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DEVELOPING ACCESSIBILITY SKILLS IN THE SPIRIT OF ACCESSCOVE: USING GEOGRAPHIC INFORMATION SYSTEMS (GIS) FOR MORE INCLUSIVE CITIES AND THE CONTRIBUTION OF ASSISTIVE TECHNOLOGY

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ABSTRACT

Cities are designed, built and managed through spatial data, yet the lived experience of people with disabilities and older adults is rarely represented in those data. This article examines how accessibility competences can be developed and professionalised, taking the Erasmus+ project AccessCoVE (European Centre of Vocational Excellence in Accessibility) as a reference point, and argues that Geographic Information Systems (GIS), combined with assistive technology (AT), constitute a core technical layer of such competences. Through a narrative and comparative review of policy documents, standards and peer-reviewed literature, the article (a) outlines the conceptual and regulatory background of urban accessibility, (b) compares the main GIS-based approaches to measuring and mapping accessibility (network-based indicators, user-centred wheelchair modelling, volunteered geographic information, crowdsourced street-level auditing and personalised routing), (c) examines the role of assistive technology in spatial navigation, and (d) proposes a GIS-and-AT competence profile for the emerging roles of Accessibility Certifier and Accessibility Consultant. The comparison shows that no single approach is sufficient: authoritative network data provide scale, crowdsourced data provide currency, and user-centred modelling provides validity. The article concludes that vocational education should train professionals to combine these sources, to evaluate data quality critically and to work participatively with the people whose mobility the data are meant to serve. It is a conceptual contribution; GIS is not presented as an official deliverable of AccessCoVE, and the proposed competence profile is the author's own.

Keywords: Accessibility; Inclusive Cities; Geographic Information Systems (GIS); Assistive Technology; Vocational Education and Training; Accesscove; Universal Design

1 INTRODUCTION

Accessibility is often discussed as a property of individual products, buildings or websites. For the people who depend on it, however, accessibility is experienced as a *chain*: leaving home, crossing a street, boarding a vehicle, finding an entrance, reading a sign, using a service. The chain is only as strong as its weakest link, and a single missing curb ramp or an out-of-service lift can make an otherwise accessible journey impossible [1], [2]. This chain-like, spatial nature of accessibility is why Geographic Information Systems have become central to its study: GIS can represent networks, attach attributes to their segments and nodes, and compute what is reachable, by whom, and at what cost.

The scale of the issue is considerable. The World Health Organization estimates that around 1.3 billion people, roughly one in six worldwide, experience significant disability [3], and that more than 2.5 billion people need one or more assistive products, a figure expected to rise markedly by 2050 as populations age [4]. In the European Union, the Strategy for the Rights of Persons with Disabilities 2021–2030 and the European Accessibility Act (Directive (EU) 2019/882), whose requirements apply from June 2025, have turned accessibility from a recommendation into an obligation for a wide range of products and services [5], [6]. Compliance, however, requires people who know how to assess, document and certify accessibility. Here the policy ambition meets a skills gap.

The Erasmus+ project AccessCoVE responds to this gap. Coordinated by the University of Macedonia (Greece) and bringing together partners from Greece, Sweden, Spain and Italy, it aims to structure excellence in vocational education and training (VET) in accessibility, and to define and certify two new professional profiles: the Accessibility Certifier and the Accessibility Consultant [7], [8]. The present article takes this initiative as a starting point and asks a complementary question: **what part should spatial technologies, and GIS in particular, play in the competences of such professionals, and how does assistive technology interact with them?**

The article makes three contributions. First, it consolidates a comparative picture of GIS-based accessibility approaches, from classical accessibility measures to crowdsourced street-level data. Second, it clarifies how assistive technology and GIS depend on each other in practice, since assistive navigation is only as good as the spatial data behind it. Third, it translates these findings into a proposed competence profile suitable for VET programmes. The structure is as follows: Section 2 presents the conceptual framework; Section 3 the policy and standards context; Section 4 AccessCoVE and the competence gap; Section 5 GIS approaches; Section 6 assistive technology in the urban domain; Section 7 a comparative synthesis; Section 8 illustrative cases; Section 9 the proposed competence profile; Section 10 challenges; and Section 11 conclusions.

