Assessing Accessibility to Primary Education and Healthcare Services: A Comparison of EU Datasets and Network-Based Analysis.

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Abstract. European medium-sized cities are increasingly affected by shrinking dynamics, characterized by sustained population decline, ageing and selective out-migration, which challenge their capacity to remain attractive and competitive in the long term. In this context, everyday accessibility to essential services such as primary education and healthcare becomes a key component of urban livability, social equity and territorial resilience, shaping residential choices of families, older adults and mobile households. This paper investigates these issues proposing a novel approach through an integrated assessment of accessibility to primary schools and healthcare facilities in two mid-sized European cities, Genoa (Italy) and Karlsruhe (Germany). Present choice descends from the aim to evaluate potential attractiveness of urban areas, as well as local administrations commitment against shrinking and ageing trends. Building on Eurostat's 2025 road-based accessibility dataset, the study compares harmonized EU driving-time indicators with fine-grained, network-based analyses and walking-time maps developed at the urban scale. The methodology adopts a proximity perspective and explicitly considers demographic trends, urban morphology and welfare governance arrangements. Results show that while EU-wide indicators are valuable for macro-regional benchmarking and cohesion monitoring, they tend to conceal significant intra-urban inequalities, particularly in morphologically complex contexts such as Genoa. The paper argues that multi-scalar and multimodal accessibility assessments, integrating EU datasets with local network models and context-specific service typologies, are needed to support more equitable, age-friendly and place-sensitive planning of primary education and healthcare in European shrinking cities.

Keywords: Accessibility, Primary Education · Healthcare · EU Datsasets

1 Introduction

European medium-sized cities are increasingly entering a phase of demographic competition [1]. Recent demographic research shows that sustained population decline is no longer an anomaly, but a structural trajectory for many European regions. Newsham and

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O. Gervasi et al. (Eds.): ICCSA 2026 Workshops, LNCS 16765, pp. 516–530, 2027.
https://doi.org/10.1007/978-3-032-30536-7_33

Rowe [2] demonstrate how sub-national depopulation is now widespread across both rural and urban areas; thus, concluding that natural decrease (low fertility combined with population ageing) is ubiquitous, while net migration determines the pace of decline. Urban shrinkage has become a new normality for a growing number of European cities, affecting roughly 40% of large cities and especially older industrial regions [3]. At EU level, projections to 2050 suggest that around 45% of Functional Urban Areas could face population decline, driven increasingly by low fertility and ageing rather than by de-industrialization alone [4]. In a context marked by population ageing, shrinking regions, and growing inter-urban mobility, cities must compete not only in economic performance but also in terms of quality of life, service provision, and everyday accessibility [5]. In the coming decades, accessibility to essential services - such as primary education and healthcare - will represent indeed a key determinant of urban attractiveness, social equity and long-term resilience [6]. Healthcare and education services are among the most fundamental components of urban welfare infrastructure. Ageing population would indeed reflect into a widespread need of proximity-based health and care facilities [7]. Older adults report a higher incidence of unmet health-care needs related to distance and transport barriers than younger cohorts, underscoring the importance of local accessibility for this group [8]. On the other hand, the will to attract families and younger couples would translate into the re-organization of a high-quality primary education system [9] as primary education and childcare are increasingly framed as strategic, place-bound services that shape residential decision of mobile households, not just as neutral welfare provisions. However, their spatial distribution is often uneven, producing differentiated access times and mobility burdens across neighborhoods [10]. Moreover, urban shrinkage, ageing and structural changes in population composition, which in turn reconfigure welfare needs spatially, would amplify the spatial and equity dimensions of demand [11]. Reliable and comparable information on geographic accessibility is therefore crucial for EU regional policy, territorial cohesion strategies, and the monitoring of the UN Sustainable Development Goals (SDGs) [12]. In this direction, present contributions aim to assess accessibility conditions to primary education and healthcare facilities following a proximity perspective, where similar equipment represent a key factor influencing city livability and attractiveness within a shrinking and ageing EU context [13]. Stemming from EUROSTAT dataset [14] including driving times to basic education and healthcare facilities, the authors will provide a comparison between the proposed approach and the results of a network analysis taking into account two territorial case-studies: Genoa (IT) and Karlsruhe (DE). Territorial similarities and similar demographic trends allow to assess how different administrative structures and basic services management schemes may translate into different accessibility conditions. The proposed novel integrated approach enables further evaluation of the potential attractiveness of cities in terms of essential services asset and accessibility.

