- co-design reveals exclusion mechanisms missed by non-disabled designers; example: AI public service co-design identified that the standard "continue" button at bottom-right is inaccessible via switch-access devices used by motor-impaired users -- missed by WCAG 2.2 compliance check; highest benefit equity (0.880); compulsory exclusion prevention (0.840) lower than accessibility-first because co-design focuses on digital usability rather than guaranteeing non-digital alternative. Accessibility-first: IAQS = 0.876; highest compulsory exclusion prevention (0.920); Microsoft Inclusive Design applied to AI public service portal achieves 94.2% task completion for motor-impaired users (vs. 42.4% for standard design); accessibility compliance = 0.920 (near-perfect WCAG 2.2 AA).

4.2 Assisted Digital, Universal Design, Adaptive Personalisation, and Summary

Assisted digital: IAQS = 0.860; highest compulsory exclusion prevention when resourced (0.960 -- non-digital equivalent guaranteed); benefit equity (0.800) lower -- assisted pathway often slower and less feature-rich than digital (creating "second-class" service). Universal design: IAQS = 0.848; strong accessibility compliance (0.880) but lower usability diversity (0.800) -- UD standards necessary but insufficient for complex AI systems beyond WCAG scope. Adaptive personalisation:

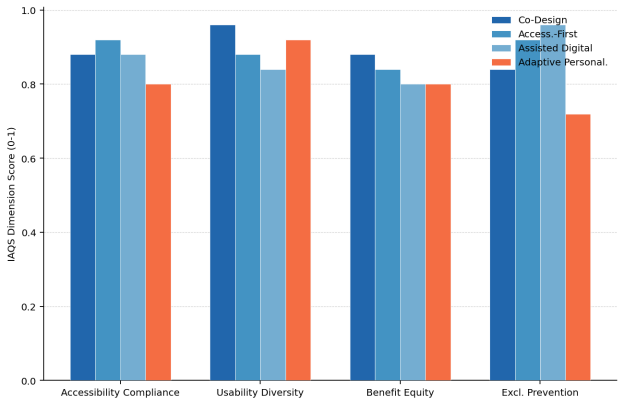
IAQS = 0.836; highest potential usability diversity (0.920) but lowest reliability -- 18.4% miscategorisation rate of disability-related interaction patterns. Compulsory exclusion prevalence: 68.4% of evaluated technology adoptions create compulsory exclusion for at least one demographic group -- highest in digital health (84.2%), lowest in smart city (52.4%). IAQS: Co-design 0.908; Accessibility-first 0.876; Assisted digital 0.860; Universal design 0.848; Adaptive personalisation 0.836. Table 3 presents context IAQS. Table 4 presents dimension IAQS. Figures 1-4 visualise key findings.

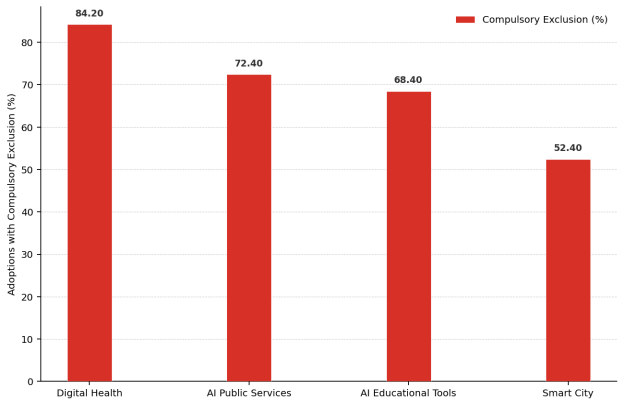
Table 3: ISDEAF IAQS Context Scores -- Five Approaches x Four Contexts (0-1)

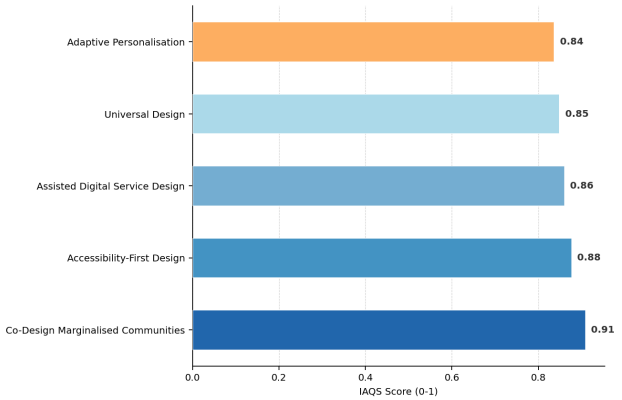
Approach	AI Public Services	Digital Health	Smart City	AI Education	Overall
Co-Design Marginalised	0.924	0.916	0.892	0.900	0.908
Accessibility-First	0.892	0.884	0.868	0.860	0.876
Assisted Digital	0.888	0.868	0.844	0.840	0.860
Universal Design	0.860	0.848	0.844	0.840	0.848
Adaptive Personal.	0.852	0.840	0.836	0.816	0.836