1.1 Method and scope

The article is a narrative, comparative review. Sources were selected purposively to cover (i) international and European policy instruments and standards, (ii) foundational and recent peer-reviewed work on accessibility measurement and GIS, (iii) literature on assistive navigation technologies, and (iv) publicly available descriptions of the AccessCoVE project. The aim is conceptual integration and comparison, not an exhaustive systematic review. Statements about AccessCoVE are limited to what the project's public materials report. These materials emphasise training programmes, certification and a web portal, and do not specify GIS tooling; the link to GIS drawn here is therefore an argument for how the project's competence agenda could be extended, not a description of its content.

2 CONCEPTUAL FRAMEWORK

2.1 Accessibility

The term *accessibility* carries two related meanings that are frequently conflated. In transport geography and planning, accessibility denotes the ease with which activities and destinations can be reached; the classic definition links it to the potential for interaction between places [9]. Geurs and van Wee [10] later distinguished four components of accessibility measures: land use, transport, temporal and individual components, and argued that good measures should be sensitive to all four. In disability studies and design, by contrast, accessibility denotes the degree to which environments, products and services can be used by people with a wide range of abilities. The two meanings meet in the concept of *individual accessibility*: the same street network offers very different opportunities to a pedestrian without impairments, a wheelchair user, a blind traveller and an older person who tires quickly [11], [1].

2.2 Models of disability and the logic of design

The social model of disability holds that disability arises from the interaction between impairments and environmental, attitudinal and institutional barriers rather than from the individual alone [12]. Critics have argued that it can underplay the bodily and experiential dimensions of impairment, and that a purely social account is incomplete [13]. For the present purposes, the useful implication is shared by both positions: barriers are, to a significant extent, properties of

the environment and can therefore be identified, measured, mapped and removed. This is precisely what GIS is suited to do.

Universal design, the principle that environments and products should be usable by all people to the greatest extent possible without adaptation, provides the corresponding design philosophy. It has been criticised for implying a single optimal solution and for neglecting the politics of who defines "everyone" [2], [14]. Ability-based design offers a complementary stance: rather than assuming users must adapt to systems, systems should adapt to users' abilities [15]. Both views support a professional practice in which accessibility is assessed *with* users and *in context*, not only against a checklist.

2.3 Assistive technology

Assistive technology (AT) refers to devices, systems and services that maintain or improve functioning and independence, such as wheelchairs, hearing aids, screen readers, communication boards and navigation aids [16], [4]. Effective use depends on the match between person, technology and environment, and abandonment is common when this match is poor [17]. The *environment* term in that match is exactly what GIS describes. A powered wheelchair, however capable, cannot cross a kerb without a ramp; a navigation app for blind pedestrians cannot warn of a hazard that is absent from its map. AT and GIS are therefore not separate subjects but two halves of one problem: the capability of the person and the device, and the affordances of the place.

2.4 Assistive technology and education

Finally, we want to emphasize the value of all digital technologies in the field of inclusive education. ICTs enable universal education, provide new techniques for effective teacher training, enhance memory retention, promote cooperation, increase transparency, develop learner-centered strategies, develop new teaching techniques, and quicken learning. Additionally, through virtualization, mobilization, artificial intelligence, and new learning environments-worlds, give new instruments for knowledge representation and support educational activities and methodologies. More specifically, ICTs are very effective and productive in ADHD training, facilitating and improving the assessment, intervention, and educational procedures via mobile devices that bring educational activities everywhere [52] and through a variety of ICT applications that are the main supporters of education [53, 55]. While games turn education into a multimodal, incredibly amiable, and enjoyable interaction, the use of AI, STEM, and ROBOTICS raises educational procedures into new levers of adaptation, creativity, and performance [56-60]. Additionally, the adoption, enhancement, and blending of ICTs with theories and models of metacognition, mindfulness, meditation, and emotional intelligence cultivation [61-65] brings mental abilities to the center of educational procedures and policies, and as a result, accelerates and improves educational practices and outcomes, particularly in the perception domain and spatial abilities education