2 Background

Shrinkage literature has increasingly focused on the mismatch between inherited infrastructure and changing demography. Rink et al. [3] conceptualize urban shrinkage as the interaction of macro-level economic restructuring, demographic change and suburbanization, leading to under-used housing, oversized technical networks, and fiscal stress.

Among the most visible consequences, the authors highlight pressure to downsize social infrastructures such as schools, nurseries and child-related services in the face of falling child cohorts, while at the same time demand for healthcare and care services for older adults increases. JRC [4] extends this analysis by distinguishing between the hardware (physical infrastructure), software (social and demographic fabric) and mindware (the city's image) of shrinking cities. On the hardware side, population loss leads to vacant housing, declining property values, and the closure of small local shops and services; financial constraints often trigger consolidation of local facilities and a reduction in service levels. On the software side, selective out-migration of young and educated residents produces an ageing, lower-income population with higher health-care needs and lower mobility, thereby increasing dependence on local services. As cities shrink and age increase, some services can be centralized for efficiency, but core everyday services -particularly primary healthcare and basic education- are difficult to withdraw or relocate without significant social and territorial costs [15]. Population ageing is the key demographic mechanism linking shrinkage to proximity-based health and care. Following a neighborhood-scale approach, focus groups with older residents across these cities reveal that proximity to essential services and amenities- especially medical services, social activities and public transport- is perceived as one of the main advantages of urban living [10]. More fine-grained empirical work quantifies this link between proximity and older people's everyday health behavior. Referring to the Basque country, Machón et al. [7] show that having park/green spaces and other community facilities within walking distance is positively associated with physical activity and satisfactory social life, controlling for age and health status. From a service-provision perspective, Guida et al. [16] develop an elderly-oriented multimodal two-step floating catchment area method to measure accessibility to primary healthcare in Milan; they find that about 40% of older residents experience poor accessibility to primary health services, with the worst conditions in peripheral neighborhoods. The authors argue that accessibility deficits, rather than merely aggregate supply, are critical to the quality of life of an ageing urban population and call for age-friendly, proximity-oriented planning of healthcare networks [17]. Recent neighbourhood-scale applications further emphasise the role of sustainable mobility in shaping accessibility to essential services [18]. Policy shifts from hospital-centric models to community-based and age-friendly approaches, where neighborhood-scale primary care, long-term care and social support are seen as prerequisites for ageing in place in shrinking and ageing cities. On the families and children side of the equation, research has begun to connect demographic decline, school networks and local attractiveness for young households. From an accessibility perspective, García-Palomares et al. [19] analyse public primary schools in four large European cities, showing substantial spatial and social imbalances in accessibility once population density and socio-economic vulnerability are taken into account. Their results indicate that, even in large metropolitan areas, access to schools is uneven, and that austerity-driven rationalisation of school networks risks worsening spatial inequalities [20]. At a broader European scale, studies on geographic inequalities in access to essential services confirm that proximity to primary schools declines sharply in demographically shrinking regions, with relatively small changes in child population leading to large increases in travel times for remaining families [21]. The shrinkage literature interprets

these dynamics within a wider welfare–territory framework. Financial logic of rightsizing encourages concentration of schools and childcare facilities [22], this can accelerate depopulation by making areas less attractive for young families, thereby undermining attempts to stabilize the age structure. With respect to attractiveness and competitiveness of cities in shrinking contexts, this work goes beyond the sectoral approach mainly found in the literature, proposing an integrated analysis considered more effective in capturing the full range of welfare policies and their impacts at the urban scale.

3 Case Studies

Italy and Germany share European demographic challenges, including rapid population ageing, persistently low birth rates, and mounting pressure on welfare systems and urban public services. These trends strain the sustainability and equitable delivery of essential services such as healthcare and education, particularly in mid-sized cities where resource allocation must balance physical constraints with territorial coverage.

Despite notable differences in economic performance, migration balance, and regional policy frameworks, a direct comparison between Genoa (Italy) and Karlsruhe (Germany) offers valuable insights. Both are mid-sized university cities with established academic profiles -the University of Genoa (UniGe) and the Karlsruhe Institute of Technology (KIT)- that attract significant student populations and contribute to local economies. Yet the two cities diverge sharply in their urban morphology and topography, as well as in demographic structure.