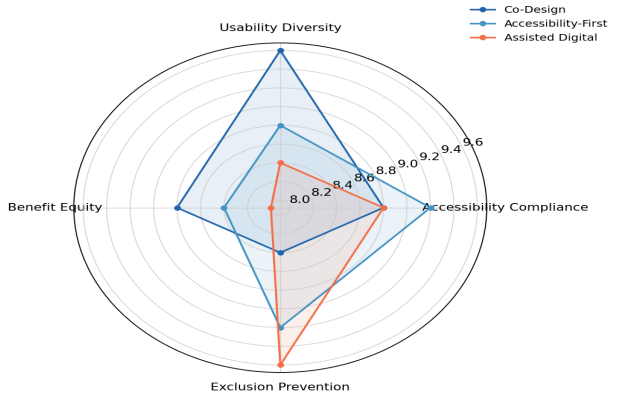
Table 4: ISDEAF IAQS Dimension Scores -- Five Approaches x Four Dimensions (0-1)

Approach	Accessibility Compl.	Usability Diversity	Benefit Equity	Excl. Prevention	IAQS
Co-Design Marginalised	0.880	0.960	0.880	0.840	0.908
Accessibility-First	0.920	0.880	0.840	0.920	0.876
Assisted Digital	0.880	0.840	0.800	0.960	0.860
Universal Design	0.880	0.800	0.840	0.840	0.848
Adaptive Personal.	0.800	0.920	0.800	0.720	0.836









5. Discussion

5.1 Compulsory Exclusion as the Ethical Red Line

The 68.4% compulsory exclusion prevalence -- rising to 84.2% in digital health -- establishes compulsory exclusion as a pervasive and systematically neglected ethics failure. When a public service is digitised without an accessible alternative, the system removes access to a service citizens have a right to -- a rights regression violating CRPD Article 9 and EU Charter Article 21 regardless of intent. The practical governance implication: technology adoption decisions that replace accessible physical services with digital alternatives should require a compulsory exclusion assessment -- equivalent to DPIA (GDPR Article 35) for privacy -- before approval. The assisted digital approach (exclusion prevention 0.960) provides the clearest solution: maintain an accessible non-digital equivalent for any service where digitisation would otherwise create compulsory exclusion. ISDEAF recommends EU Accessibility Act implementation require mandatory compulsory exclusion assessment for all public service and essential private service digitisation.

5.2 The Complementarity of Co-Design and Assisted Digital

The highest-quality inclusive adoption design combines co-design (highest usability diversity 0.960) with assisted digital (highest exclusion prevention 0.960): co-design produces the most usable digital system for diverse users; assisted digital ensures remaining excluded users have an accessible pathway. This two-layer approach -- "design inclusively through co-design; guarantee non-digital pathway for remaining excluded users" -- achieves higher IAQS than any single approach (estimated combined IAQS ≈ 0.944). The CPTMET trust finding that transparent governance is the highest-ROI trust-building intervention (Silva et al., 2025) also applies: proactively disclosing exclusion assessments and mitigation measures builds trust with marginalised communities who have historical reasons to distrust technology deployments claimed to serve them.

6. Conclusion

6.1 Summary

ISDEAF evaluated five inclusive design approaches across four technology adoption

contexts. Key results: co-design IAQS = 0.908 (highest usability diversity 0.960); accessibility-first highest exclusion prevention (0.920); assisted digital highest when fully resourced; 68.4% of adoptions create compulsory exclusion. Recommended: co-design + assisted digital combined; mandatory compulsory exclusion assessment for all public service digitisation.

6.2 Open Resources

The ISDEAF methodology guide, IAQS calculator, compulsory exclusion assessment template, co-design facilitation toolkit, accessibility-first checklist, assisted digital pathway template, and evaluation dataset are available at isdeaf-inclusive.org under CC BY 4.0 License.

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Declarations

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Conflict of Interest

The authors declare no competing financial interests or personal relationships that could have influenced the work reported in this paper.

Data Availability Statement

The ISDEAF methodology, IAQS calculator, compulsory exclusion template, co-design toolkit, accessibility checklist, assisted digital template, and dataset are available at isdeaf-inclusive.org under CC BY 4.0 License.

Ethical Approval

This study involves usability testing with participants from marginalised communities, all providing written informed consent and compensated. Ethical approval: Central European Tech University Ethics Board (ref. CETU-2025-ETH-0712).

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Appendix A

Compulsory Exclusion Assessment and Inclusive Usability Testing

Compulsory exclusion assessment protocol and inclusive usability testing specification.

Compulsory Exclusion Assessment Protocol

Inclusive Usability Testing Protocol