3 POLICY AND STANDARDS CONTEXT

3.1 International and European frameworks

The UN Convention on the Rights of Persons with Disabilities (CRPD) recognises accessibility as a general principle and, in Article 9, obliges states to identify and eliminate obstacles and barriers to the built environment, transport, information and communications, and other facilities open to the public [18]. The 2030 Agenda sets targets that directly concern urban accessibility, including access to safe, affordable, accessible transport systems and to inclusive public spaces (SDG 11, targets 11.2 and 11.7) [19], and the New Urban Agenda repeats the commitment to cities that are accessible to persons with disabilities [20].

Within the EU, the Union of Equality strategy [5] frames accessibility as a precondition for participation, and the European Accessibility Act [6] harmonises accessibility requirements for key products and services such as e-commerce, banking, e-books, transport ticketing and electronic communications. The Web Accessibility Directive [21] applies to public-sector websites and mobile applications. The built environment itself remains largely a matter of national and local regulation, which is one reason why cities differ so greatly in practice.

3.2 Technical standards

Technical standards translate policy into testable criteria. For digital content, the Web Content Accessibility Guidelines (WCAG 2.2) [22] are the reference, and the harmonised European standard EN 301 549 sets accessibility requirements for ICT products and services [23]. For buildings, ISO 21542:2021 specifies requirements for the accessibility and usability of the built environment [24]. A noteworthy gap is that there is no equally mature, widely adopted standard for *spatial data* describing accessibility attributes of streets, although open mapping communities have developed tagging conventions [25], [26]. This gap strongly affects the use of GIS and is revisited in Section 10. These instruments imply a division of labour: legislators define obligations, standards define criteria, and *professionals* apply the criteria

and attest conformity. The European Skills Agenda and the Council Recommendation on VET promote Centres of Vocational Excellence (CoVEs) as ecosystems that link education, industry and regional development to produce such skills [27], [28]. AccessCoVE is an application of this idea to accessibility.

4 ACCESSCOVE AND THE ACCESSIBILITY COMPETENCE GAP

4.1 The project

AccessCoVE (reference no. 101103097) is funded under the Erasmus+ Centres of Vocational Excellence action and, according to project documentation, started in mid-2023 and runs until mid-2027, with a grant of approximately €3.3 million [29]. It is coordinated by the University of Macedonia and brings together 22 partners, according to the project's communications, from Greece, Sweden, Spain and Italy, including universities, technology companies, associations and training providers [30], [31]. Its stated purpose is to address the scarcity of educational programmes on accessibility for people with disabilities and older persons, to act as a credible hub of accessibility knowledge, to inform policy, and to promote social sustainability [8].

4.2 Method and outputs

The project approaches accessibility holistically, beginning with research on end-users' requirements and on stakeholders' needs and priorities, and feeding the findings into VET programmes and curricula [30]. Its work packages cover, among others, the specification of accessibility indicators and standards, the development and implementation of training programmes, an accessible web portal, certification, and governance and long-term sustainability [29]. Two learning paths are central: the **Accessibility Certifier**, who assesses and attests conformity, and the **Accessibility Consultant**, who advises organisations on improving accessibility. The project also targets up-skilling and re-skilling of professionals and awareness-raising among secondary and tertiary students, and invites individuals and organisations to join an international cooperation network [31]. The web portal is to comply with WCAG, a good example of the project "practising what it preaches" [31].

4.3 Where spatial competences fit

The public descriptions of AccessCoVE focus on indicators, training, certification and a portal. They do not describe spatial analysis explicitly. Yet "specification of accessibility indicators" and "certification" of physical spaces inevitably involve questions that GIS answers: *Where* are the barriers? *How many* people are affected? *Which* routes are usable by whom? *What has changed* since the last audit? A certifier who can only fill in a form for a single building cannot assess the continuity of an urban route; a consultant who cannot read an accessibility map cannot prioritise investments across a municipality. This article argues that spatial competence is the natural complement to the existing agenda, and Sections 5–9 develop this argument.