This combination of similarities and contrasts makes the pair particularly suitable for examining how different expression of demographic challenges, together with differences in urban form and accessibility conditions, shape strategies for the equity and resilience of essential public services for residents and families.

This paper compares the Eurostat 2025 road-based accessibility dataset with network-based accessibility analyses conducted specifically for Genoa and Karlsruhe.

Both cities prove particularly representative of the investigated phenomenon, thus allowing for a more detailed analysis of accessibility data and metrics provided on a EU level by Eurostat. Moreover, the choice of open and EU-wide dataset supports research transferability to other any other urban contexts covered by the dataset.

Next sub-sections will present the two case studies.

3.1 Genoa

Genoa, the capital of the Liguria region, has ancient origins dating back to pre-Roman times and developed around its major historic port. Today, the city exhibits a highly constrained spatial configuration: a narrow coastal strip compressed between the Mediterranean Sea and the steep slopes of the Apennines. This dense and morphologically fragmented landscape has generated a complex, winding street network that poses persistent infrastructural and mobility challenges, These logistical barriers prove critical when addressing the vulnerabilities of a rapidly aging population. With approximately 564,000 inhabitants [23], Genoa faces a chronic demographic contraction and is currently one of Europe's oldest urban areas. Low birth rates and the continuous out-migration

of young professionals have driven the old-age dependency ratio to nearly 48.5% [24]. Although the presence of around 32,000 students at the University of Genoa and an immigrant population (11.4% foreign residents) provide a modest buffer, they are insufficient to reverse this structural imbalance.

Advanced aging has triggered a surge in demand for chronic and geriatric care, overwhelming the city's major hospitals. To mitigate this pressure, the region is implementing decentralized 'Community Houses' (*Case di Comunità*), offering integrated primary care, specialist outpatient services, nursing, social support, vaccinations, and point-of-care testing to reduce inappropriate hospital use and improve local access. However, their full deployment is still in progress, long waiting lists remain systemic, and topographical constraints hinders equitable spatial access, especially for elderly residents in remote areas. The demographic decline also impacts primary education, forcing the consolidation of schools into broader administrative units (Istituti Comprensivi). This rationalization reduces the capillary presence of neighborhood schools, subtly eroding the local social fabric. Furthermore, a large portion of school buildings date back to the early-to-mid 20th century, presenting severe accessibility shortcomings that are further aggravated by transport issues for those living in the inland valleys.

3.2 Karlsruhe

Founded in 1715 by Margrave Karl III Wilhelm as his retreat (Karl's Rest), Karlsruhe features a distinctive fan-shaped layout situated on the flat, open terrain of the Upper Rhine Plain. Unlike topographically constrained cities, this radial structure facilitates efficient land use and barrier-free accessibility. Karlsruhe exemplifies demographic resilience, with a growing municipal population of over 309,000 residents [25]. This vitality is heavily fueled by its robust tech-university ecosystem, notably the Karlsruhe Institute of Technology (KIT). With a student body comprising 12.5% of the total urban population and a high retention rate of skilled international graduates, Karlsruhe successfully maintains a balanced age structure, actively mitigating broader national ageing trends and population decline.

The city's balanced demographics and flat morphology ensure high, equitable spatial access to its comprehensive healthcare network. Karlsruhe effectively supports citizens through well-established outpatient nursing services (*Ambulante Pflegedienste*) that deliver care directly to patients' homes. Consequently, the city avoids shrinkage-driven service closures and the spatial isolation of the elderly, allowing authorities to focus on technological integration rather than demographic emergencies, though national challenges regarding nursing staff shortages persist. Benefiting from favourable demographic trends, Karlsruhe sustains a dense, decentralized network of neighborhood primary schools. Guided by the urban planning principle of "short legs, short distances", this capillary distribution preserves local community cohesion. The absence of topographical barriers, combined with a highly integrated transit and cycling infrastructure, ensures safe, active, and highly accessible mobility for young students across all districts.