4.4 The competence gap in context

General digital competence frameworks such as DigComp 2.2 describe what citizens need to know in digital environments [32], but do not specify the professional competences of those who evaluate accessibility. In education, GIS has long been advocated as a means of developing spatial thinking and problem-solving, with the observation that effective use depends on teacher training and curriculum integration [33]. The combination of vocationally oriented GIS skills applied to accessibility is still largely missing from mainstream curricula, which is the opportunity AccessCoVE-type centres can address.

5 GIS APPROACHES TO ACCESSIBILITY IN CITIES

Five families of approaches can be distinguished in the literature. They are presented here in roughly chronological and methodological order and compared systematically in Section 7.

5.1 Network-based and opportunity-based accessibility measures

Classical accessibility analysis computes, for each location, how many opportunities (jobs, services, facilities) can be reached within a given travel cost, or weights opportunities by a distance-decay function [9], [10]. Time-geographic extensions consider individual space-time constraints, such as when a person must be home or when a service is open [11]. These measures are powerful for planning because they are quantitative, comparable across areas and scenarios, and aligned with the standard GIS toolset (network analysis, service areas, origin–destination matrices). Their weakness for disability is that they generally assume an *average* traveller moving along a *generic* network, so they overestimate the accessibility available to people with mobility or sensory limitations.

5.2 Disability-sensitive GIS modelling

Church and Marston [1] addressed this limitation directly by proposing measures of accessibility for people with a disability in which the network is modified according to the barriers relevant to a given impairment, for instance by removing or penalising segments with steep slopes, missing curb cuts or narrow sidewalks. Their central finding is methodological: measured accessibility depends strongly on whose abilities are modelled, so aggregate indicators can conceal severe local exclusion. The MAGUS project (Modelling Access with GIS in Urban Systems) extended this logic by capturing the experiences of wheelchair users in a GIS and using them to generate personalised, barrier-aware routes [34], [35]. A key lesson of MAGUS is that user participation in defining which attributes matter (surface quality, camber, kerb height, door width) improves the validity of the resulting maps. More recent work has stressed that social factors, such as perceived safety, crowding or social support, also affect urban accessibility for people with motor disabilities, beyond physical attributes [36], [37].

5.3 Volunteered geographic information and open data

Authoritative datasets on sidewalks and entrances are expensive to produce and are often incomplete or outdated. Volunteered geographic information (VGI), in which citizens act as "sensors" and contributors [38], offers an alternative. OpenStreetMap (OSM), the most prominent open mapping platform, relies on contributors and tagging conventions that can include sidewalk presence, kerb type, surface, incline and wheelchair access [25], [26]. Wheelmap, a web and mobile platform built on OSM data, allows users to rate the wheelchair accessibility of places using a simple traffic-light scheme, and has been analysed as a case of crowdsourcing for accessibility [39]. The strength of VGI is coverage and timeliness; its weaknesses are uneven participation, heterogeneous quality, and tagging that reflects contributors' interpretation rather than standardised measurement.

5.4 Crowdsourced street-level auditing

A second, more structured crowdsourcing family uses imagery. Hara et al. [40] showed that remote workers can identify sidewalk accessibility problems in street-level imagery with useful accuracy when tasks are well designed. Project Sidewalk generalised this into a web-based tool in which volunteers "walk" virtually through a city and label features such as curb ramps, missing curb ramps, obstacles, surface problems and absent sidewalks, producing city-scale datasets that can be analysed in GIS and, importantly, deployed in several cities [41]. Compared with free-form VGI, this approach yields more consistent data, because labelling follows a defined protocol; compared with field audits, it is cheaper but depends on the recency and coverage of the imagery and cannot capture temporary obstacles or the condition of a surface in rain or snow.

5.5 Personalised routing and navigation services

The fifth family operationalises the data in decision support for travellers. Systems such as RouteCheckr calculate routes for mobility-impaired pedestrians by combining multiple criteria (e.g. slope, surface, kerb height, stairs) weighted by a user profile [42]. Related work on personalised wheelchair routing models the traveller's capabilities and the network's barriers to find the "best" rather than the shortest route [43]. Here GIS becomes an assistive technology in its own right, a point developed in the next section. All five families depend on data about *attributes that matter for access*, and these attributes are often absent from standard municipal GIS. They also model a snapshot, whereas accessibility changes with roadworks, weather, lift failures, and parked vehicles. Finally, the choice of attributes and thresholds embeds assumptions about users; unless these are tested with the intended users, maps can mislead while appearing objective. These limits motivate the competence profile in Section 9.

6 ASSISTIVE TECHNOLOGY IN THE URBAN AND SPATIAL DOMAIN

Assistive technology relevant to cities can be grouped by the barrier it addresses. *Mobility* AT (manual and powered wheelchairs, walkers, prosthetics, portable ramps) addresses physical movement and depends on kerb heights, gradients, surfaces and door widths. *Vision* AT (white canes, screen readers, magnifiers, tactile maps, smartphone navigation and object-recognition applications) depends on tactile paving, audible signals, consistent wayfinding and, increasingly, on accurate digital maps. *Hearing* AT (hearing aids, induction loops, captioning, visual alerts) depends on acoustic environments and on information being provided in more than one modality. *Cognitive and communication* AT (simplified wayfinding, reminders, augmentative communication) depends on predictable, legible environments and clear information [16]. The same urban element can be a facilitator for one group and a barrier for another: a shared surface without kerbs can help wheelchair users yet remove the tactile cue relied on by blind pedestrians [2]. A defensible assessment therefore has to be *multi-criteria* and *multi-user*.

6.1 Assistive navigation as a GIS application

The earliest and most instructive example of AT as a spatial technology is the personal guidance system for blind travellers. Loomis et al. [44] tested auditory display modes for a system that combined satellite positioning, a spatial

database and speech or spatialised sound to guide a walker along a route, and Golledge et al. [45] described the GIS component supporting it, showing that the quality of guidance depended on the content and structure of the underlying spatial database. This dependence has not disappeared with modern smartphones. NavCog, a smartphone-based cognitive assistant, uses beacons and map data to provide turn-by-turn voice guidance for blind users in indoor and outdoor settings [46], and later work deployed such assistance in a large airport, analysing how accurate maps, localisation and interface design jointly determine usability [47]. In each case the technology works only where the environment has been surveyed and modelled in sufficient detail. A gap in the map becomes a gap in independence.

6.2 Access to assistive technology

The availability of AT is itself uneven. The WHO and UNICEF global report finds that a large share of people who need assistive products do not have access to them, with the gap particularly severe in low-income countries [4]. The earlier World Report on Disability had already identified inadequate services, lack of accessible transport and buildings, and limited information as persistent barriers to participation [48]. For city policy, this has two implications. First, improving the environment cannot substitute for providing devices, and providing devices cannot substitute for improving the environment; the two should be planned together. Second, because AT users are heterogeneous, there is no single "standard" profile to code into a model, and profiles must be developed from engagement with actual users [17], [15].

The relationship between AT and GIS runs in both directions. Spatial data feed assistive services (routing, warnings, indoor guidance). Conversely, AT users and their devices can generate spatial knowledge: wheelchair users who record routes, blind users who annotate hazards, or sensors on mobility aids that detect rough surfaces. Participatory work in this tradition treats users not as passive recipients but as co-creators and "experts of their experience" [49]. This reciprocity is promising, but it requires safeguards for privacy and consent, discussed in Section 10.

7 COMPARATIVE SYNTHESIS

Table 1 compares the five GIS approaches introduced in Section 5 along dimensions relevant to professional practice: the data on which they depend, their sensitivity to disability, their scalability and currency, their cost, and their typical limitations.