4 Materials and Methods

In January 2026, Eurostat released a new geospatial dataset describing accessibility to healthcare and education services by road transport [14]. The dataset identifies potential population clusters with low or limited accessibility based on driving time to the nearest facility. It combines the 2021 Census population grid at 1 km resolution with road network data to calculate driving times to healtchare services and primary education for the reference years 2020 and 2023. This release follows the 2023 launch of a harmonised geospatial database of healthcare and education services across the EU, including detailed attributes such as service name, type, capacity, address and geographic location, derived from national administrative registries.

To better interpret the results of the geodataset, it is important to understand how it was set. Specifically, accessibility is defined as the driving time to the nearest facility; for healthcare facilities, only those offering first aid and specialist clinics are included; for education, the term 'primary' covers all levels from nursery school to adult education, effectively excluding higher education institutions such as universities, research centres, and specialist schools.

These choices and definitions affect the use of the tool in decision-making and strategic assessment processes. When applying this framework to the selected case studies, the following key insights emerge:

4.1 Healthcare

As shown in Fig. 1, both cities present adequate healthcare coverage, with a high probability of reaching a facility within a 5 min drive. It is important to note that healthcare services are less accessible in the outlying areas of Karlsruhe. In contrast, the linear development and morphology of the city of Genoa results in less equitable service distribution as one moves away from the coast. For instance, a substantial area in the north-west of the city is characterised by high population density; however, the nearest healthcare facility is located more than 15 min away by car.

4.2 Primary Education

As shown in Fig. 2, the observed scenarios are evidently favourable in both contexts, resulting from a pervasive distribution of facilities that ensures travel times of less than two minutes for the majority of the territory. In terms of comparison, while Karlsruhe show almost homogeneous results, the city of Genoa again suffers from the impact of the hilly terrain, resulting in increased travel times for students living in the outskirts of the city.

4.3 Overcoming Dataset's Issues

The Eurostat visualization is therefore readily comprehensible and practical, yet there are some critical issues that could hinder one of the potential applications for which the dataset was produced, namely to support local administrations and authorities in the spatial analysis of their territory as an aid tool for decision-making:

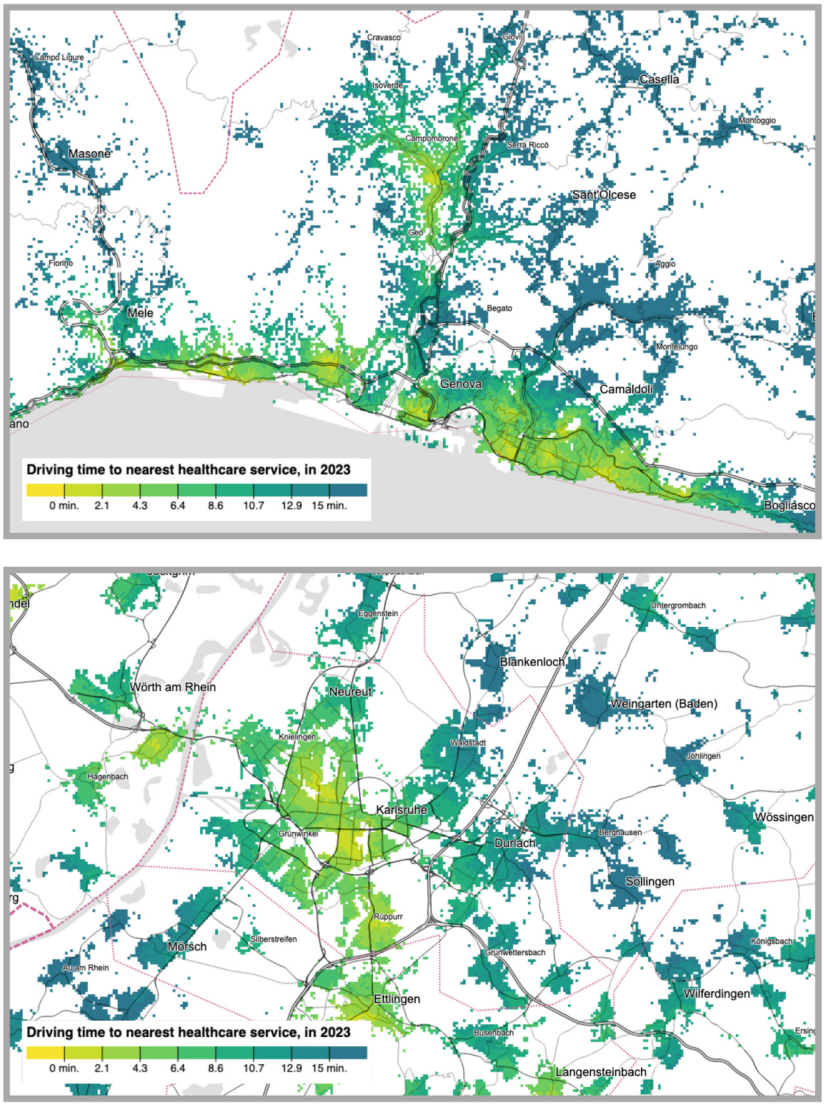

Fig. 1. Driving time to the nearest healthcare service in 2023 for the city of Genoa (above) and Karlsruhe (below). Source: [14]

- The 'driving time' metric used by Eurostat contrasts with the logic of proximity and sustainable mobility. In this sense, an assessment based on walkability could provide a clearer and more accurate picture of the possibilities for accessing primary services without necessarily having to rely on private transport.
- The selection of healthcare facilities included in the dataset seems biased; the inclusion of hospitals only appears to suggest an emergency-based approach, thus excluding a network of outpatient and primary care services that would be more appropriate

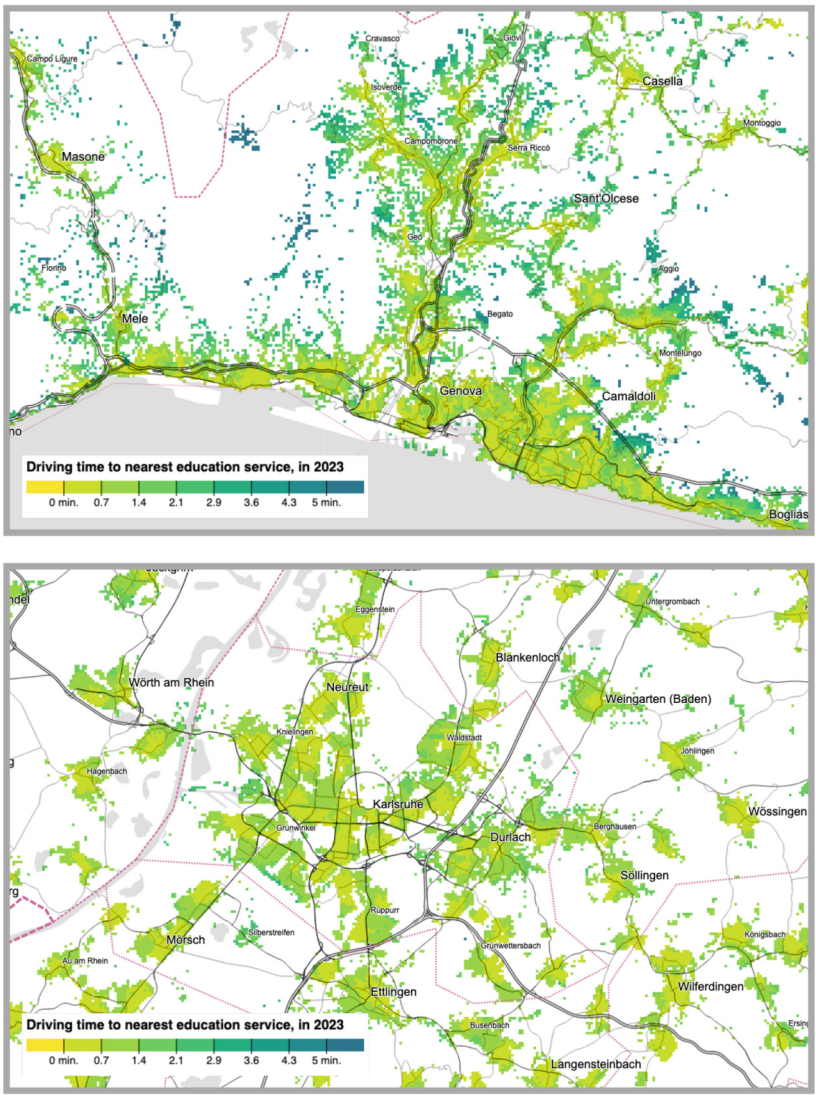

Fig. 2. Driving time to the nearest education service in 2023 for the city of Genoa (above) and Karlsruhe (below). Source: (Eurostat, 2026)

for capturing a picture of proximity and equitable distribution of essential services across a certain territory.

- The dataset's inclusion of all schools, regardless of level, under the umbrella of 'primary education' demands attention: the visualisation provided offers no differentiation based on user category, thereby diminishing the tool's capacity to accurately depict access possibilities in relation to the age and mobility asset of students.

In light of the aforementioned considerations, it is the intention of the authors to propose a network-based analysis approach as a solution to the issues found in the Eurostat dataset. The purpose of this approach is to provide a more effective representation of local accessibility to essential services. This approach will ensure better targeted decision support aimed at ensuring resilience in the demographic challenges that cities face.

The proposed methodology consists of generating pedestrian isochrones from healthcare and education facilities selected from the EU dataset. These isochrones are produced through a network-based analysis implemented in a GIS environment, using the ArcGIS Network Analyst tool. The road network was constructed by integrating data from the Liguria Region Geoportal with OpenStreetMap (OSM) layers, transformed within ArcGIS into a Network Dataset. Each network segment was assigned a travel-time cost based on its length, assuming an average walking speed of 4 km/h, thus enabling a time-based accessibility analysis. Service Area analysis was then applied by loading facilities as origin points and generating isochrone polygons along the network, reflecting actual pedestrian accessibility conditions. Pedestrian isochrones were calculated with thresholds of 10, 20, and 30 min for healthcare facilities, and 5, 10, and 15 min for a selected subset of education facilities (levels 0–1 in the EU dataset, namely nurseries and primary schools). These thresholds were defined in line with proximity-based planning principles and with the literature on walkable neighbourhoods and 15-min city frameworks, which identify different acceptable travel times depending on the type of service and user group. Resulting isochrone layers were finally exported and aggregated to produce continuous accessibility maps, which were then used to assess spatial coverage, identify underserved areas, and compare results with the Eurostat driving-time dataset.

This step of the analysis was conducted only for the case of Genoa, due to the lack of detailed EU geospatial data for the facilities in Karlsruhe. Despite the abovementioned similarities, differing administrative structures and governance mechanisms hampered the performance of a complete analysis for both cities. The decision to maintain Karlsruhe as a case study is due to the aim to highlight the limitations of the EU tool, which may be effective for visualization purposes and preliminary evaluations, but limited in terms of processing capabilities. The outputs, presented in the next section, consist of walking-time accessibility maps for both healthcare and education services.

5 Results

The following section presents the results of applying the proposed methodology to the city of Genoa, where all required data were available and the authors' contextual knowledge allowed for informed interpretation beyond purely technical outputs.

Unlike the Eurostat tool, which relies on driving times, the present analysis adopts walking time isochrones at 10, 20 and 30 min intervals for healthcare and 5, 10, and 15 min intervals for primary education. This choice was made to evaluate accessibility to essential services from the perspective of everyday needs rather than emergency scenarios or car-dependent trips. In the case of healthcare, the focus is on care provision for an ageing population; in the case of primary education, the analysis is restricted to facilities serving the youngest residents -from nurseries through to lower-secondary

schools- thereby concentrating on the needs of families with children and excluding upper-secondary institutions.

The resulting maps, presented in Fig. 3, diverge markedly from the Eurostat visualisation. For healthcare, coverage within a 30 min walk is largely confined to the dense central neighbourhoods, where the high concentration of facilities creates redundancy. Along the coast, however, even densely populated districts show walking times exceeding 30 min because of the spacing between hospitals. Additionally, the paediatric hospital Istituto Gaslini (south-east) was excluded from the analysis, as it serves a specialised paediatric population rather than the elderly demographic demand; its removal further accentuates the aforementioned gap areas that appear well-covered in the Eurostat tool. For primary education the differences are less pronounced: the great majority of the inhabited territory remains within a 15-min walk of a nursery or lower-secondary school, and the few uncovered zones are mainly low-density, industrial or commercial areas where low or absent demand makes the shortfall acceptable.