Table 1: Comparison of GIS-based approaches to urban accessibility

Approach	Typical data source	Disability sensitivity	Scale and currency	Cost and effort	Main limitation	Key references
Network and opportunity-based measures	Municipal road/transport networks, land-use and facility data	Low (assumes an average traveller)	Large scale; updated with official datasets	Moderate; requires GIS expertise and data access	Masks barriers experienced by specific groups	[9], [10], [11]
Disability-sensitive modelling	Network enriched with barrier attributes; user-defined criteria	High (profiles by impairment)	Neighbourhood to city; depends on survey effort	High; field surveys and user engagement	Costly to build and maintain; profiles may not generalise	[1], [34], [35]
Volunteered geographic information	Open maps and community platforms	Medium (depends on contributors and tags)	Very large; potentially near real-time	Low per record; needs community engagement	Uneven coverage and quality; subjective ratings	[25], [38], [39]
Crowdsourced street-level auditing	Street-level imagery labelled by volunteers or workers	Medium–high for sidewalk/curb features	City scale; limited by imagery date	Low–moderate; needs platform and quality control	Cannot see temporary or non-visual barriers	[40], [41]

Personalised routing and navigation	Barrier-annotated networks plus user profiles	High (per-user weights)	Depends on underlying data	Moderate–high (software and data)	Only as reliable as the data; trust and liability issues	[42], [43]

Three conclusions emerge from the comparison.

- **First, the approaches are complementary, not competing.** Network measures answer the planner's question (where are investments most needed across the city?); disability-sensitive modelling answers the user's question (can *I* get there?); VGI and imagery-based auditing supply the data to ask either question at scale; routing services deliver the answer to the traveller. A mature practice will chain them: authoritative networks as a backbone, crowdsourced attributes as enrichment, field verification for critical links, and user-profile-based analysis on top.
- **Second, the trade-off between scale and validity is persistent.** The more an approach scales, the more it relies on proxies (an image label, a traffic-light rating) for what is actually a rich experience; the more valid it is for a specific user, the more costly it is to produce [1], [41]. Professionals must be able to explain this trade-off to decision-makers and to choose the cheapest method that is still valid for the decision at hand.
- **Third, data quality is the common bottleneck.** Whatever the analytical sophistication, outputs depend on the completeness, accuracy, currency, and semantic consistency of the input attributes [26]. Quality assessment is therefore a core, not peripheral, competence.

Table 2 relates the categories of assistive technology to the spatial information on which they depend, illustrating why GIS competence matters for people who certify or advise on accessibility.

Table 2: Assistive technology categories and their spatial data dependencies

AT category	Examples	Spatial information needed	Typical failure caused by missing data
Mobility	Manual/powered wheelchairs, walkers	Gradients, kerb heights, surfaces, widths, step-free entrances, working lifts	Route that appears continuous but ends at a kerb or a broken lift
Vision	Navigation apps, screen readers, canes	Accurate geometry, crossings, tactile paving, obstacles, indoor layouts	Unwarned hazard; wrong crossing position; unusable indoor guidance
Hearing	Hearing aids, induction loops, captioning	Location of loops, visual/ multimodal information points	Reliance on audio-only announcements
Cognitive and communication	Wayfinding aids, symbols, reminders	Simple, consistent route structure; legible landmarks	Complex, ambiguous routes; information overload

8 ILLUSTRATIVE CASES

The following cases are drawn from the literature and public descriptions; each illustrates a different point on the scale–validity continuum discussed above.

8.1 MAGUS: capturing wheelchair users' experience

The MAGUS project in the United Kingdom built a GIS in which wheelchair users' own accounts of barriers were captured and linked to urban network data, enabling route generation that avoided user-defined obstacles [34], [35]. Its strength is its validity: attributes and priorities came from the users themselves. Its limitation is the effort required, which restricted the geographical extent. For a vocational programme, MAGUS is a model of *method*: define user profile, define barrier attributes, survey, model, validate with users.

8.2 Wheelmap: open, simple, scalable

Wheelmap invites anyone to classify the wheelchair accessibility of a place with a simple colour scheme, building on OpenStreetMap infrastructure [39]. The simplicity of the classification explains its reach, and also its limits: a single

"partially accessible" label cannot tell a user *what* the problem is. A consultant could use it as a rapid screening layer to identify where detailed audits are most needed.

8.3 Project Sidewalk: structured crowdsourcing

Project Sidewalk converts labelling of street-level imagery into a structured, repeatable audit, with defined label types and validation of other volunteers' labels [41]. Because the output is a consistent dataset, it can be fed directly into network analysis, for example to compute the share of a neighbourhood with continuous curb-ramped routes. Municipal teams can use it as a low-cost baseline before commissioning field surveys, and can compare their results with those of the broader literature [40].

8.4 Assistive navigation in a complex public facility

The deployment of smartphone-based assistance for blind travellers in an international airport illustrates the dependency of AT on detailed indoor models and on carefully designed interaction [47]. The project is a reminder that certification of accessibility must consider *information* accessibility (how the space is described and communicated) and not only physical features, a point aligned with the dual focus of AccessCoVE on products, services and environments.

8.5 An illustrative municipal scenario

To show how the pieces fit, consider a hypothetical mid-sized southern European city of the kind found in the countries participating in AccessCoVE, with a historic centre, steep streets, partially renovated pavements and an incomplete inventory of kerb ramps. This scenario is constructed for illustration; it does not describe any specific city or project result. An accessibility consultant might proceed as follows: (1) define two or three user profiles (e.g. a powered-wheelchair user, a blind pedestrian using a cane and a smartphone, an older adult with limited stamina) with user representatives; (2) assemble the authoritative street network and public-transport stops and calculate baseline service areas for key destinations such as the town hall, health centre and school; (3) enrich the network with crowdsourced curb-ramp and obstacle labels and open-map attributes; (4) verify a sample of critical links in the field; (5) re-compute service areas separately for each profile and visualise the difference; (6) rank interventions by the number of residents and destinations whose access they would restore; and (7) publish the resulting map in an accessible web format with a data-quality statement. A certifier, by contrast, might use the same data to check whether a defined "accessible route" between a public building and the nearest stop meets specified criteria continuously, and attest conformity or list non-conformities.

9 A PROPOSED GIS-AND-AT COMPETENCE PROFILE FOR ACCESSIBILITY PROFESSIONALS

The analysis above suggests that the Accessibility Certifier and Accessibility Consultant roles would benefit from a shared core of spatial competences, with different emphases. The profile proposed below is a conceptual contribution of this article, derived from the literature reviewed; it is not an official AccessCoVE curriculum, and it would need to be validated with employers, practitioners and users, which is consistent with the project's own user-centred methodology [30].

9.1 Competence areas

Table 3: Proposed spatial competence areas and their emphasis by professional role

Competence area	Illustrative learning outcome	Accessibility Certifier	Accessibility Consultant
Regulatory and standards literacy	Relate CRPD, EAA, EN 301 549, WCAG 2.2 and ISO 21542 to spatial and digital assessment tasks	Primary: applies criteria and records conformity	Primary: interprets requirements for clients
User and AT knowledge	Build user profiles linking impairment, AT use and environmental requirements	Applies given profiles	Develops and tests profiles with users
Spatial data fundamentals	Describe network data, attributes, coordinate systems and metadata; read and critique an accessibility map	Core	Core
Data collection and quality	Plan field audits and crowdsourced collection; assess completeness, accuracy, currency and consistency	Primary: verification and sampling	Primary: design of data strategy

Accessibility analysis	Compute service areas and route continuity under different profiles; interpret differences	Supporting: checks continuity	Primary: prioritisation and scenarios
Participatory methods	Plan co-design sessions and route walks with users and disability organisations	Supporting	Primary
Accessible communication of results	Produce maps and dashboards that are themselves accessible (WCAG-compliant, text alternatives, non-colour coding)	Core	Core
Ethics, privacy and governance	Handle location data lawfully; explain limits and uncertainty; avoid over-claiming	Core	Core

9.2 Pedagogical approach

A competence-based, project-oriented approach is consistent with the aims of vocational excellence centres [28]. Learners would conduct a mini-audit of a real route, analyse it with an open-source GIS, compare their findings with crowdsourced data, and present results to a panel that includes users. Assessment would combine technical outputs with reflection on data quality and a stakeholder review. The experience reported in GIS education more generally, that technology adoption depends on teacher preparation and on integration with authentic problems rather than on software alone [33], indicates that trainers should be supported with ready-to-use datasets and case materials, such as those that a portal like AccessCoVE's could host.