Two important limitations must nevertheless be acknowledged. First, at this stage, the analysis does not incorporate terrain topography -a factor of critical importance in Genoa's hilly and valley landscape- and therefore presents a more optimistic picture of actual walking accessibility than residents experience on the ground. Second, the dataset used does not yet include the Community Houses' described in Sect. 3.1. These proximity facilities are specifically designed to expand the network of local care, manage lower acuity needs close to home and channel only the most critical cases to hospitals; their omission underestimates the level of territorial coverage that Genoa is progressively achieving. Future studies will need to integrate both topographic correction and updated geospatial layers for these community-based structures in order to provide a more realistic assessment of service equity in morphologically complex urban settings.

6 Discussions

This paper examines accessibility to healthcare and primary education as a central pillar of urban livability, social equity, and territorial resilience in European cities facing current challenges of population shrinkage and ageing. In this context, Eurostat remains an essential reference, offering harmonised cross-national data to support evidence-based policy-making across Europe [26]. Its 2026 geospatial accessibility dataset represents a major milestone in large-scale assessment, attempting to provide a clear and homogeneous picture of accessibility across different regions. EU datasets effectively support macro-territorial benchmarking and the development and monitoring of cohesion policies. Nevertheless, the interpretative power of macro-level datasets at the intra-urban scale remains limited [27].

Administrative unit discrepancies (often not complying with the EU NUTS classification) and diverse service provision schemes (varying public-private roles and responsibilities) lead to unequal data availability on a national level. Consequently, a multi-scalar approach is required for accurate accessibility measures and evaluation.

While macro-data is useful globally, an urban planning perspective requires proximity-based assessments [16, 28, 29]. Fine-grained, local network-based analysis is essential for targeted urban interventions [30], particularly within morphologically complex cities like Genoa.

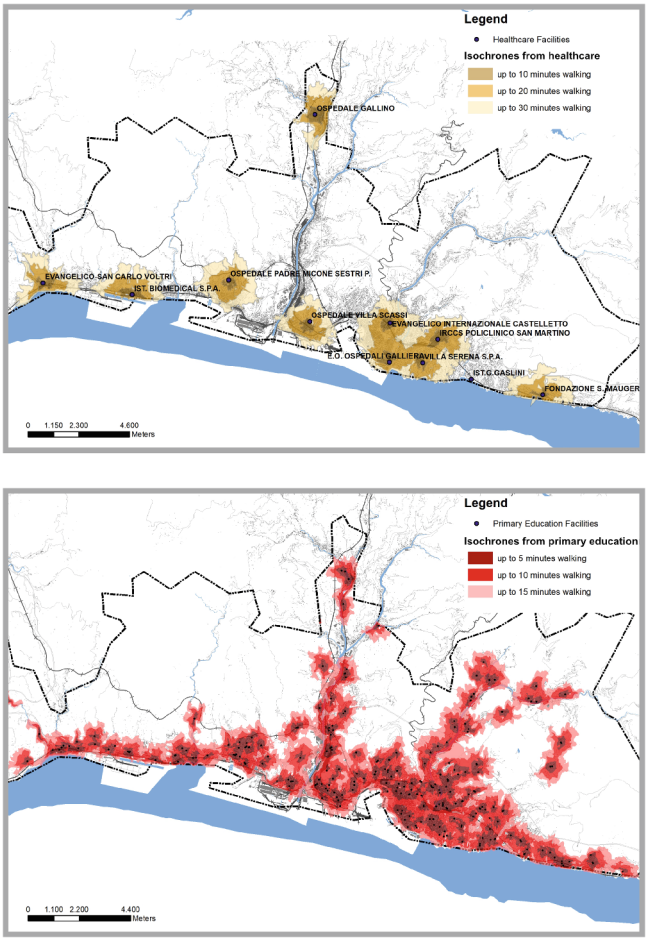

Fig. 3. Results of the analysis for Genoa. Walking time to the nearest healthcare facility (above) and primary education (below) in 2023. Source: authors' elaboration.

Applying downscaled evaluations requires a rigorous understanding of how key terms such as accessibility, primary education, and healthcare are defined. When assessing spatial access to hospitals and schools, macro-level datasets like Eurostat's would arguably offer greater utility for decision makers if they evaluated true active proximity rather than driving times.

Shifting the focus to proximity would better align with '15-min city' paradigms [31] and avoid reinforcing car-centric mobility habits [32]. Furthermore, the current categorization of services within the dataset lacks the granularity required for targeted strategies. For instance, the 'primary education' category indiscriminately covers everything from nursery schools to adult evening classes, obscuring the distinct spatial needs of different user demographics [19]. Proximity evaluations must account for facility types,

as being close to a high school serves an entirely different demographic requirement than being close to a kindergarten.