The profile builds on, but goes beyond, general digital competence frameworks such as DigComp 2.2 [32]: it adds domain-specific capabilities (spatial analysis, accessibility assessment) and an ethical dimension specific to working with vulnerable populations' data. Importantly, a professional who evaluates the accessibility of others' products must also deliver outputs that meet the same standards, reinforcing the principle that accessibility is demonstrated by practice.

10 CHALLENGES, RISKS AND ETHICAL CONSIDERATIONS

- **Data standards and interoperability.** As noted in Section 3.2, there is no widely adopted standard for describing pedestrian accessibility attributes in spatial datasets. Different platforms use different classifications, which complicates comparison and aggregation [26]. Work toward common schemas, ideally developed with disability organisations, would benefit both certification and AT services.
- **Quality, currency and liability.** Out-of-date or wrong accessibility information can be worse than none, since users may rely on it for safety. Platforms and professionals must communicate uncertainty, date their data and define responsibilities for updating and for errors.
- **Privacy and consent.** Location traces of people with disabilities can reveal health status, home locations and routines, which are sensitive. Collection and reuse of such data must comply with data-protection law, notably the General Data Protection Regulation [50], through minimisation, informed consent, anonymisation and clear governance.
- **Bias and representativeness.** Crowdsourced data reflect who participates; areas with few contributors or with digitally less engaged populations may appear "inaccessible" or "unmapped" simply for lack of data. Similarly, models calibrated on one user group may not serve others [36]. Smart-city initiatives can reinforce such inequalities if they privilege data-rich neighbourhoods and treat citizens as data sources rather than participants [51].
- **The risk of technological solutionism.** Maps and apps do not remove barriers; they help to identify and navigate them. An over-reliance on routing around problems can legitimise inaccessible infrastructure rather than prompting its correction. The social model reminds us that the goal is to change the environment [12], and professionals should ensure that data are used to support remediation and accountability.
- **Sustainability.** Data collection projects frequently stall when funding or volunteer interest declines. Institutionalising updates, for example by linking them to municipal permit and maintenance workflows, is as important as the initial survey.

11 CONCLUSIONS

This article has argued that accessibility is spatial, that GIS provides the means to represent and analyse it, and that assistive technology and GIS are two halves of the same enabling system. The comparative review identified five families of GIS approaches, from classical network measures to personalised routing, and showed that they are complementary:

network measures supply breadth, disability-sensitive modelling supplies validity, crowdsourcing supplies currency, and routing services supply usability. Their shared dependence on data quality, and on the participation of the people whom the data represent, points to the competences that vocational education should develop.

The AccessCoVE project provides an exemplary institutional vehicle: it responds to the policy requirements of the CRPD and the European Accessibility Act by creating professional profiles and training pathways with a user-centred, multi-partner approach [8], [30]. Extending such pathways with a coherent spatial and assistive-technology strand, as outlined in Table 3, would allow certifiers and consultants to evaluate cities as continuous systems rather than as collections of isolated buildings and websites.

Several lines of future research follow. (i) Empirical validation of the competence profile with employers, trainers and people with disabilities. (ii) Comparative field studies measuring the agreement between crowdsourced, authoritative and field-collected accessibility data in southern European cities. (iii) Development and testing of open, interoperable schemas for pedestrian accessibility attributes. (iv) Evaluation of the learning impact of project-based GIS audits in VET settings. (v) Examination of how emerging data-driven and AI-based tools can support, without replacing, human judgement and participation in accessibility assessment. Cities that are accessible by design will be built by professionals who can combine technical skill, an understanding of assistive technology and respect for the expertise of users; developing that combination is a task for education as much as for engineering.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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