Similar issues arise in the healthcare domain, where the dataset primarily focuses on hospital care operating on a macro-territorial scale. For the Genoa case study, for example, the dataset includes the Gaslini Institute, a specialized pediatric hospital that authors argue must be explicitly distinguished from general acute care to avoid skewing local accessibility metrics. Moreover, it remains unclear whether the Eurostat dataset adequately captures decentralized, such as German non-facility-based home care services and Italian outpatient proximity network. Due to these methodological issues, the EU dataset alone is insufficient for conducting the granular, neighborhood-level assessments.

To address these limitations, this work mapped walking-time isochrones for the Genoa case study, setting thresholds at 5, 10, and 15 min for education, and 10, 20, and 30 min for healthcare. To accurately reflect the true proximity needs of the community, we rigorously filtered the input datasets. For the education sector, we included only nurseries, kindergartens, primary, and lower secondary schools, excluding high schools and professional institutes to focus on essential services required by young families. For the healthcare sector, the highly specialized pediatric hospital was excluded to prevent skewing the accessibility metrics for general acute care, which would otherwise obscure the actual healthcare gaps faced by Genoa's rapidly aging population.

The results of the local, walking-based assessment reveal a significantly less favorable accessibility landscape in Genoa than what is indicated by the macro-level Eurostat tool. These discrepancies are particularly pronounced in the healthcare sector compared to education. These results demonstrate how in-depth knowledge of the local context is indispensable for accurately evaluating citizens' accessibility to essential public services.

7 Conclusions

This study examined accessibility to primary education and healthcare services in two mid-sized European cities -Genoa and Karlsruhe- against the backdrop of demographic shrinkage and population ageing. Drawing on the Eurostat 2025 road-based accessibility dataset, authors demonstrate that, while such macro-regional indicators are valuable for cross-country benchmarking and EU cohesion monitoring, they frequently obscure substantial intra-urban disparities, especially in morphologically complex settings such as Genoa.

Fine-grained, network-based analyses and walking-time isochrones developed at the urban scale reveal pronounced differences between the relatively homogeneous picture provided by the Eurostat data and the lived realities of local populations. Although both cities exhibit broadly adequate accessibility when measured in terms of driving times, a walking-based perspective uncovers marked inequalities in service coverage and identifies areas where residents -particularly children, older adults and individuals with reduced mobility options- encounter significant barriers to essential services. These findings emphasise the critical role of context-sensitive data and multi-modal assessment in producing reliable accessibility estimates.

The comparative analysis highlights the necessity of moving beyond macro-scale, private mobility-centric evaluations towards multi-scalar, place-based approaches that

integrate European datasets with detailed local street network models, while explicitly accounting for urban morphology and ongoing demographic trends.

The proposed framework, which combines EU-level indicators with high-resolution network analysis tailored to walking (and extensible to other modes), constitutes a robust and transferable methodology for supporting equitable, age-friendly, and resilient urban planning in shrinking and ageing European cities.

Several limitations of the present work point to promising directions for future research. First, incorporating topographic variables into walking-time calculations would markedly improve model accuracy, especially in hilly cities such as Genoa. Secondly, extending the network analysis to encompass cycling infrastructure and public transport timetables would yield a more comprehensive representation of accessibility understood as effective proximity across transport modes.

Further development of the present study may widen the application of the proposed approach to accessibility evaluations to healthcare and education facilities in Karlsruhe, as well. Nevertheless, the lack of EU dataset coverage in this area would require collecting specific data though a dedicated campaign (or validation of OSM data). Moreover, an in-depth and systematic comparison between EU accessibility thresholds and isochrones calculated though local network analysis could be deployed to optimize data-driven decision-making process.

Acknowledgements. The authors jointly designed and contributed to the paper. Conceptualization: V.C., F.C., S.R.; Data curation, V.C., F.C.; Investigation, F.C., V.C.; Validation: F.C., V.C.; Methodology, V.C., F.C.; Supervision: S.R.; Writing—original draft, F.C., VC.; Writing—review and editing, F.C., V.C., S.R. All authors have read and agreed to the published version of the manuscript.

Attribution: Research did not receive dedicated funding.

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

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